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CONTENTS

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The Effect of Socioscientific Topics on Discourse within an Online Game Designed to Engage Middle School Students in Scientific Argumentation

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Abstract

The purpose of this study was to investigate the types of argumentation discourse displayed by students when they engaged in chat as part of an online multiplayer game about both socioscientific and scientific topics. Specifically, this study analyzed discourse episodes created by middle school students as they discussed scientific and socioscientific topics within an online, multiplayer game. Using a Discourse Analysis Scoring Guide, student discussions were coded based on the type of interaction or statements made. Analysis included a comparison between the types of topics (scientific vs. socioscientific) and the student author's justification for their decision to accept, reject or withhold judgement about the claim; teammate comments related to the author's justification; an overall rating of the discourse episode interaction; and frequency of argumentation vocabulary use throughout the discourse episode. Results indicated that socioscientific topics produced collaborative discourse episodes that were positive, supportive, and civil within an argumentation framework.

Introduction

The ability to engage in productive discourse is a skill that has been recognized as key to learning. The theoretical perspective that learning can be socially constructed through conversation or discourse is well founded (Berland & Reiser, 2011; Clark & Sampson, 2007; Pellegrino & Hilton, 2013; Prestridge, 2009; Vygotsky, 1978). Argumentation is a type of discourse that involves a group of equal participants, or learners, engaged in the social construction of knowledge by specifically addressing evidence and reasoning to consider or advance a claim (Duschl & Osborne, 2002; Osborne et al., 2013; Toulmin, 2003; Toulmin, Rieke, & Janik, 1984). Argumentation is a cross-curricular skill that is difficult to teach. Research suggests that integrating argumentation into science instruction is a significant challenge, both for teachers and students (Alozie, Moje, & Krajcik, 2010; Bulgren & Ellis, 2010). Because of this difficulty, a game has been developed that can be used to engage students in learning the knowledge and skills related to argumentation. This study addressed whether the chat section of the online game environment can engage students in quality argumentation discourse with either scientific or socioscientific content.

The need for students to develop skills and knowledge related to argumentation is reflected in both the Common Core State Standards (CCSS) (2010) and the Next Generation Science Standards (NGSS) (Achieve, 2013). The CCSS reflect an integrated view of reading, writing, speaking/listening, and argumentation across content areas, including science, mathematics, social studies, and English language arts. Argumentation skills encourage thoughtful student discourse by creating an environment in which students question each other's claims and evaluate the strength of their evidence. These standards emphasize the need for students to know how to take a more critical stance when confronted with an argument; evaluate the quality of what they read, see, or hear; and defend their claims with appropriate evidence and reasoning. It has been noted that argumentation skills help increase students' achievement and content knowledge by requiring them to think deeply about content, construct their own understanding of content, and apply it as they construct their arguments or critique those of others (Berland & Reiser, 2011; Clark & Sampson, 2007; Nussbaum, 2008; Osborne, Simon, Christodoulou, Howell-Richardson, & Richardson, 2013; Pelligrino & Hilton, 2013, Scheuer, Loll, Pinkwart, & McLaren, 2010).

The critical role of discourse, particularly argumentation, in students' understanding of and learning about science has also become increasingly evident. The NRC (2012) notes that "science is fundamentally a social enterprise" (p. 27) where scientists engage in ongoing discourse with their colleagues, informally and formally, to share insights, brainstorm, and problem-solve. As defined by the NGSS, argumentation is "a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation" (Achieve, 2013). Toulmin, Rieke, and Janik (1984) defined argumentation as "the whole activity of making claims, challenging them, backing them up by producing reasons, criticizing those reasons, rebutting those criticisms, and so on" (p. 14). Middle school standards now require students to engage in scientific argumentation as a critical science practice.

Using Argumentation in Socioscientific Discourse

When presented with open-ended, controversial issues, students are empowered to discuss science-related topics that shape their current world and have a large impact on their future (Driver, Newton, & Osborne, 2000; Kolstø, 2001). These dynamic interactions between science and society focus not only on the issues behind science, but also the relationship with social, political, economic, and moral challenges (Sadler & Fowler, 2006). Discourse about socioscientific topics involves the skills of identifying evidence, reasoning, evaluating information, and the development of conceptual understandings (Sadler, 2004). Argumentation is also an important part of decision-making (Patronis, Potari, & Spiliotopoulou, 1999) when dealing with socioscientific issues (Fleming, 1986; Kolstø, 2001; Zeidler, 2003). Practice in argumentation (Duschl & Osborne, 2002; Kuhn, 1993) in the context of controversial issues is needed for making informed decisions, which is considered vital for developing scientifically literate students and advancing democratic societies (Aikenhead, 1985; Fullinwider, 1987; Kolstø, 2001).

Socioscientific content-based scenarios address issues that are personally meaningful and engaging to students. Oftentimes, they are controversial in nature but the topics have an added element of requiring a degree of moral reasoning or the evaluation of ethical concerns that are personally relevant in the process of arriving at decisions regarding possible resolution of those issues (Zeidler & Nichols, 2009; Chang & Chiu, 2008). These topics mirror issues found in modern society and connect to student lives through their environment, media, and personal interests. Components of argumentation provide a structure for students to discuss these contentious topics in a productive and meaningful manner.

Learning Argumentation in a Computer-Mediated Environment

A number of reviews summarize the history of computer-supported learning and, specifically, computer-support of argumentation skill development (Scheuer, Loll, Pinkwart, & McLaren, 2010; Soller, Martínez, Jermann, & Muehlenbrock, 2005). These results, as well as the work of Linn and her colleagues and others, have demonstrated the ability to engage students in discourse and argumentation in scaffolded and controlled web-based spaces (Jeong & Joung, 2007; Linn, Clark, & Slotta, 2003; Linn & Eylon, 2011). The review by Soller et al. (2005) addressed computer-supported applications that were designed to support collaborative learning. They identified features that were characteristic of successful collaborative learning environments. While their interest was specifically in whether it is possible to design online learning environments to be facilitated by a coach, the framework they described informs online instructional environments, in general. The salient characteristics of the instructional environments that can be applied to supporting argumentation in an online environment include a shared work-space that supported a social awareness of teammates, a chat function allowing for open-ended interactions, delineated roles, problem-solving actions, and graphical visualizations of performance. The chat and graphic visualizations were intended to give students a metacognitive perspective of their discourse actions.

Scheuer, Loll, Pinkwart, and McLaren's (2010) more recent work reviewed a collection of software applications that were successful in teaching students the components of scientific argumentation. They identified five different types of support for argumentation, including free-form arguments, arguments based on transcripts, and system-provided prompts and examples. They concluded that software could be designed and implemented to support the development of the complex skill of argumentation. They suggested that by scaffolding good argumentation practices, the systems not only supported students in "learning to argue" but also supported "arguing to learn," helping students learn about specific domain topics through argumentation (pg. 45). The systems they reviewed, however, were client-based and ran on individual computers. As such, they were not networked and tended to be for single users (Graesser, Gernsbacher, & Goldman, 2012). The users, therefore, learned the components of argumentation but did not engage in the practice with peers.

The increased use of online environments, such as chat, forums, or blogs, provides an additional space in which to observe and quantify discourse outside of specifically structured applications. For example, Jepson (2005) developed a scoring protocol for discourse that occurs in text and voice chat rooms. In these unstructured environments, he identified two roles – speakers (initiators) and interlocutors (responders) – and could quantify negotiation of meaning and feedback for both roles. Chen and Chiu (2008) looked at online discussions in college-based discussion forums (such as Blackboard). Even though they were looking at a small number of participants and number of posts overall, they could quantify the flow of discussion. They identified five different types of messages and described the message properties. The online message types included: evaluation, knowledge statement, social statement, personal information, and elicitation. The message properties included agreement, disagreement, unresponsive/new topic, contribution, repetition, null content, positive social cue, negative social cue, and non-personal social cue. Chen and Chiu were interested in the ongoing exchanges and if the types and properties of comments predicted further types of comments. They examined how the flow of a discussion predicted later messaging and demonstrated statement properties of disagreement, contribution, social cue, and past visits can affect the properties of subsequent messages.

Many researchers have specifically attempted to quantify and then describe argumentation in online environments. Clark and Sampson (2007) developed an analytic framework for assessing argumentation in these more open online science learning environments (Clark, Sampson, Weinberger & Erkens, 2007). Based on the previous work of Erduran, Osborne, and Simon (Erduran, Simon, & Osborne, 2004; Simon, Osborne, & Erduran, 2003) Clark and Sampson use a strategy to score what they identified as discourse moves, the use of evidence and reasoning, and the conceptual quality in asynchronous threaded discussions in online environments. Their analysis described the overall quality of the online argumentation discussion, with the purpose of the discussion being to reach an agreement. This is because, they argue, from scientists' perspective, the role of argumentation is persuasion in the process of developing new knowledge, the definition of dialogic communication. They see argumentation as both a social and a collaborative process and recognize, therefore, that many statements made in the process of argumentation cannot be defined based solely on Toulmin's model. They suggest that there are elements to online (as well as face-to-face) argumentation that involve other operations, such as requests for clarification or statements of support for another's claim. Their analysis included eight different types of discourse moves, some specifically reflecting Toulmin's model and others describing social interactions. These more social statements included items such as: changing a claim, providing clarification, providing support, asking a question about meaning, requesting clarification about meaning, as well as social organizational comments and social but off-task comments. Given the social nature of argumentation, these discourse elements provide an organizing and supportive role that facilitates continuing the conversation in an egalitarian manner. Lu, Chiu, and Law (2011) expanded Clark and Sampson's coding protocol. Based on their analysis of online interactions they expanded the coding of elements addressing Toulmin's model and introduced two additional types of disagreements: disagreement with added justifications and disagreement against earlier justification. Overall, they agreed with Clark and Sampson that episodes of argumentation in an online environment can occur and be quantified; that the cognitive and social communicative processes of argumentation are closely related in online argumentation, as they are in a face-to-face episode; and that online and face-to-face argumentation interactions differ in use of evidence and explanations. It is clear, therefore, that students can learn and engage in a robust dialogue during argumentation in online spaces. These actions can include complex discourse moves and negation of meaning and are consistent with the interactions that re desired when addressing socioscientific content.

Argumentation Using Chat within a Multiplayer Online Game

Supporting argumentation using chat within a game combines the free form of the chat environment with the many motivational aspects of a game environment. Argumentation that is included as a part of a game has the potential to engage participants more than a course-based online chat or threaded discussion. This is because games can be specifically designed to include features that create a heightened emotional attachment during play, resulting in a level of engagement that does not occur with typical online or face-to-face instruction. Research on the effect of technology-based games has consistently shown positive results regarding motivation, persistence, curiosity, attention, and attitude toward learning (Shin, Sutherland, Norris, & Soloway, 2012). Early studies of online games demonstrate that many features are successful in engaging players. These include features such as social interaction, competition, and collaborative play (Malone, 1981), the social context of the game (Choi & Kim, 2004; Hsu & Lu, 2004), and competition (Koster, 2005).

One highly compelling feature is the opportunity for players to interact. Because of the rich and compelling environment, online games have been a place for discourse, and discourse analysis, since the late 1970s when the first multi-user games appeared (Brown & Bell, 2006; McEwan, Gutwin, Mandryk, & Nacke, 2012). Gee (1992, 1996, 1999) studied the components of discourse within the context of online games. He suggested that this type of online environment constitutes a rich space in which discourse emerges and allows for integrating language with the use of symbols and slang. Discourse that occurs within multi-player online games is persistent, player-produced, and useful; generally focusing on problem-solving and sense-making. The multi-user chat environments in games promote naturally occurring conversations between both known and anonymous players. Not only are these interactions used to gather information about the game, they are also used to instruct others and socialize about events in and outside the game (Brown & Bell, 2006; Ferrari, Lessiter, & Freeman, 2011; Nardi, Ly, & Harris, 2007). As Steinkuehler (2006) suggests, the chat conversations initially appear superficial because of the use of abbreviations, images, grammatical and spelling errors, and slang. Her further analysis, consistent with the views of Gee and others, suggests that the chat conversations in MMOGs (massively multiplayer online games) have the same level of complexity as off-line language. Because of the suitability of the online chat environment to engage players, particularly youth, in discourse, a number of researchers have recognized that chat, within a game environment, is a suitable space for the development of scientific argumentation skills & discourse (Squire & Jan, 2007; Steinkuehler & Chmiel, 2006).

Research Focus

The purpose of this study, therefore, was to investigate the types of argumentation discourse displayed by students when they engaged in chat as part of an online multiplayer game about both socioscientific and scientific topics. The question was whether there was a difference in the discourse in an online environment when the game content was socioscientific or scientific in nature. The game, *Reason Racer,* was used to present the topics and engage the students in a game environment. The game engages students in the skills and knowledge of scientific argumentation within a fast-paced, competitive game. The last part of the game provides students with the opportunity to engage with their fellow players about the topic of game play in an unstructured chat environment. Our interest is in the content and general characteristics of these discourse episodes during chat, whether students applied their recently acquired skills in scientific argumentation as a part of the chat conversation and if the nature of the topic (scientific vs. socioscientific) impacted student discourse.

Method

Participants and Setting

Over 500 middle school students from six school districts in the Midwest participated in the use of the *Reason Racer* game during science instruction in the Fall of 2012. These schools were in both rural and suburban districts. Students were enrolled in the 7th and 8th grade and were between 11 to 15 years old. Mixed-gender classrooms were comprised of 49% female students, 46% male students, and 5% unreported; taught by seven different teachers within the six schools. These students completed 937 discourse episodes through their *Reason Racer* game-play sessions using multiple scenarios that were of both scientific and socioscientific nature. Individual students completed at least one discourse episode, however some students completed as many as six discourse episodes including introductory game play. The seven teachers volunteered to participate in the project and use the *Reason Racer* game (described below) as part of their science instruction.

Procedures

This study utilized data generated from student game play during the *Reason Racer* game. *Reason Racer* is an online multiplayer arcade-style game that contains four parts, each designed to engage players in skills and knowledge related to scientific argumentation. When setting up play for students, the teacher assigns the game by selecting from 40 different scenarios covering topics in physical science; life science; earth and space science; and engineering, technology and the application of science. The different scenarios, selected and developed to be interesting to middle school students, populate the content of the game's challenges. Students play the game with their peers by interacting with one game scenario. Other play sessions may use the same or different scenarios. The areas of argumentation addressed in the game include understanding a claim, judging evidence about a claim based on type (fact, opinion, data, or theory) and quality, determining the reasoning (authority, theory, or logic), considering counterarguments and rebuttals, and making judgments, based on Toulmin's model (Toulmin, 2003; Toulmin, Rieke, & Janik, 1984). Students who played the game 10 times across a two-month period as a part of instruction improved in every aspect of argumentation skill and judgment and reported an increase in confidence and motivation to engage in science compared to students who did not play (Ault, Craig-Hare, Frey, Ellis, & Bulgren, 2015).

The first part of *Reason Racer* orients the players to the game through a humorous 30-second video. This video is one of 40 possible short previews of specific elements of the game such as the content of a particular scenario, a review of a specific component of scientific argumentation, or advice about how to participate in the chat environment.

The second part of *Reason Racer* engages the players in a competitive, multiplayer rally-race game; alternating between challenges, or PitStops, and racing segments across a variety of racecourses. The PitStops require actions that are common to fast-paced games, such as matching, ranking, sorting, and discriminating, all within a competitive, rate-based game interface. Figure 1 shows six of the eight PitStops from one scenario as an example. This scenario presents the claim that a new technology for biofuel production could utilize an enzyme found in a panda's digestive system to help convert plant matter to biofuel. The PitStops contain the content of the game, requiring students to identify components or make decisions about the claim, evidence, reasoning, and challenges to the claim. During game play, students attempt to move through each PitStop as quickly, and with as few errors, as possible. The competitive racing component, Figure 2, is completed between each PitStop. Students navigate various racing tracks' turns and obstacles as quickly as possible to move to the next PitStop. The speed and accuracy of a player's performance in the PitStop affect the speed with which his or her car can move through the next racing segment. Incorrect responses slow down the presentation of items in the PitStop, which discourages guessing. The experience of the racing component occurring between the challenges results in students completing the PitStops faster and more accurately (Ault, Craig-Hare & Frey, 2016) than with a no-race option in between PitStops.

Figure 1. A sample of reason racer pit-stop challenges

Figure 2. Reason racer staging area and sample racecourses

The third part of the game involves decision-making. Students read a brief article that reviews most of the content they just encountered. Their task is to decide whether to accept, reject, or withhold their decision about the claim and write a justification statement, as seen in Figure 3. This comment populates the final portion of the game, the discourse part, as seen in Figure 4. After making the decision and entering a statement supporting their decision about the claim, the players race to the end of the game and receive their scores. This score provides achievements that allow the player to be more competitive during the next round of play.

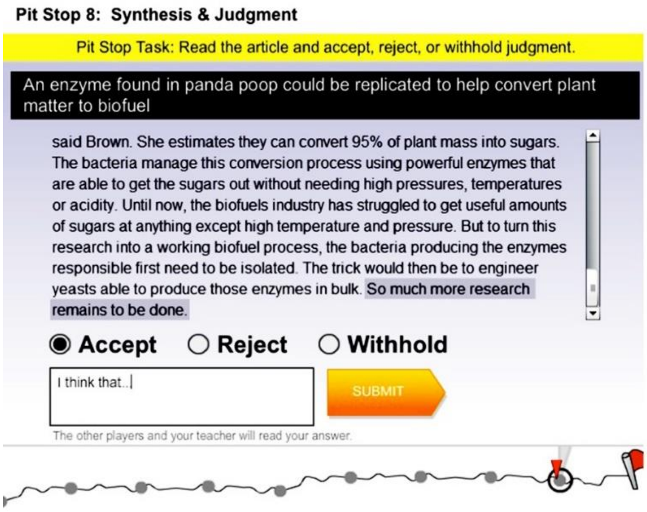

Figure 3. Decision portion of the reason racer game

The fourth part of the game, seen in Figure 4, involves players interacting with the other players in a peer-scored discourse environment. This environment is an unstructured chat window, monitored by fellow students and the teacher. In this environment, each player in the game begins a chat episode by submitting a justification statement (Figure 3). Students can identify teammates by their nicknames and select any justification statement in the window to add their comments. A chat episode further develops when a player selects another player's justification statement or comment and posts an additional comment (Figure 4). In this chat episode, the player can make any type of comment, either a statement addressing the original author's justification statement, or comments to other players who have posted in this discourse episode. For clarification, the author is identified as the student who submits their decision and justification; the other students (teammates) respond to the author's justification and/or additional comments within that thread. Since all the players in a game can see each other's justification statements and comments, they are free to select and continue commenting in all the different chat episodes that were created at the end of the game. Players can continue commenting until the teacher or students end the game session.

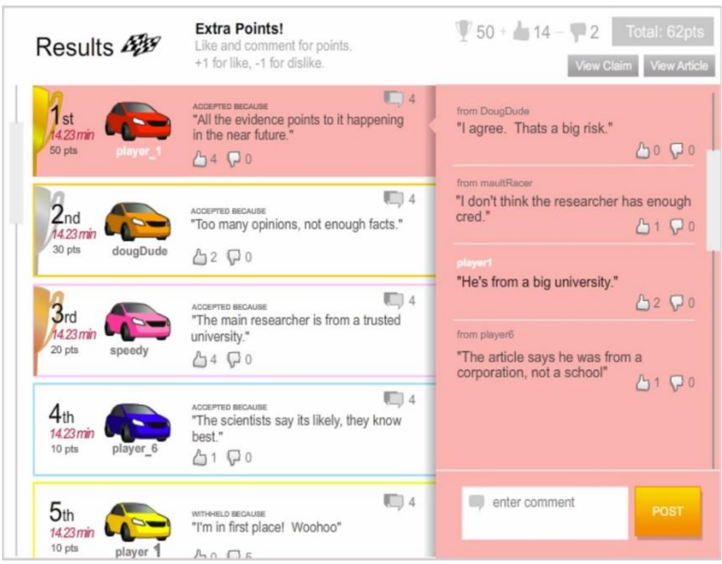

Figure 4. Reason racer discourse with other players

Players also have the opportunity to add or remove game points from other players by providing a thumbs-up (adding one point) or a thumbs-down (removing one point) to any author's justification statement or to any comment made by another player in any chat episode that is part of this game. The directions provided to the teachers, as well as several introductory videos, encourage students to add points to teammates who make quality comments and remove points from those who do not address the claim, evidence, or content of the article, or who make negative or non-constructive comments. This is referred to as peer-mediated chat and is the game-based strategy used to provide students with the opportunity to regulate the quality of the conversation or discourse in the game (Ault et. al., 2014).

Data Collection

The materials used in this study included the log files capturing information related to student game play of the *Reason Racer* game. Students accessed the game through the Internet and individual student performance data were recorded to a server database. The log files contain information about the scenarios that were utilized, decisions that were made about the claim (students determining if they should accept, reject, or withhold judgment about the claim), and student discourse about the scenario.

Data Analysis

This research was designed to explore differences in student discourse of scientific and socioscientific topics. During the fourth component of the *Reason Racer* game, students engage in discourse with peers about decisions regarding a claim and the content of the brief article. The *Reason Racer* Discourse Analysis Scoring Guide (RR-DASG) was created and refined in the current study by an iterative process involving multiple comparisons and discussions within the research team until a degree of consistency was reached. Refinements included collapsing item types and improving item descriptors for clarity, ensuring that they represented a coherent summary of author statements and interaction types. Once the RR-DASG could be applied with 85% reliability between the scorers, the research team began to review and score the discourse episodes.

Table 1. Summary of interaction codes for overall discourse episode

Type of Interaction	Item Code within Interaction Type
No Substantive Interaction	1. Nonsense text, playful use of typing, no content
	2. No interactions with another player, same player comments to self
Social Interaction	3. Social discussion, unrelated to content or game
	4. General positive or supportive comments
	5. General negative comments (mean-spirited)
Non-Specific Discussion	6. Agreement about or referring to content or process in a positive or agreeing way, agreeing with other teammates in the conversation
	7. Disagreement about or referring to content or process in a negative or disagreeing way, disagreeing with other teammates in the conversation
Discussion Based on Components of Argumentation	8. Agreement with use of argumentation vocabulary or application evidence and reasoning
	9. Disagree with use of argumentation vocabulary or application of evidence and reasoning
	10. Questioning or asking for more information or explanation
	11. Exploring different views with two or more viewpoints expressed, discussion between two or more players about claim, content, or process

The scoring process included the research team (a) reviewing the author statement and discourse episode in its entirety, (b) scoring the interaction of the overall discourse episode, (c) scoring the author's decision, justification type and argumentation vocabulary use frequency, (d) scoring the teammate(s) type of comment and argumentation vocabulary use frequency, and (e) counting the frequency of likes/dislikes for the author and teammate comments as well as the number of teammates involved in the discourse episode, number of author comments and number of teammate comments.

The overall discourse episode was scored based on the type of interaction between students, such as no substantive interaction, social interaction, non-specific discussion, or discussion based on components of argumentation (Table 1). The author's decision and justification, as well as the teammate(s) comment, were scored based on the type of statement provided. Table 2 identifies the statement categories as well as descriptors for types of responses in each of these categories.

Table 2. Summary of author statement & teammate comment codes

Type of Statement	Item Code within Type of Statement
Agree or Disagree	1. Basic or simplistic, no explanation or description of why agree or disagree
	2. Based on evidence in the scenario
	3. Based on reasoning from the scenario
Questioning	4. General question about the claim or indicating that there was not enough information
	5. Question about another's statement based on the use of evidence
	6. Question about another's statement based on reasoning
Disagree with a Challenge	7. Disagreement and providing a new question, counterargument, or rebuttal,
	8. Weighing both sides of the argument with no resolution
	9. Indecisive based on evidence and willing to accept conflicting views, or
	10. Withholding judgment based on conclusions about limited evidence, reasoning, or claim
Other	11. Unrelated to the content of the article or claim, social in nature,
	12. Positive or affirmative and related to the topic but not specifically addressing the claim
	13. Negative and related to the topic but not addressing the claim,
	14. Assist other players on how to play the game or perform better
	15. Correcting own or other's grammar, spelling, word choice, etc.

The research team also identified each scenario as scientific or socioscientific, based on a mutually agreed upon definition of socioscientific and an understanding of the scenario content. Overall, 21 scenarios were accessed during the game play sessions, with five featuring socioscientific issues and 16 of scientific content. The scenario type and discourse episode scoring were used in this analysis exploring student discourse of scientific and socioscientific topics.

Descriptive statistics were used to determine the frequency of scenarios played, student decisions, and use of scientific argumentation vocabulary. The analysis included independent-samples *t* tests, using discourse episodes from all scenarios played using the interaction type and author statement or teammate comment type as the dependent variable with the factor being the type of scenario played; scientific or socioscientific.

Results and Discussion

Data were gathered in 5,897 game play sessions from the six classrooms over a two-month period. This analysis addressed the chat episodes of the game for each student during his or her last game play day, totaling 937 discourse episodes. As student groups competed against each other in one game session, each student was the leader on a discourse episode, with any or all the other teammates participating in the chat. As a result, there might be four to six discourse episodes occurring simultaneously at the end of each game play session, with all teammates who played the game participating in one or more chat episodes. Students were not required to engage in a chat but were generally encouraged by their teachers to comment on other student's rationale statements and to use the thumbs-up or thumbs-down to reward teammates' discourse.

The sample consisted of 937 discourse episodes. Approximately 74% of the episodes involved scientific scenarios (n=691), while 26% were socioscientific scenarios (n=246). Table 3 reports the frequencies and percentages associated with the scenarios used during all game play. The most frequently accessed scenario was a socioscientific issue, Energy Drinks? Don't Waste Your Energy, and the least accessed scenario was Return of the Mammoth, also a socioscientific issue.

Table 3. Frequencies and percentages of scenarios accessed

Type	**Scenario Name**	**Scenario Topic**	**Frequency**	**Percent**
Scientific	1908 Russian Explosion	Meteoroids and comets	3	0.3
	Beam Me Up!	Teleportation	8	0.9
	Carbon Dioxide Sponge (Keep It Clean!)	Absorbing carbon dioxide	44	4.7
	Deep Oceans and Global Warming	Global warming	45	4.8
	Dogs Can Read Human Faces	Dog intelligence	89	9.5
	Elevator to Outer Space	Large-scale engineering projects	176	18.8
	Graphene Valley	Can graphene replace silicon?	10	1.1
	Leapin' Lizards	Search and rescue robots	69	7.4
	Panda Poop to the Rescue	New technology for biofuel production	8	0.9
	That Shrimp Packs a Punch!	Super-strong materials from shrimp	12	1.3
	The Artificial Leaf	A step toward energy independence	28	3.0
	The Earth's Two Moons	New theory explains features of Earth's moon	51	5.4
	The New North	Reversal of the Earth's magnetic poles	57	6.1
	Was Einstein Wrong?	Challenging the speed of light	43	4.6
	Weather Is One Big Headache	Relationship between weather and migraine headaches	2	0.2
	Worm Glue? Give Me a Break!	Biomimicry leads to possible new bone glue	46	4.9
Socio-scientific	Are Fatty Foods Addictive?	Fat triggered endocannabinoids and overeating	27	2.9
	Energy Drinks? Don't Waste Your Energy	Risks associated with energy drinks	192	20.5
	Mindless Eating	Nutrition	19	2.0
	Return of the Mammoth	Scientists trying to clone a mammoth	1	0.1
	Violent Video Games and the Brain	Violent video game and aggressive behavior	7	0.7

Author Justification Statements

After deciding to accept, reject or withhold judgment about a claim, the author provided justification for their decision. These justification statements were analyzed using independent-samples *t* test to evaluate the relationship between the scenario type and the author's rationale. The independent variable, the scenario type, included two different levels: scientific and socioscientific. The dependent variable was the type of author statement, as scored by the research team using the *Reason Racer* Discourse Analysis Scoring Guide. An independent-samples *t* test was conducted to investigate the types of argumentation discourse displayed by students when they engaged in chat as part of an online multiplayer game about both socioscientific and scientific topics. Results can be found in Table 4 and in the following paragraphs.

Table 4. Type of author justification statement

	Scientific Topic			Socioscientific Topic			95% CI for Mean Difference		
	M	SD	n	M	SD	n		t	df
Agree or Disagree	.57	.49	396	.74	.44	183	-.0.24, -0.10	-5.08*	484
Questioning	.00	.05	2	.00	.06	1	-0.01, 0.01	-0.26	376
Disagree with a Challenge	.22	.41	152	.13	.34	33	0.03, 0.14	3.19*	519
Other	.20	.40	141	.12	.32	29	0.04, 0.14	3.35*	534

* p < .05

The test was significant, t(484) = -5.08, p = .00 for author justifications scored as "Agree or Disagree". Students playing the *Reason Racer* game using a socioscientific topic (M = .74, SD = .44), on average were scored as a general agree or disagree on their decision justification more often than those playing *Reason Racer* using a scientific topic (M = .57, SD = .49). The 95% confidence interval for the difference in means ranged from -0.24 to -0.10. The strength of the scenario type and student interaction scored as having a small effect size as assessed by η^2, accounted for 2% of the variance of the dependent variable. This category was scored for author justifications that were based on basic or simplistic explanations which may have included evidence and/or reasoning in the scenario.

The test was not significant, t(376) = -0.26, *p* = .80 for author justifications scored as "Questioning". Students playing the *Reason Racer* game using a socioscientific topic (M = .00, SD = .06), on average were scored as questioning on their decision justification equal to than those playing *Reason Racer* using a scientific topic (M = .00, SD = .05). This category was scored for author justifications that were based on general questions about the claim, or where students indicated that not enough information was provided, or that they had questions based on the use of evidence or reasoning.

The test was significant, t(519) = 3.19, *p* = .00 for author justifications scored as "Disagree with a Challenge". Students playing the *Reason Racer* game using a socioscientific topic (M = .13, SD = .34), on average were scored as disagree with a challenge on their decision justification less often than those playing *Reason Racer* using a scientific topic (M = .22, SD = .41). The strength of the scenario type and student interaction scored as having a small effect size as assessed by η^2, accounted for 1% of the variance of the dependent variable. This category was scored for author justifications that disagreed with the claim; provided a new question, counterargument, or rebuttal; indecisive, or withholding judgment about the claim.

The test was significant, t(534) = 3.35, *p* = .00 for author justifications scored as "Other". Students playing the *Reason Racer* game using a socioscientific topic (M = .12, SD = .32), on average were scored as other on their decision justification less often than those playing *Reason Racer* using a scientific topic (M = .20, SD = .40). The strength of the scenario type and student interaction scored as having a small effect size as assessed by η^2accounted for 1% of the variance of the dependent variable. This category was scored for author justifications that were unrelated to the content, affirmative relating to the topic but not necessarily the claim, or negative related to the topic but not addressing the claim.

Overall, student authors within socioscientific topics supported their decision to accept the claim based on general agreement using basic or simplistic explanations, which may have included evidence, and/or reasoning from the scenario more often than student authors within scientific topics. Socioscientific topics also yielded fewer disagreements, student challenges, and unrelated justifications that did not address the claim.

Teammate Comments

The author's decision to accept, reject or withhold judgment about a claim, as well as their justification for this decision fueled teammate comments within the discourse episode. These teammate comments were analyzed using an independent-samples *t* test to evaluate the relationship between the scenario type and the type of comment provided by the teammate(s). The independent variable, the scenario type, included two different levels: scientific and socioscientific. The dependent variable was the type of teammate comment, as scored by the research team using the *Reason Racer* Discourse Analysis Scoring Guide. Results can be found in Table 5 and discussed in the following paragraphs.

Table 5. Type of teammate(s) comment in response to author justification

	Scientific Topic			Socioscientific Topic			95% CI for Mean Difference		
	M	SD	n	M	SD	n		t	df
Agree or Disagree	.40	.91	273	.22	.59	55	0.07, 0.27	3.37*	665
Questioning	.21	.71	145	.20	.56	48	-0.07, 0.10	.33	546
Disagree with a Challenge	.03	.20	23	.02	.13	4	0.00, 0.04	1.53	690
Other	1.21	2.12	836	1.82	3.29	448	-1.05, -0.17	-2.72*	320

* $p < .05$

The test was significant, $t(665) = 3.37$, $p = .00$ for teammate comments scored as “Agree or Disagree”. Students playing the *Reason Racer* game using a socioscientific topic (M = .22, SD = .59), on average were scored as a general agree or disagree less often than those playing *Reason Racer* using a scientific topic (M = .40, SD = .91). The strength of the scenario type and student interaction scored as having a small effect size as assessed by η^2, accounted for 3% of the variance of the dependent variable. This category was scored for teammate comments that were based on basic or simplistic explanations which may have included evidence and/or reasoning in the scenario.

The test was not significant, $t(546) = .33$, $p = .74$ for teammate comments scored as “Questioning”. Students playing the *Reason Racer* game using a socioscientific topic (M = .20, SD = .56), on average were scored as questioning less often than those playing *Reason Racer* using a scientific topic (M = .21, SD = .71). This category was scored for teammate comments that were based on general questions about the claim, students indicating that there was not enough information, or questions based on the use of evidence or reasoning. The test was not significant, $t(690) = 1.53$, $p = .13$ for teammate comments scored as “Disagree with a Challenge”. Students playing the *Reason Racer* game using a socioscientific topic (M = .02, SD = .13), on average were scored as disagree with a challenge less often than those playing *Reason Racer* using a scientific topic (M = .03, SD = .20). This category was scored for teammate comments that disagreed with the author; provided a new question, counterargument, or rebuttal; indecisive, or withholding judgment about the claim. The teammates may have also been weighing both sides of the argument with no resolution or were indecisive based on evidence and willing to accept conflicting views.

The test was significant, $t(320) = -2.72$, $p = .01$ for teammate comments scored as “Other”. Students playing the *Reason Racer* game using a socioscientific topic (M = 1.82, SD = 3.29), on average were scored as other more often than those playing *Reason Racer* using a scientific topic (M = 1.21, SD = 2.12). The strength of the scenario type and student interaction, as assessed by η^2, accounted for 1% of the variance of the dependent variable. This category was scored for teammate comments that were unrelated to the content, affirmative relating to the topic but not necessarily the claim, or negative related to the topic but not addressing the claim. Teammates were also scored as “other” when they were assisting other players on how to play the game or perform better or correcting their own or another player’s grammar, spelling or word choice. Overall, socioscientific topics lead to student comments that were positive, helpful for other players, and supportive of their teammates more often than students discussing scientific topics. There was less general agreement/disagreement, questioning and challenging other players when students played *Reason Racer* with a socioscientific topic than when they played using a scientific topic.

Discourse Episodes

The discourse episodes occurring during the fourth part of the game (Figure 4) were analyzed based on the interaction type scored by the research team using the *Reason Racer* Discourse Analysis Scoring Guide. An independent-samples *t* test was conducted to evaluate the relationship between the scenario type and the student interaction within the discourse episode for each type of interaction. The independent variable, the scenario type, included two different levels: scientific and socioscientific. The dependent variable was the type of student interaction during the overall discourse episode. Results can be found in Table 6 and in the following paragraphs.

Table 6. Type of student interaction during overall discourse episode

	Scientific Topic			Socioscientific Topic			95% CI for Mean Difference		
	M	SD	n	M	SD	n		t	df
No Substantive Interaction	.49	.50	338	.41	.49	102	0.00, 0.15	2.03*	436
Social Interaction	.26	.44	179	.35	.48	87	0.16, 0.03	-2.72*	400
Non-Specific Discussion	.15	.48	101	.14	.35	35	-0.05, 0.06	0.15	435
Discussion Based on Components of Argumentation	.11	.31	73	.09	.29	22	-0.03, 0.06	0.75	461

* p < .05

The test was significant, t(436) = 2.03, *p* = .04 for student interactions scored as "No Substantive Interaction". Students playing the *Reason Racer* game using a socioscientific topic (M = .41, SD = .49), on average were scored as "No Substantive Interaction" less often than those playing *Reason Racer* using a scientific topic (M = .49, SD = .50). The strength of the scenario type and student interaction scored as having no substantive interaction, as assessed by η^2, accounted for 1% of the variance of the dependent variable. No substantive interaction was scored for discourse episodes having nonsense text, playful use of typing, no content or no interactions with another player. Upon further analysis of the discourse episodes, students playing *Reason Racer* using scenarios with scientific topics were scored as having no interactions with another player more often (46.8%) than students using socioscientific topics (40.2%). In other words, students playing the game with socioscientific topics played the game more often with teammates than alone.

The test was significant, t(400) = -2.72, *p* = .01 for student interactions scored as "Social Interactions". Students playing the *Reason Racer* game using a socioscientific topic (M = .35, SD = .48), on average were scored as "Social Interaction" more often than those playing *Reason Racer* using a scientific topic (M = .26, SD = .44). The strength of the scenario type and student interaction scored as being a social interaction, as assessed by η^2, accounted for 3% of the variance of the dependent variable. Discourse episodes were scored as social interactions when the student engagement was mostly social discussion unrelated to the content or game, general positive or supportive comments, or negative, mean-spirited comments. Upon further analysis, students playing the *Reason Racer* game using a socioscientific topic were scored as having more general positive/supportive comments (27.6%) over students playing the game using scientific topics (19.7%). In addition, students in socioscientific topics were never scored as being negative or mean-spirited in their overall discourse episode interaction.

The test was not significant, t(435) = .15, *p* = .88 for student interactions scored as "Non-Specific Discussion". Students playing the *Reason Racer* game using a socioscientific topic (M = .14, SD = .35), on average were scored as "Non-Specific Discussion" less often than those playing *Reason Racer* using a scientific topic (M = .15, SD = .48). Non-specific discussion included general agreement or disagreement about or referring to the content or process with other teammates.

The test was not significant, t(461) = .75, *p* = .46 for student interactions scored as "Discussion Based on Components of Argumentation". Students playing the *Reason Racer* game using a socioscientific topic (M = .09, SD = .29), on average were scored as engaged in "Discussion Based on Components of Argumentation" less often than those playing *Reason Racer* using a scientific topic (M = .11, SD = .31). Discourse episodes scored as discussion based on components of argumentation included agreement/disagreement with the use of argumentation vocabulary or application of evidence or reasoning, questioning or asking for more information or exploration, or students exploring different views with two or more viewpoints expressed having discussion between two or more players about claim, content or process. Upon further analysis, students playing the *Reason Racer* game using a socioscientific topic generally were agreeing, questioning, or exploring different views using components of argumentation. They were never scored in disagreement with their teammates on socioscientific topics.

Overall, socioscientific topics produced positive social discourse relating to the issue being discussed within a competitive, yet collaborative, environment. While their conversations may have been less focused on the components of argumentation, students discussed potentially controversial topics in a civil and affirmative manner, supporting their own beliefs as well as the beliefs of their teammates.

Use of Scientific Argumentation Vocabulary

Throughout the discourse episodes, students were encouraged to use vocabulary related to scientific argumentation. This vocabulary included basic words such as claim, qualifier, and evidence, as well as words to describe evidence, such as data, fact, opinion and theory. Vocabulary also included terms relating to reasoning, such as authority and logic, and the application of reasoning such as if-then statements. Challenges to the claim were identified as counterarguments and rebuttals, while new questions were indicated by students using the terms why or how within the discourse episode.

Table 7 reports the frequencies and percentages of scenarios in which students used scientific argumentation vocabulary during their discourse episode. Scientific argumentation vocabulary was used by the author of the discourse episode 43.9% of the time for socioscientific topics (n=108) and 39.1% of the time for scientific topic scenarios (n=270). Teammates within the discourse episode used one or more scientific argumentation terms in 13.4% of the socioscientific topics (n=33) and 14.2% of the scientific topic scenarios (n=98). Authors within discourse episodes frequently used words such as accept, because, and fact.

Table 7. Scientific argumentation vocabulary usage within discourse episode

	Scientific Topic (N=691)		Socioscientific Topic (N=246)	
	n	%	n	%
Author using 1 or more vocabulary term	270	39.1%	108	43.9%
Teammate(s) using 1 or more vocabulary term	98	14.2%	33	13.4%

Conclusion

Counter to the findings from Linn and her colleagues, as well as others, demonstrating the ability to engage students in discourse and argumentation in scaffolded and controlled web-based spaces, argumentation discourse in an online chat-like environment was successfully implemented without programmatic scaffolding through the *Reason Racer* game (Jeong & Joung, 2007; Linn, Clark, & Slotta, 2003; Linn & Eylon, 2011). The salient characteristics identified by Soller et al. (2005) as common to applications that support collaboration include a shared work-space that supported a social awareness of teammates, a chat function allowing for open-ended interactions, delineated roles, problem-solving actions, and graphical visualizations of performance. These were present within the game environment. The graphical displays of the interactions were similar to social sites such as Facebook, Twitter, or other chat environments. They did not provide students with an extensive metacognitive perspective of their actions; instead, allowing for productive discourse to take place.

Soller et al. (2005) also suggested that a key component of the online system was the manager who provided feedback, remedial actions, or helped students with their online behaviors The game, particularly the chat environment, also provided feedback, but from peers, rather than a manager. While the students were aware that the teacher could also see their comments, it could be argued that the peer mediation also had a mitigating nuance on discourse.

Scoring students' discourse involves components of argumentation, as outlined by Toulmin, as well as other components, such as an alternative strategy used to quantify what occurs during the process of scientific argumentation focused on discourse characteristics as either sense-making or persuasion (Berland & McNeill, 2010; Berland & Reiser, 2011). Through analyzing student discourse episodes, argumentation components, as well as student understanding of argumentation, can be identified. While some results were significant for the analysis categories, effect sizes remained small for these interactions. In general, students engaged in discourse of socioscientific topics had positive, supportive, and civil dialogue with their teammates.

Limitations of the Study

We believe there are two possible limitations to this study. First, there were a limited number of scenarios accessed for student game play. The Reason Racer game contains 40 scenarios containing scientific and socioscientific topics. The data set analyzed only included 21 of these scenarios, or a little over half of the scenarios. Most the 21 scenarios represented scientific topics (n=16), while 5 scenarios were about socioscientific topics. While this imbalance in scenarios can be addressed through statistical methods, it is clear that more scenarios were accessed for scientific topics rather than socioscientific topics.

Second, because the research team was only accessing the game play log files and did not have interaction with the classroom teacher regarding the selection of scenarios, it cannot be determined if the scenarios were assigned to the students as part of a classroom lesson, or if students were able to choose the scenario they played. Student choice could make a difference in discourse engagement for the different scenario types. Similarly, students played at least one game, but up to five game sessions that were included in this analysis. Therefore, if students had more opportunity to play and discuss across multiple scenarios it might have an impact on discourse engagement.

Recommendations

The *Reason Racer* game can be used to begin the process of engaging students in discourse and argumentation. The chat feature within the *Reason Racer* game is effective to monitor discourse in scientific and socioscientific topics, providing feedback and models for students to support the development of the skill. Recognizing that it may be difficult for middle school students to grasp what is "fun" about engaging in argumentation, this study investigated the differences in student-level discourse between socioscientific and scientific topics as discussed through an online game. This study finds that students can and will engage in productive and positive discourse through socioscientific topics. These results add to what is known about using online, educational games in the classroom for collaborative discourse.

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References

Achieve, Inc. (2013). *Next Generation Science Standards*. Retrieved from http://www.nextgenscience.org/

Aikenhead, G.S. (1985). Collective decision making in the social context of science. *Science Education.* 69(4):453–475.

Alozie, N. M., Moje, E. B., & Krajcik, J. S. (2010). An analysis of the supports and constraints for scientific discussion in high school project‐ based science. *Science Education, 94*(3), 395–427.

Ault, M., Craig-Hare, J., & Frey, B. (2016). The Impact of a Racing Feature on Middle School Science Students' Performance in an Educational Game: The Effect of Content-Free Game-Actions. *International Journal of Game-Based Learning, 6*(3), 18-32.

Ault, M., Craig-Hare, J., Frey, B., Ellis, J. D., & Bulgren, J. (2015). The Effectiveness of Reason Racer, a Game Designed to Engage Middle School Students in Scientific Argumentation. *Journal of Research on Technology in Education, 47*(1), 21–40. doi:10.1080/15391523.2015.967542

Ault, M., Craig-Hare, J., Scherrer, D., Kroge, J., Kretschmer, I., Bulgren, J., Adams, D., & Tran, P. (2014) Patent. "Peer-Scored Communication in Online Environments", Patent Pending: 13KU035L-01. (application: March 2014).

Berland, L. K., & McNeill, K. L. (2010). A learning progression for scientific argumentation: Understanding student work and designing supportive instructional contexts. *Science Education, 94*(5), 765–793.

Berland, L. K., & Reiser, B. J. (2011). Classroom communities' adaptations of the practice of scientific argumentation. *Science Education, 95*(2), 191–216.

Brown, B., & Bell, M. (2006). Play and sociability in there: Some lessons from online games for collaborative virtual environments. In *Avatars at work and play*. (227–245). Springer Netherlands.

Bulgren, J. & Ellis, J. (2010). *Argumentation and evaluation in science classes: Teaching with Toulmin.* Center for Research on Learning, University of Kansas.

Chang, S.N., & Chiu, M.H. (2008). Lakatos' scientific research programmes as a framework for analysing informal argumentation about socio-scientific issues. *International Journal of Science Education*. 30:1753–1773.

Chen, G. & Chiu, M. M. (2008). Online discussion processes: Effects of earlier messages' evaluations, knowledge content, social cues and personal information on later messages. *Computers & Education 50*, 678–692.

Choi, D. H. & Kim, J. (2004). Why people continue to play online games: In search of critical design factors to increase customer loyalty to online contents. *Cyberpsychology & Behavior*, *7*(1), 11–24.

Clark, D. B., & Sampson, V. D. (2007). Personally- seeded discussions to scaffold online argumentation. *International Journal of Science Education, 29*(3), 253–277.

Clark, D. B., Sampson, V., Weinberger, A., & Erkens, G. (2007). Analytic frameworks for assessing dialogic argumentation in online learning environments. *Education Psychology Review, 19,* 343–374.

Common Core State Standards Initiative. (2010). *Common Core State Standards*. Washington, DC: National Governors Association Center for Best Practices and the Council of Chief State School Officers.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*. 84:287–312.

Duschl, R.A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education, 38*, 39–72.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education, 88,* 915–933.

Ferrari, E., Lessiter, J., & Freeman, J. (2011). Users and uses of multiplayer games and community activities. *Proceedings of the Networked & Electronic Media Summit (NEM Summit'11).*

Fleming, R. (1986). Adolescent reasoning in socio-scientific issues, part I: social cognition. *Journal of Research in Science Teaching.* 23:677–687.

Fullinwider, R. K. (1987). Technological literacy and citizenship. *Bulletin of Science, Technology and Society, 7,* 320-324.

Gee, J. P. (1992). *The social mind: Language, ideology, and social practice*. New York: Bergin & Garvey.

Gee, J. P. (1996). *Social linguistics and literacies: Ideology in discourses* (2nd ed.). London, England: Routledge/Falmer.

Gee, J. P. (1999). *An introduction to discourse analysis: Theory and method*. New York: Routledge & Kegan Paul.

Graesser, A. C., Gernsbacher, M. A., & Goldman, S. R. (Eds.). (2012). *Handbook of discourse processes*. New York: Routledge.

Hsu, C. L., & Lu, H. P. (2004). Why do people play on-line games? An extended TAM with social influences and flow experience. *Information and Management, 41*, 853–868.

Jeong, A. & Joung, S. (2007). Scaffolding collaborative argumentation in asynchronous discussions with message constraints and message labels. *Computers & Education 48*, 427–445.

Jepson, K. (2005). Conversations and negotiated interaction in text and voice chat rooms. *Language Learning & Technology, 9*(3), 79–98.

Kolstø, S.D. (2001). Scientific literacy for citizenship: tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*. 85:291–310.

Koster, R. (2005). *A theory of fun for game design*. Scottsdale, AZ: Paraglyph Press.

Kuhn, D. (1993). Science as argument: implications for teaching and learning scientific thinking. *Science Education,* 77(3), 319-337.

Linn, M. C., & Eylon, B. S. (2011). *Science learning and instruction: Taking advantage of technology to promote knowledge integration*. New York: Routledge.

Linn, M. C., Clark, D., & Slotta, J. D. (2003). WISE design for knowledge integration. *Science Education, 87*(4), 517–538.

Lu, J., Chiu, M. M., & Law, N. W. (2011). Collaborative argumentation and justifications: A statistical discourse analysis of online discussions. *Computers in Human Behavior, 27*(2), 946–955.

Malone, T. W. (1981). Toward a theory of intrinsically motivating instruction. *Cognitive Science, 5*(4), 333–369.

McEwan, G., Gutwin, C., Mandryk, R. L., & Nacke, L. (2012). I'm just here to play games: Social dynamics and sociality in an online game site. In *Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work* (pp. 549–558). ACM.

Nardi, B. A., Ly, S., & Harris, J. (2007, January). Learning conversations in World of Warcraft. *System Sciences, HICSS 2007. 40th Annual Hawaii International Conference on IEEE*. (79–79).

National Research Council, Board on Science Education, Behavioral and Social Sciences and Education (2012). *A framework for K-12 science education*. Washington, DC: National Academies Press.

Nussbaum, E. M. (2008). Collaborative discourse, argumentation, and learning: Preface and literature review. *Contemporary Educational Psychology, 33*, 345–359.

Osborne, J., Simon, S., Christodoulou, A., Howell- Richardson, C., & Richardson, K. (2013). Learning to argue: A study of four schools and their attempt to develop the use of argumentation as a common instructional practice and its impact on students. *Journal of Research in Science Teaching, 50*(3), 315–347.

Patronis, P.T., Potari, D., & Spiliotopoulou, V. (1999). Students' argumentation in decision-making on a socio-scientific issue: Implications for teaching. *International Journal of Science Education*. 21:745–754.

Pellegrino, J. W. & Hilton, M. L. (2013). *Education for life and work: Developing transferable knowledge and skills in the 21st century*. National Research Council of the National Academies. Washington, D.C.: National Academies Press.

Prestridge, S. (2009). Teachers' talk in professional development activity that supports change in their ICT pedagogical beliefs and practices. *Teacher Development, 13*(1), 43–55.

Sadler, T. (2004). Informal reasoning regarding socioscientific issues: a critical review of research. *Journal of Science Teaching*. 41:513–536.

Sadler, T.D., & Fowler, S.R. (2006). A threshold model of content knowledge transfer for socioscientific argumentation. *Science Education*. 90:986–1004.

Scheuer, O., Loll, F., Pinkwart, N., & McLaren, B. M. (2010). Computer-supported argumentation: A review of the state of the art. *International Journal of Computer-Supported Collaborative Learning, 5*(1), 43–102.

Shin, N., Sutherland, L. M., Norris, C. A., & Soloway, E. (2012). Effects of game technology on elementary student learning in mathematics. *British Journal of Educational Technology, 43*(4), 540–560.

Simon, S., Osborne, J., & Erduran, S. (2003). Systemic teacher development to enhance the use of argumentation in school science activities. In J. Wallace & J. Loughran (Eds.), *Leadership and professional development in science education: New possibilities for enhancing teacher learning* (198–217). London & New York: RoutledgeFalmer.

Soller, A., Martínez, A., Jermann, P., & Muehlenbrock, M. (2005). From mirroring to guiding: A review of state of the art technology for supporting collaborative learning. *Computer Science and Artificial Intelligence, 15,* 261–290.

Squire, K. D., & Jan, M. (2007). Mad City Mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers. *Journal of Science Education and Technology, 16*(1), 5–29.

Steinkuehler, C. A. (2006). Massively multiplayer online video gaming as participation in a discourse. *Mind, Culture, and Activity, 13*(1), 38–52.

Steinkuehler, C., & Chmiel, M. (2006). Fostering scientific habits of mind in the context of online play. In *Proceedings of the 7th international conference on Learning sciences* (pp. 723–729). International Society of the Learning Sciences.

Toulmin, S. (2003). *The uses of argument*. Cambridge, UK: Cambridge University Press.

Toulmin, S., Rieke, R., & Janik, A. (1984). *An introduction to reasoning*. Upper Saddle Ridge, NJ: Prentice Hall.

Vygotsky, L. S. 1978. *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Zeidler, D. L. (2003). *The role of moral reasoning on socioscientific issues and discourse in science education*. The Netherlands: Kluwer Academic Press.

Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. *Journal of Elementary Science Education*, 21(2), 49-58.

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Examination of Students' Small Groups Discussion in Argumentation Process: Scientific and Socio-Scientific Issues

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Abstract

The purpose of this study was to examine processes experienced by students of different achievement levels in small group discussions in argumentation applications conducted in scientific and socio-scientific issues. Case study which is a qualitative research design was used for the study. In this line, a success test including mechanical subjects comprising multiple-choice and open-ended questions was applied to students by researches in the beginning of semester. Looking at points taken from the success test, student levels (high, medium and low) were determined and groups were formed in accordance with these levels. One group was selected from each level representing that level, and processes experienced by discussions relating to scientific issue as well as socio-scientific issue were individually examined. Study group consisted of 10 preservice teachers having education in Department of Science Teaching. Voice records of both issues were taken during student discussions and analyzed by transcription. Codes prepared by the researchers (cause-effect relationship, using clues, proposing suggestions, prediction, deduction etc.) were combined under certain categories and entitled. As a consequence, it was revealed that students were more effective in supporting argumentation process in non-scientific issue with respect to scientific issue; and in terms of evaluation, metacognition and process management, students were more effective in scientific issue with respect to non-scientific issue. Moreover, it was seen that students were more effective in non-scientific issue with respect to scientific issue in scientific process skills. When student-student questions were examined, there were more questions in scientific issue in the low-level; and there were more questions in non-scientific issue in the medium level.

Introduction

Argumentation applications are a part of targets of constructivist science classes and are based on social constructivism (Jiménez-Aleixandre, 2007). Argumentation is a discourse form regarded as important in education (Kuhn, 1993). It may be expressed as a discourse form in which individuals determine their locations, defend a situation with claims and evidences, and express potential arguments (Anderman & Anderman, 2009). Argumentation represents a process in which propositions are supported, justified and proved. It is the basic thought in this process to reveal a justified result and to attempt to prove this result (Norris, Phillips & Osborne, 2008). Argumentation in science enables revealing inconsistencies between thought and evidences and eliminating them (Berland & Hammer, 2012). Due to these reasons, argumentation should be rendered as a part of science and should be integrated into science education (Erduran & Jiménez-Aleixandre, 2007). Science education programs (National Research Council [NRC], 1996; Ministry of National Education [MNE],2013) highlight the necessity of improving skills in discussion in scientific or socio-scientific issues, performing analyses and making knowledge-based decisions by students, and study based on argumentation places the inquiry in center.

Students should be given opportunities to attend in applications of science in learning environments along with argumentation (Sampson, Enderle & Grooms, 2013). Argumentation is not a beneficial skill only for science education, school courses, and scientific issues. It may also be used in every field as a key skill requiring answering questions with claims supported with evidences. Thus, inquiry based models in education are more than memorizing truths about science, rather a platform in which students learn argumentation skills to understand and explore natural world (Hand & Schoerning, 2012).

Argumentation normally comprises relevant assumptions relating to a problem and results thereof. Determination of advantages and disadvantages of a subject to reach certain results requires determination of conflictions on the subject. Argumentation helps students to constitute strong content knowledge and provides context for deepening knowledge (Anderman & Anderman, 2009). In processes of deepening knowledge, students attempt to understand the reasons instead of simply accepting a situation. Students go beyond simply expressing a text or speech, and can provide a more complex and interrelated knowledge. Thus, knowledge gets more meaningful for students.

Argumentation is regarded as an important education for life and, when applied, value and importance thereof are revealed. Individuals attempt to solve a problem in argumentation process, examine a subject deeply and arrive at a decision by discussing together (Kuhn, 2005). Thusly, structuring of knowledge is enabled by paying attention to claims within the scope of alternatives (Anderman & Anderman, 2009). During this argumentation process, students reply claims of others with their own claims and adverse claims, provide explanations, pose questions and feel the requirement of proving the opposite by refuting alternative ideas. When students pose questions about what they want to learn, they are more aware of what they do not know or astonished/surprised by this. Posing questions to themselves and their peers has a role as a "thought-initiator" and metacognition or epistemic tool, thereby structuring their thoughts (Chin & Osborne, 2010). While individuals perform these activities, they have dialogue with peers, their teachers and sometimes with themselves to assess claims and evidences (Anderman &Anderman, 2009).

Argumentation may be used in constituting and testing explanatory bases of knowledge as a teaching tool to improve learning. These processes are effective in improving thinking skills (Felton & Khun, 2007). Argumentation helps students to fill blanks in understanding, questioning claim and evidences, and considering other points of view (Anderman & Anderman, 2009). Kuhn (1993) stated that it was important that educators were present in discussion environments and allocated time for these discussion environments in class. Moreover, Kuhn (1993) highlighted that argumentation might be in inner/individual form in which individual could discuss by themselves and could arrange a series of thoughts in proving a claim and external/social form is a process in which two or more individuals discussed with the other. From this point of view, individual-form argumentation is a product, and a process in social form (Kuhn, 1993). Along with recent developments, argumentation theory shows that argument is a social field (Driver, Newton & Osborne, 2000). Education programs should incorporate not only cognitive models but also social and cultural fields to improve argumentation processes. Hence, students gain social skills with argumentation applications in education (Driver, Newton & Osborne, 2000). In order to do it, in this study applications were associated with scientific and socio-scientific issues.

Recently, argumentation has gained an important support in favor of inquiry learning. Inquiry Learning is an educational activity requiring taking positions in gathering information about the world by scientists. Students directly involve in their own research activities such as formulating hypotheses, designing experiments to test them, gathering information and writing their results (Keselman, 2003). Thus, they actively participate in acquisition of knowledge (de Jong & van Joolingen, 1998). Inquiry Learning can be expressed as an educational activity in which a series of virtual or real facts are searched individually or as a group and in which results are acquired and written, and their causes and effects are determined (Kuhn, Black, Keselman & Kaplan, 2000). Furthermore, natural world is used as a teaching strategy in catching the spirit of development of spirit and scientific inquiry (Bybee, 2004). Inquiry provides opportunities to make explanations and research for conceptualization of a problem in science education and its answer (NRC, 2000). This inquiry based education is regarded as important in raising effective 21st century individuals who are problem-solvers, and have communication and thinking skills (MNE, 2013).

Scientific inquiry is closely related with scientific processes as well as being directly contributive to improvement of skills such as making observations, inferences, classifications, predictions, measurements, inquiry, interpretation and analysis of data. In scientific inquiry, socio-scientific issues may be used in supporting perceptions and reaching success in line with scientific literacy target (Lederman, Antink & Bartos, 2012). Abd-El-Khalick (2003) stated that what was experienced by students in decision-making processes in socio-scientific subject-based learning environments was similar to processes experienced by confirmation of scientific information. These issues may be complicated, be controversial, not have one absolute right answer, be based on explanation and be open-ended (Sadler, 2004). Socio-scientific issues are current and authentic situations having a scientific base and a great importance for society (Ekborg, Ottander, Silfver & Simon, 2013). Socio-scientific issues (for example, climate change, gene therapy, nuclear power, biological issues, etc.) are open ended social problems and strongly associated with science. Scientific information and inquiry applications may be used in negotiating socio-scientific issues. Tytler (2012) stated that modern science knowledge may also comprise unclear and complex socio-scientific issues. Socio-scientific issues, inquiry and negotiation enable integration of scientific concepts and processes with social structure and applications, thereby forming a strong context (Sadler, Barab & Scott, 2007).

Socio-scientific inquiry has three main components as participation in story, structuring of writing and scientific inquiry (Barab et al., 2007). Socio-scientific inquiry contributes to interpretation of socio-scientific story/narrative/events and skills for understanding charts, tables and diagrams comprising interpretation of scientific writings. It gives clues about epistemologies of individuals via complexity and dynamics in socio-scientific problems conceptualized by individuals (Barab et al., 2007).

Scientific and socio-scientific issues can be used in argumentation studies. Students provide active participation in inquiry/argumentation process within the frame of these issues, they act like scientists in this process (Abd-El-Khalick, 2003; de Jong & van Joolingen, 1998; Keselman, 2003). Furthermore, it provides important gains in line with purposes of scientific conceptualization and scientific literacy (Lederman, Antink & Bartos, 2014; Sadler, Barab & Scott, 2007). In studies based on socio-scientific issues, it was highlighted that it helped students understand science concepts better (Klosterman & Sadler, 2010), helped in improvement of a positive attitude of students towards science by making learning attractive and it positively affected epistemologies (Zeidler, Sadler, Applebaum & Callahan, 2009). It is also similar in scientific issues centered argumentation applications. It was stated that it helped in better learning and making sense of scientific concepts by students (Hand, Wallace & Yang, 2004; Schroeder, 2008; Kabataş Memiş, 2014) and progression of metacognitive thinking (Grimberg, 2008; Kabataş Memiş & Seven, 2015) and development of positive attitude of students towards science (Hand, Wallace & Yang, 2004). Thus, two issues were determined in this study as scientific and socio-scientific issue. Small group discussions reflecting perceptions of members of groups (Young & Henquinet, 2000) determined within the scope of these issues were examined in terms of different achievement levels experienced in the argumentation process.

Method

In this research aiming to examine experiences in the argumentation processes of the students in the scientific and socio-scientific issues, the case study was based as one of qualification research patterns. The case study method includes deep examination of a single situation or event instead of examining limited number of variables and following certain rules (Davey, 1991). Case studies are ways to look what really happens in environments, systematically collecting data, analyzing and revealing results thereof. In this study, assessment of the argumentation process performed in the scientific and socio-scientific issues in terms of the different achievement levels was realized.

Participant

The study was conducted with 25 prospective teachers having education in Science Education of an intermediate-scale university in north of Turkey in fall semester of 2013-2014 academic years. Students determined small groups to study on their own in the beginning of semester without any teacher interference. Seven different groups were formed, each comprising 3 or 4 students. Three different groups (totally 10 students) were selected and constructed working group of this study. The working group was determined by purposive sampling method. The reason behind the preference of this method was the advantage of incorporation of the most appropriate groups for purpose of study into the study (Balcı, 2013; Çepni,2014). Furthermore, while working in collaboration, the students were asked to create their own groups to prevent the process from negative effects of binary relations.

Groups' Achievement Level

Mechanics subject-based success test was applied prior to application to determine mechanics subject-based achievement levels of the students. There are 28 multiple-choice and 7 concept questions in the test prepared by researchers. The test questions were selected as appropriate for levels of students from different sources and examinations made by ÖSYM (ÖSS and ÖSYS). For provision of scope and structure validity, expert opinions in physics and language fields were taken and required corrections were made on the test. Cronbach's alpha reliability coefficient of the test was determined as .71. Answer keys were formed for concept questions and concept questions were graded by masking student names by an expert in their fields independent of researchers.

Distribution of questions in the achievement test in accordance with cognitive steps is given in indication table (see Table 1).

Table 1. Mechanics subject based success test indication table

Subject	Cognitive Level					
	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluated
Density		8,11,12,15,18, A3, A4	9,13,14,16, 17	10, A5		
Force		4, 11, A1	1,2,3,5,6,7	10		
Linear Motion		19,20, 21, 22				
Projectile Motion	25	24	23	A6,A7		A2
Energy and conservation		26	27, 28, 29			

Note: Multiple-choice question in success test was shown with numbers (1, 2, 3…) and open-ended questions as A1, A2,…etc.

Achievement levels of student groups were determined based on points taken from mechanics subject-based success test. Study of Akkuş, Günel and Hand (2007) was taken as reference on determination of the achievement levels. Taking averages and standard deviations of points taken from the test for achievement levels into consideration, groups with low achievement level($\bar{X}-1/4$ SD and below), medium achievement level ($\bar{X}-1/4$ SD , $\bar{X}+1/4$ SD) and high achievement level ($\bar{X}+1/4$ SD and upper) were defined. In this context, it may be expressed that 3 groups were in low achievement level, 2 groups in medium achievement level and 2 groups in high achievement level. Groups randomly selected from each achievement level was examined within the scope of this study. There were totally three students (2 male, 1 female) in low achievement level, four students (3 female, 1 male) in medium achievement level and three students (3 female) in high achievement level examined within the scope of study. This achievement level is considered to form the study groups. When we look at the literature, for National Assessment Governing Board (as cited in Akkuş, Günel and Hand, 2007) using a method to define student performance standards. Therefore, this method identifies what students should know and think and also be able to do at each level (basic, proficient, and advanced). In other study, Yerrick (2000) was to examine the effects of open inquiry instruction with low achieving. Thus, in this study researchers grouped students in such a way.

Argumentation Applications

Students have carried out science laboratory applications within the period of applications as appropriate for argumentation. In these applications, students experienced preparing questions, making experiments, forming claims and evidences one by one. On doing so, students performed small group discussions. Afterwards, large group discussions were made by sharing claims and evidences with the whole class. Within the scope of this study, small group discussions were carried out for socio-scientific (biological-based) and scientific (horizontal force) issue. Based on the SWH approach student template, the applications in a course are basically stated below. In both scientific and socio-scientific issues, students followed this process.

Students prepared their own questions (Beginning ideas - What are my questions?)
Students made experiments in small group discussions (Tests - What did I do?)
Students formed claims using observation and experiments (Observations - What did I see? and Claims- What can I claim?)
Students supported their claims with evidences (Evidence - How do I know? Why am I making these claims?)
Students presented these claims and evidences to the other classmates in large group discussions.

Socio-scientific issues are issues that are complicated, open-ended, mostly controversial, and not having one absolute right answer (Sadler, 2004). These issues represent social conflictions comprising science (Sadler & Zeidler, 2005). The text prepared for the socio-scientific issue of the argumentation application within the scope of the study was individually distributed to the students. After reading of the text by the students, they were asked to solve the problem in their groups. In the small group discussions, the students were expected to provide claims for the solution of the problem and support their claims with evidences given within the text. The given text comprised, as Sadler (2004) stated, a socio-scientific issue which did not have one absolute answer, was controversial and did not have only one right answer, was based on healthy life and balanced nutrition. Within the scope of this study, it was examined that experiences of students in not only scientific but also socio-scientific issues in argumentation applications.

The researcher took the role of a guide when the students had trouble in understanding the scientific process with the aid of auxiliary questions by enabling them to think of different dimensions. While doing so, the teacher incorporated questions such as why, what for and how. Moreover, the teacher guided them with questions when the students had trouble. Also, the researcher incorporated questions to enable negotiation initiation and continuation of the students in this period. The students searched different dimensions of the issue in different groups. Afterwards, each of the groups presented to the other groups and the researcher what questions they tested, what kind of way they proceeded in, what were claims and evidences formed, and thus carried out large group discussions. As in the small group discussions, researcher enabled thinking, negotiating, and making inquiries by student by asking questions such as "Do/don't you agree with what our friends say?, and "Why?" in the whole class discussions. Sometimes he/she encouraged the students to ask questions.

The scientific issue was the issue of "horizontal force". The students tried to find questions for questions determined by them within the scope of this issue. The students performed their experiments on sub-subjects of force effect, friction force, factors affecting friction force relating to the force subject. Experiment arrangements for their own questions were prepared, and the students formed claims using observation and experiments. They supported their claims with evidences. They conducted these applications in small group discussions having the teacher as the guide. Then, they presented what they did, their claims and evidences to the other classmates in large group discussions. As in the socio-scientific issue, the teacher involved in the process by mostly helping reasoning.

Data Analysis

Voice records of the group were taken during the small group discussions. The recordings were made with permission form the students. These voice records were then decrypted and transformed into a written document on a computer medium. In assessment of the data in this study, discourse analysis was used. Discourse analysis is a method enabling the understanding of what is going on within the class from the dimensions of both the teacher and the students by means of deep examination of spontaneous (without researcher interference) conversations within the class and texts of these conversations.

In this study, written documents representing the process carried out in small groups. Coding in the study was performed considering argumentation process experienced by the students. Written documents were firstly independently coded by each researcher, and then codings were compared and differences between the codings were eliminated. Certain themes were formed after the coding. The themes were determined considering the process experienced in small groups (inquiry, justification, explanation, persuasion, cause-effect relationship, peer education, comprehension control, etc.). The themes determined are scientific process skills, evaluation, advanced level thinking, process management, argumentation process support and student-student questions.

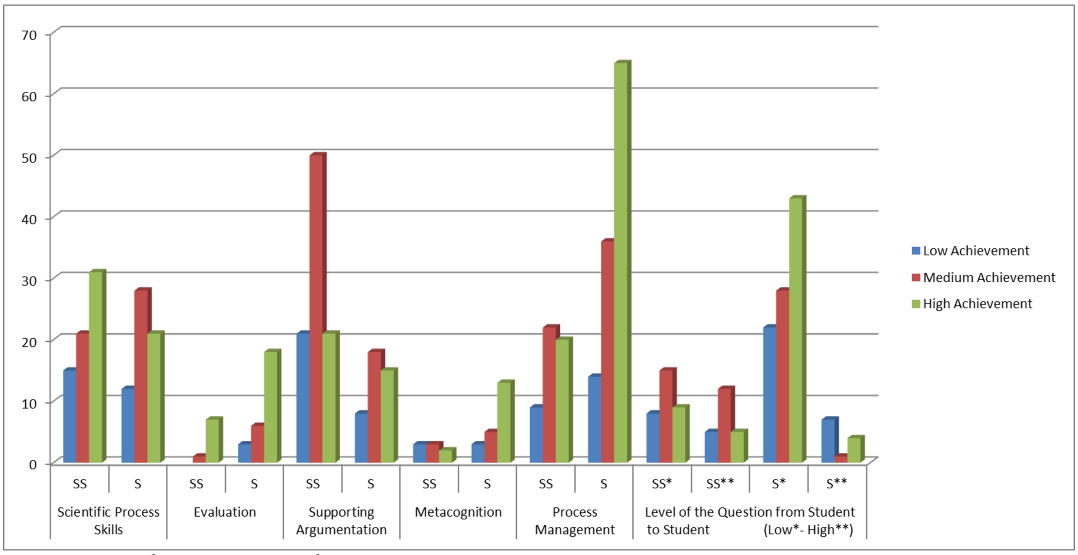
Threats to Internal Validity

Possible threats to internal validity and the methods used to tolerate them were discussed below:

To control location threat, the researcher kept location the same for all groups. Thus, all groups had the application and tests at the same place. Mortality threat was controlled in this research study because there was no missing participants during the application. To control instrumentation, the test questions were presented in multiple-choice form. Therefore, instrument decay was eliminated by scoring procedure. Besides, voice redors were essay type, but it was used coding procedure from the literature review. So, this threat was controlled completely.

Results

The codes formed as a result of analyses of dialogues within small group discussions performed for two weeks by the students were combined and six different themes were formed. These themes are scientific process skills, evaluation, metacognitive thinking, process management, argumentation process supporting and student-student questions. In Chart 1, formed themes and total code numbers of groups of high, medium, low achievement level relating to scientific and socio-scientific issues are present. While presenting students statement, students in each group were coded both using group symbol (High: H, Medium: M and Low: L) and number (1,2, 3,…etc). For instance, H1 represent high achievement level first student.



SS: Socio-scientific issue; S: Scientific issue

Chart 1. Results of three different groups about the themes

Theme 1. Scientific Process Skills

Scientific process skills theme consists of codes of "measurement, classification, observation, classification, prediction, inference, variable control, determination of variables, interpretation/argument, deduction, revealing of data, making references, exhibiting references to an authority, comparison, planning experiment arrangement, using pre-knowledge, explanation (communication)". When Chart 1 was examined, it was seen that the students in low and high achievement levels conducted situations reflecting scientific process skills better with respect to the scientific issue. As the opposite in the group of medium achievement level, the students incorporated statements in the scientific issue reflecting scientific process skills more than the socio-scientific issue.

Table 1. Coding samples relating to scientific process skills theme

Issue	Groups	Coding Samples "Statement relating to code" / code / students
Scientific	High	*"This is our glass. We thought it would break, but it may not. I think it will probably be broken" / prediction* / H_3
	Medium	*The object go once pulled. It can go forever" / deduction* / M_4
	Low	*We said gravity force exists, and there is a reaction force against it" /* variable control / L_3
Socio-scientific	High	*Is it possible? Can he throw himself on the glass?" / argument/ H_1*
	Medium	*Maybe he is schizophrenic, he did it himself."* /interpretation/M_2
	Low	*The guy is paranoid and very rich, he may have enemies* /prediction /L_1

On comparison of the groups of three different achievement levels, the students of high achievement level mostly incorporated such statements in the socio-scientific issue and the students of medium achievement level in the scientific issue while it is experienced the least commonly in the group of low achievement level in both issues. With the change applied in 2013, it was aimed to develop scientific process and life skills of students in a program arranged as a science-teaching program as well as developing scientific thinking habits with socio-scientific issues (MNE, 2013). In this context, teaching of scientific and socio-scientific issues with argumentation-based application may be stated to be effective in the development of scientific process skills in students. Coding samples of the groups are given in Table 1.

Theme 2. Evaluation

When dialogues of the students in the small group discussions were examined, it was determined that there were statements representing the codes of “evaluation, self-evaluation and peer evaluation”. An evaluation theme was formed combining these codes. When Chart 1 was examined, it was remarkable that the students in all three achievement levels incorporated evaluation statements in the scientific issue with respect to the socio-scientific issue more. The students in high achievement level incorporated evaluation statements in socio-scientific issues more with respect to the students in the other two achievement levels; however, no evaluation statement was detected in student dialogues in low achievement level. Looking from this angle, as Alaçam-Akşit (2011) stated, the students may be said to be insufficient in making evaluation. Coding samples of the groups are indicated in Table 2.

Table 2. Coding samples relating to evaluation theme

Issue	Groups	Coding Samples “statement relating to code”/code / students
Scientific	High	*“I don’t remember the net force.”* / self-evaluation / H_3
	Medium	*“You didn’t pull fast. You pulled fast here.”* / peer evaluation / M_4
	Low	*“That’s what we said. There is gravity force downwards, there is an opposite reaction force.”* / evaluation / L_3
Socio-scientific	High	*“You scrutinize it. Because the man may have eaten little or a lot according to his hunger status.”* / peer evaluation / H_1
	Medium	*“Either sometime broke in from the window by hitting on the glass or he broke the window, then killed himself.”* / evaluation /M_2
	Low	-

Theme 3. Supporting Argumentation Process

For argumentation process supporting theme, “claim, evidence, rebuttal, justification, inquiry, persuasion, non-adoption-resistance, cause-effect” codes were combined. As discussions occurred during the socio-scientific issues enable the suggestion of different opinions, along with being beneficial for the argument (Simonneaux, 2007), the argumentation based inquiry approach is effective in explaining and making sense of science concepts of students in the scientific issues and experiencing the scientific discussion (Akkuş *et al.*, 2007). When results relating to argumentation process supporting theme in Chart 1 were examined, it was seen that students in all three achievement levels experienced a situation such as inquiry, cause-effect, resistance, persuasion, using justified statements and refutation (of himself and his peers) in the socio-scientific issue with respect to scientific issue. While the students of high and medium achievement levels incorporated such statements in similar ratios, the students of low achievement level incorporated such statements less than the other two groups. Coding samples of the groups are seen in Table 3.

Table 3. The coding examples of the theme for supporting the argumentation process

Issue	Groups	Coding Samples “statement relating to code”/code / students
Scientific	High	*“It is impossible. Look what Songül says. F- fs =fnet oh! Fnet… the one which is 120”* / rebuttal / H_3
	Medium	*“There is no risk for our comparison as the weight is identical, the same thing is happening”* / cause-effect / M_4
	Low	*“It is not like that, it has a friction coefficient.”*/ rebuttal / L_1
Socio-scientific	High	*“He fired his servant.”* / evidence / H_2
	Medium	*“If he is thinking in that way, he would not leave the knife.”* / rebuttal / M_3
	Low	*A knife with blood thereon.* / evidence / L_2

Theme 4. Metacognition

Metacognition theme was created by combining the themes of “indecision, showing empathy, awareness raising and decision making”. It was seen that when the chart was examined the statements which supported metacognition such as indecision, awareness raising decision-making were experienced maximally in the group that was in the high achievement level in scientific issue. It was understood that this group was followed by the students who were in the medium achievement level while the students who were in the low achievement level used such statements. It was seen that the groups were approximately equal in social-scientific issue. In this respect it was specified that the argumentation process supported metacognition usage of the students. Furthermore, it could be specified that when the relationship between the socio-scientific issues and the science education was considered, socio-scientific issues were important in understanding the advanced level thinking, discussion skills, scientific argumentation, inquiry based learning and the nature of science according to the needs of students (Nuangchalerm, 2010, s.36).The coding examples of each group are provided in Table 4.

Table 4. The coding examples of metacognition theme

Issue	Groups	Coding Samples "statement relating to code"/code / students
Scientific	High	"*I think this… how do I…" / indecision* / H_2
	Medium	*"It means it is changing" / awareness* /M_2
	Low	*"I wonder if we apply less force or we get used to it."* / indecision /L_2
Socio-scientific	High	*"And also under the table… if servant killed why did he put it under the table"* / indecision / H_1
	Medium	*"Well, yes because he thinks like that, he sees like that, doesn't he..."* / awareness / M_1
	Low	*"It is ok then let's go to this way" /making decision* / L_2

Theme 5. Management Process

A process management theme was created by combining the codes of giving instruction, peer education, proposal/alternative suggestion, giving consent, asking for a proposal, using clues, giving clues, comprehension control and peer support. It was seen that when the chart 1 was examined the statements reflecting the process management theme were seen more in the scientific issue compared to socio-scientific issue. On the basis of groups in scientific issue the students in the high achievement level were the ones who used the statements relating to the process management maximally while this was encountered minimally in the students in the low achievement level. In socio-scientific issue the students who were in the high and medium achievement level used these statements in a similar ratio while these statements were used minimally in the group in the low achievement level. The coding examples of the groups are provided in Table 5.

Table 5. The coding examples of the management process theme

Issue	Groups	Coding Samples "statement relating to code"/code / students
Scientific	High	*"I agree that this is good."* /peer support / H_2
	Medium	*For example should those have the same size, right? /asking for consent* / giving consent / M_3
	Low	*"L_3! Look at the coefficients of the friction force or something like that / giving instruction/ L_2*
Socio-scientific	High	*"He was also saying that there has been a blood y knife, right?"* / giving consent / H_2
	Medium	*Yes, I also think the same thing/ peer support* / peer support / M_1
	Low	*"If we eliminate the trauma, then we can say he died because of cuts" /suggesting alternative* / L_1

Theme 6. Student-Student Questions

Students' questions were coded as low level (comprising short answers such as yes/no) questions and medium level (requiring explanation) questions. It was specified that the questions functioned as a basis during the process such as inquiry, discussing and decision making about an issue (Hand, 2008), and the students were required to ask qualified questions in order to create a question-claim-evidence triad. It was seen that when student-student questions were examined in chart 1 high level questions were used more in scientific issue whereas medium level questions were used more in socio-scientific issue. The students in the high achievement level used low level questions quite a lot in scientific issue and similarly, in socio-scientific issue low level questions were used more than the medium level questions. When the groups of medium and low level were examined (see chart 1) it was understood that a similar situation was experienced and the students used more low level questions than the medium level questions. The coding examples of the groups are provided in Table 6.

Table 6. The coding examples of student-student questions theme

Issue	Groups	Coding Samples "statement relating to code"/code / students
Scientific	High	*"Is it m times a?"* / low level question / H_3
	Medium	*"Do you know?"* / low level question / M_3
	Low	"*Does the friction force have less impact after it is applied?"* / medium level question / L_1
Socio-scientific	High	*"Could he do this with panic?"* / low level question / H_1
	Medium	*"But then how did he handle the fingerprints?" /* medium level question / M_3
	Low	*"How do we find without saying anything about the position of the chair and the table because the smallest hair can be an evident?"* / medium level question / L_2

Discussion

When the research results were considered it was seen that the students who were in high achievement level were more active in scientific issue (horizontal force), evaluation and process management. In scientific process skills and argumentation process supporting themes the students who were in medium achievement level executed this process more often while the ratios used by the students who were in different achievement level in the high-level thinking were close to each other. In this respect it could be specified that the argumentation applications performed by the students who were in different achievement level in scientific issue played an important role in small group discussions. It was determined that in the research carried out by Akkus et al.(2007) taking into consideration the achievement level the applications of argumentation based inquiry approach had a positive effect on the students' achievement. In similar studies in the literature it was specified that argumentation based inquiry approach had a positive effect on explanation of science concepts/conceptual understanding for the students (Keys, Hand, Prain & Collins, 1999; Kıngır, Geban & Günel, 2012).

On the other hand it was seen that when socio-scientific issue was considered, scientific process skills, evaluation and high-level thinking were experienced more often by the students in the high achievement level compared to the students in the medium achievement level whereas these were experienced more often by the students in the medium achievement level compared to the students in the lower achievement level. In the argumentation process supporting theme and process management it was detected that the students in the medium achievement level were more active. It was said that socio-scientific issue was a broad term which encompassed STS (science-technology-society) and required taking into consideration the ethical aspects of science and moral conditions and affective development of a child (Zeidler et al., 2002). Socio-scientific issues which were assumed as an important approach in the science education had a functional role in understanding the science concepts, argumentation skill development, critical thinking, inquiry development and decision making skills, and moral/ethic value adding (Molinatti, Girault, & Hammond, 2010; Sadler & Zeidler, 2005; Zeidler vd., 2002). Metacognition is an important factor in raising individuals who are aware of their own mental process and learn more consciously (Çakıroğlu, 2007). The studies indicate that inquiry applications in which the argumentation is used are efficient for students to develop high-level thinking skills and to learn and implement the science (Hand,Prain &Wallace, 2002; Hand, Wallace & Yang, 2004; Keys, Hand, Prain & Collins, 1999).

Another theme in the study was student-student questions. With reference to student-student questions low level questions were used in scientific issue whereas medium-level questions were used in socio-scientific issue. When the students' dialogs were considered in the environments in which the inquiry process was experienced in this process it was important that students asked questions to each other in terms of understanding inquiry that was inherent for the science (Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005). In addition, asking question helps to direct the different dialogs in order to solve the problems encountered (Aguiar, Mortimer & Scott, 2010). Blonder (2007) who focused on the questioning behaviors of the high school students interested in the research-inquiry reported that asking question helped student to reach a certain purpose and to be successful in lessons in which these questions were created. A similar situation was seen in this study. Because as students asked more questions they might experience much more guidance, inquiry and criticizing, and they can get result more readily. During this process with the applications within the triad of question-claim-evidence in the class, the students used and developed their thinking skills much better (Kana, 2014). Besides small and big group discussions were important for students to express themselves and to get different point of views by asking questions to each other.

According to the results obtained, it can be said argumentation skill were important in terms of inquiry development, critical thinking, decision making etc. In the science curriculum for primary schooling the relevance of the use of argumentation is emphasized in the adopted strategies and methods (MNE, 2013). Besides, one of the inquiry learning process in the curriculum focuses on the creating argument. On the other hand, in many important exams, such as in the PISA report, argumentation is included (Organization for Economic Co-operation and Development [OECD], 2001). In this sense, skill to assess claim and evidence were particular importance. In the present study, it was seen that emphasizing the importance of this, applying the argumentation practices in teaching in both scientific and socio-scientific issues are necessary.

Generally, it was concluded that during the process all applications based on socio-scientific issue along with the scientific issue contributed to the development of argumentation skill of the students in all levels. As the sciences in which the argumentation skill were important in terms of raising science-literate individuals were highlighted in the education program it could be suggested that socio-scientific issue could be used more along with scientific issue to develop such skills in the program (MNE, 2013). In addition it is thought that the seminars (along with exemplary applications) which will be held for the teachers in this issue will enable this approach to be used more often by the teachers.

References

Abd-El-Khalick, F. (2003). Socioscientific issues in pre-college science classrooms: The primacy of learners' epistemological orientations and views of nature of science. In D. L. Zeidler (Ed.), The role of moral reasoning in socioscientific issues and discourse in science education (pp. 41–61). Dordrecht, The Netherlands: Kluwer.

Aguiar, O. G., Mortimer, E. F., & Scott, P. (2010). Learning from and responding to students' questions: The authoritative and dialogic tension. *Journal of Research in Science Teaching.* 47(2), 174-193.

Alaçam-Akşit, A. C. (2011). Sınıf öğretmeni adaylarının sosyobilimsel konularla ve bu konuların öğretimiyle ilgili görüşleri (Yüksek lisans tezi, Ege Üniversitesi, İzmir).

Akkuş, R., Günel, M., & Hand, B. (2007). Comparing an ınquiry-based approach know as the science writing heuristic to tradational science teaching practices: are there differences. *International Journal of Science Education,* 1-21.

Anderman, E. M. & Anderman, L. H. (Ed.) (2009). *Psychology of classroom learning: An encyclopedia.* Detroit: Macmillan Reference USA.

Balcı, A. (2013). Sosyal Bilimlerde Araştırma: Yöntem, Teknik ve İlkeler.10. Baskı, Pegem Akademi, Ankara.

Barab,S., Zuiker, S., Warren, S., Hickey, D., Ingram-goble, A. Kwon,E., Kouper, I., & Herring,S.C. (2007). *Science Education, 91*(5), 750-782.

Berland, L. K., & Hammer, D. (2012). Framing for scientific argumentation. *Journal of Research in Science Teaching, 48* (1),68-94.

Besnard, P., & Hunter, A. (2008). Elements of Argumentation. Cambridge, MA: MIT Press.

Bybee, R. W. (2004). Scientific inquiry and science teaching. In L. B. Flick, & N. G. Lederman (Eds.), Scientific inquiry and nature of science (pp. 1- 14). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Chin, C., & Osborne, J. (2010). Supporting argumentation through students' questions: Case studies in science classrooms. *Journal of the Learning Sciences*, *19*(2), 230-284.

Çakıroğlu, A. (2007). Üstbiliş. *Türkiye Sosyal Araştırmalar Dergisi*, 11 (2).

Çepni, S. (2014). Araştırma ve Proje Çalışmalarına Giriş. Yedinci baskı, Trabzon.

Çolakoğlu K. (Ed.). (2002). Serway fen ve mühendislik için fizik (5. Baskı). Ankara: Palme Yayıncılık

de Jong, T., & van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research, 68*(2), 179-201.

Davey, L. (1991). The application of case study evaluations. *Practical Assessment, Research & Evaluation, 2*(9), 1-2.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*(3), 287–312.

Ekborg, M. , Ottander, C., Silfver, E., & Simon, S. (2013). Teachers' experience of working with socioscientific issues: A large scale and in depth study. *Research in Science Education, 43*(2), 599- 617. doi: 10.1007/s11165-011-9279-5

Felton, M. K., & Kuhn, D. (2007). "How Do I Know?" The Epistemological Roots of Critical Thinking. *The Journal of Museum Education, 32*(2), 101-110.

Hand B. M. (2008). Introducing the science writing heuristic approach. B. M., Hand (Ed.). *Science inquiry, argument and language* içinde(ss.1-11). Rotterdam: Sense Publisher.

Hand, B., & Schoerning, E. (2012). The Discourse of Argumentation. *Mevlana International Journal of Education (MIJE), 2*(3), 43-52.

Hand, B., Prain, V., & Wallace, C. (2002). Influences of writing tasks on students' answers to recall and higher-level test questions. *Research in Science Education, 32,*19–34.

Hand, B., Wallace, C., & Yang, E. (2004). Using the science writing heuristic to enhance learning outcomes from laboratory activities in seventh grade science: Quantitative and qualitative aspects. *International Journal of Science Education, 26*, 131-149.

Hofstein, A., Navon, O., Kipnis, M., & Mamlok-Naaman, R. (2005). Developing students' ability to ask more and better questions resulting from inquiry-type chemistry laboratories. *Journal of research in science teaching, 42*(7), 791-806.

Jimenez-Aleixandre, M. P. (2007). Designing argumentation learning environments. S. Erduran ve M. P. Jiménez-Aleixandre (Ed.) *Argumentation in science education:Perspectives from classroom-based research* içinde (ss. 91-115). Dordrecht: Springer.

Jimenez-Aleixandre, M. P., & Erduran, S. (2007). Argumentation in science education: An overview. S. Erduran and M. P. Jiménez-Aleixandre (Ed.) In *Argumentation in science education: Perspectives from classroom-based research* (pp. 3-27). Dordrecht: Springer.

Kabataş Memiş, E. (2014). Elementary Students' Ideas About On Implementation Of Argumentation Based Science Learning Approach. *Kastamonu Education Journal, 22*(2), 1-18.

Kabataş Memiş, E., & Seven, S. (2015). Effects of an SWH Approach and Self-Evaluation on Sixth Grade Students' Learning and Retention of an Electricity Unit. *International Journal of Progressive Education, 11*(3), 32-49

Kana, F. (2014). The effect of argumentation-based language teaching approach pre-service Turkish language teacher attitudes to special teaching methods course. *International Journal of Language Academy, 2*(1), 107-125.

Keselman, A. (2003). Supporting inquiry learning by promoting normative understanding of multivariable causality. *Journal of Research in Science Teaching, 40* (9), 898-921.

Keys, C. W., Hand, B., Prain, V. & Collins, S., (1999). Using the science writing heuristic as a tool for learning from laboratory ınvestigations in secondary science. *Journal of research in science Teaching, 36*(10), 1065-1084.

Kıngır, S., Geban, Ö., & Günel, M. (2011). Öğrencilerin kimya derslerinde argümantasyon tabanlı bilim öğrenme yaklaşımının kullanılmasına ilişkin görüşleri. *Selçuk Üniversitesi Ahmet Keleşoğlu Eğitim Fakültesi Dergisi, 32,* 15-28.

Kuhn, D. (1993). Science as argument: Implications for teaching and learning scientific thinking. *Science Education, 77*, 319-337.

Kuhn, D. (2005). *Education for thinking*. Cambridge, MA: Harvard University Press.

Kuhn, D., Black, J., Keselman, A., & Kaplan, D. (2000). The development of cognitive skills to support ınquiry learning. *Cognition and Instruction, 18*(4), 495-523.

Lederman N.G., Antink, A., & Bartos, S. (2012). Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: A Pathway to developing a scientifically literate citizenry. *Science & Education, 23,* 285-302. DOI 10.1007/s11191-012-9503-3

Klosterman, M. L., & Sadler, T. D. (2010). Multi-level assessment of scientific content knowledge gains associated with socioscientific issues based instruction. *International Journal of Science Education, 32*, 1017-1043.

MNE (Ministry of National Education) (2013). "İlköğretim Kurumları Fen Bilimleri Dersi (3, 4, 5, 6, 7 ve 8. sınıflar) Öğretim Programı".

Molinatti, G., Girault, Y., & Hammond, C. (2010). High School Students Debate the Use of Embryonic Stem Cells: The influence of context on decision-making. *International Journal of Science Education*, *32*(16), 2235-2251.

Norris, S. P., Phillips, L. M., & Osborne, J. F. (2008). Scientific inquiry: The place of interpretation and argumentation. In J. Luft, R. L. Bell, & J. Gess-Newsome (Eds.), *Science as inquiry in the secondary setting* (pp. 87-98). Washington, DC: National Science Foundation.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

Nuangchalerm, P. (2010). Development of Socio Scientific Issues-based Teaching for preservice science Teacher. *Journal of social Sience,* 5 (3), 239-243.

OECD (Organisation for Economic Co-operation and Development) (2001). *Knowledge and skills for life. First results from PISA 2000. Organisation for Economic Co-operation and Development.* Available at https://www.oecd.org/edu/school/programmeforinternationalstudentassessmentpisa/33691620.pdf (09.02.2017)

Potter, J. (2004). Discourse analysis as a way of analyzing naturally occurring talk. D. Silverman (Ed.) In *Qualitative analysis: Issues of theory and method, 2nd Edition* (pp. 200-221). London:Sage.

Sadler, T. D. (2004). Informal reasoning regarding SSI: A critical review of research. *Journal of Research in Science Teaching, 41*(5), 513–536.

Sadler, T. D., Barab, S. A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? *Research in Science Education, 37*, 371-391.

Sadler, T. D., & Zeidler, D. L. (2005). Patterns of informal reasoning in the context of socioscientific decision making. *Journal of Research in Science Teaching, 42,* 112–138.

Sampson, V., Enderle, P., & Grooms, J. (2013). Argumentation in science and science education. *The Science Teacher, 80*(5), 30-33.

Schroeder, J. D. (2008). The lab-lecture correlation: From the Science Writing Heuristic to the Traditional Organic Chemistry Laboratory. In ***Science Inquiry Argument and Language: A Case for the Science Writing Heuristic*** by Brian M. Hand, Ed.; Sense Publihers, Rotterdam, the Netherlands 2008.

Tytler, R. (2012). Socio-scientific issues, sustainability and science education. *Research in Science Education, 42,* 155-163. DOI 10.1007/s11165-011-9262-1

Young, C. B., & Henquinet, J. A. (2000). Viewpoint: A conceptual framework for designing group projects. *Journal of Education for Business, 76*(1), 56-60.

Zeidler, D. L., Sadler, T. D., Applebaum, S., & Callahan, B. E. (2009). Advancing reflective judgment through socioscientific issues. *Journal of Research in Science Teaching,* 46(1), 74-101. doi: 10.1002/tea.20281

Zeidler, D. L., Walker, K. A., Ackett, W. A., & Simmons, M. L. (2002). Tangled up in views: Beliefs in the nature of science and responses to socioscientific dilemmas. *Science education*, *86*(3), 343-367.

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Characterizing Middle Grade Students' Integrated Alternative Science Knowledge about the Effects of Climate Change

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Abstract

Recent reforms emphasize a shift in how students should learn and demonstrate knowledge of science. These reforms call for students to learn content knowledge using science and engineering practices, creating integrated science knowledge. While there is existing literature about the development of integrated science knowledge assessments, few studies examine the character of alternative integrated science knowledge (AISK) that students demonstrate when responding to these assessment items. This study describes the AISK middle grade students demonstrate in response to integrated science tasks. Students completed a pre-instruction task by making predictions, justifying their predictions about the geographic range of species' habitats, and adjusting that prediction based on a climate change scenario. These findings revealed four areas of AISK: 1) Climate Data Interpretation and Analysis, 2) Identifying Climate Patterns, 3) Identifying Causes of Climate Patterns, and 4) Justifying Climate Claims. For each area, specific patterns in AISK were identified and described. The findings indicate that integrated assessments can provide insights into students' struggles coordinating science content and practices for integrated knowledge products, and present a continuum to which students' AISK can be compared. This work has potential to be used for the development of teaching strategies to support students' developing integrated science knowledge.

Introduction

What does it mean to know or understand science knowledge? For many years, individuals in pre-college science classes were characterized as knowing science knowledge if they could recite definitions of key scientific terms or recall important scientific formulas. Since the 1990s, there has been a slow shift in terms of how we characterize science knowledge in the United States (NRC, 1996; NRC, 2012; NGSS Lead Sates, 2013) and internationally (e.g. United Kingdom Department of Education, 2015; National Curriculum Board, 2009). In the United States, the *Framework for K-12 Science Education* (Framework; NRC, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013) have shifted to an emphasis on science knowledge as having three interconnected dimensions: (1), *disciplinary core ideas* (DCIs), (2) *science and engineering practices* (SEPs), and (3) *crosscutting concepts* (CCCs).

The documents used in the United Kingdom (United Kingdom Department of Education, 2015) and in Australia (National Curriculum Board, 2009) delineate similar components to science knowledge. This shift in how we describe science knowledge, towards a description of that interconnects science facts and content with science ways of knowing necessitates a corresponding shift in characterizing an individual's understanding of science concepts (Songer & Kali, 2014). While research exists that characterizes students' knowledge associated with disciplinary core ideas and science practices (e.g. Gotwals & Songer, 2013), there is a need for additional research that characterizes students' misconceptions associated with this newer integrated science knowledge and that characterizes intermediate and final form integrated science knowledge.

In the United States, the crosscutting concepts and disciplinary core ideas are collectively referred to as the science content. As presented in the Framework (NRC, 2012), the disciplinary core ideas are the fundamental aspects of the four disciplines of science: Life Science, Earth and Space Science, Physical Science, and Engineering Science, whereas, the crosscutting concepts are the broad themes of science that cut across disciplinary core ideas, such as: systems and system models, energy and matter, consistency and change, etc. (NRC, 2012).

The crosscutting concepts (CCCs) will support students in making connections across science disciplines and to support deeper understanding of science content (NRC, 2012), though little research has empirically examined classroom practice using the CCCs. The science and engineering practices (SEPs) are the ways of knowing, e.g., the means through which the science content is developed. The Framework (NRC, 2012) suggests that students should be learning science as an integration of science practices, disciplinary core ideas, and crosscutting concepts (e.g., a three-dimensional product).

Characterizing Integrated Science Knowledge

While integrated science knowledge is the goal, not all integrated products are accurate or complete. Students' integrated responses, when not complete or accurate, can reveal student's challenges and struggles. Though questions remain about what kinds of tasks provide good evidence of students complete and incomplete integrated science knowledge. A recent document from the National Academy of Science titled, *Developing Assessments for the Next Generation Science Standards* (NRC, 2014), states that tasks designed to provide evidence of integrated science knowledge should have these characteristics:

- "multiple components that reflect the connected use of different scientific practices in the context of interconnected disciplinary ideas and crosscutting concepts,
- reflect the progressive nature of learning by providing information about where students fall on a continuum between expected beginning and ending points in a given unit or grade; and
- an interpretive system for evaluating a range of student products that is specific enough to be useful in helping teachers understand the range of student responses and that provides tools to helping them decide on next steps in instruction." (NRC, 2014; p. 130)

The research literature documents that studies describing students' integrated knowledge on a continuum from early to late form integrated science knowledge are needed. In particular, we need research that characterize the products of learning associated with the development of integrated science knowledge.

Alternative Integrated Science Knowledge (AISK)

While many research groups have focused on students' alterative science knowledge (e.g. Driver et al., 2008; Minstrell, 2001; Arslan et al., 2012) their contributions primarily focus on the ways that students misunderstand content only, e.g., without consideration for how students' might represent misunderstandings in integrated science knowledge. For example, Driver and colleagues' work focused on ways of eliciting students' alternative science knowledge using images (Driver et al., 2008), though the images are generally ones produced by others to clarify how students are thinking about a concept. Similarly, Keeley and colleagues (e.g. Keeley & Tucker, 2016) created a series of books focused on prompts to understand which common misconceptions students demonstrate. While at times these researchers provided insights about how students reason (e.g. Keeley & Tucker, 2016) and their certainty about their knowledge (Arslan et al., 2012), in general, there is no systematic documentation of alternative integrated science knowledge (AISK) existing in the literature.

Students' Scientific Predictions

Scientific predictions consist of evidence generated to support a claim about an unknown or future event that can be verified at a later time. Two examples of everyday predictions that individuals encounter are daily weather reports and predictions about the long-term impacts of climate change. Predictions are an important tool used by scientists. For example, the Intergovernmental Panel on Climate Change (IPCC) generates predictions about the future impacts of climate change (IPCC, 2014). Despite the common use of scientific predictions, those outside science often do not understand how predictions are generated or how they should be interpreted (Pielke et al., 2003).

As students learn about predictions in the classroom, their construction of predictions has traditionally worked within the model of the scientific method, focusing on the formulation of hypotheses and hypothesis testing (Davis & Linn 2000; White & Frederiksen, 1998). A second model focuses on having students revisit their predictions at the end of a lesson, as a tool, which can help make students aware of how their knowledge has changed during the lesson (Linn, 2006). In this context, predictions can be used as a powerful tool for characterizing students' prior knowledge and initial ideas. Here we think about predictions as a measure of progress in students' understanding, where a student's initial prediction can serve as a marker of the starting point.

Based loosely on models of decomposing the science and engineering practice of explanation or argument building explored by a variety of research teams (Songer, Kelcey, Gotwals, 2009; McNeill et al., 2006; Windschitl et al., 2008), we have adopted a definition of a scientific prediction that identifies the prediction as the claim, similar to a claim within a scientific argument, and identifies reasoning and/or evidence as the supporting material for the prediction (see Lee & Songer, 2003). The supporting material might be evidence from a previous experiment (evidence), a related scientific definition or principle (reasoning), and/or previous experience with the phenomenon (prior knowledge or experience). Since a student can use any available related information in support of a prediction a new term is needed; in this case, the term *justification* is used. Students' selection of justification to support their scientific predictions involves a similar process to selecting evidence from data or selecting appropriate reasoning, an area where students traditionally struggle (e.g. Sadler 2004). Therefore, in these studies, the process of selecting justification involves identifying appropriate evidence, experience, or scientific principles to support the prediction. While using justification is an important part of encouraging students to support their thinking, teachers often fail to push students to use justifications to support their predictions (Arias et al., 2016).

Study Design

This study is designed to answer the research question: *What alternative integrated science knowledge do eighth grade students demonstrate in response to integrated assessment items?* This descriptive study focuses on characterizing the types of information that eighth grade students demonstrate pre-instruction relative to assessment task prompts that ask students to develop integrated predictions about the effects of climate change on species habitats. An assessment was developed that required students to demonstrate their knowledge of the disciplinary core ideas of climate data through three sub-areas of the science practice of interpretation and analysis: identification, pattern identification, and data manipulation. The assessment questions required a variety of levels of prior knowledge of scientific and geographic phenomena through the science practices of interpretation and analysis. This assessment focused on integrated knowledge designed to be a realistic replication of a classroom task.

Data Analysis Constructs

This assessment was designed to generate evidence of students' pre-instruction integrated science knowledge about potential human impacts on species' habitat due to climate change. The three dimensions of integrated science knowledge (e.g., DCI, CCC and SEP) that formed the basis for this assessment is illustrated in Table 1. The assessment was also designed to provide evidence of students' abilities to develop integrated knowledge products about the potential effects of climate change (DCI), analyzing data from models (SEP) to find patterns (CCCs) to support a prediction (SEP) in integrated science knowledge products. If students were completely successful, they would demonstrate DCIs about climate change's effect on species habitat (CCC-cause and effect) through the SEP of using models to make predictions. The specific DCIs, CCCs, and SEPs associated with various assessment questions are represented in Table 2.

The assessment also focused on the integrated knowledge of temperature and precipitation data through the science practices of analyzing and interpreting data and drawing on evidence to construct a prediction (Table 2: Maps 6, 7, and 8). The term "interpreting data" represents the sub-area of the science practice of "interpreting graphical displays of data" (NGSS Lead States 2013b, p.57), including finding the locations of a value, or range of values, found on a map. To do this requires the ability to do three things: recognize which of the climate data ranges on the legend represents a given range of values, identify the color aligned with that range of values, and find patches of that color on the map. Since the data represented on the map (Figure 1 and Figure 2) was climate data, the interpretation task requires some knowledge of the disciplinary core knowledge related to climate integrated with the science practice of interpretation. The term "analyze" includes: "interpret graphical displays of data… to identify linear and non-linear relationships" (NGSS Lead States 2013b, p.53), and, "use graphical displays (e.g., maps…) of large data sets to identify temporal and spatial relationships" (NGSS Lead States 2013b, p.53). Part of the analysis task is focused on the identification of patterns (CCC) within the data (Figure 1). Pattern identification tasks within the assessment required students to use the science practice of data analysis for identifying patterns related to the disciplinary core idea of weather and climate (Table 1). In the assessment, students were given the definition of a pattern as: "When something is placed in a way that is not completely random [statistically random]. There is an order to the way things look." Pattern recognition requires that students notice when there is a non-random organization of the data. The recognition of patterns requires the ability to observe regularity. When students are asked to describe a pattern, that process requires some geographic or scientific prior knowledge. Describing a pattern or explaining why it might occur requires knowledge of geography and scientific processes that might cause the pattern. Pattern recognition was considered a content dependent scientific practice. While students might observe a pattern, it is possible they do not recognize it as such unless they have supporting scientific content.

Table 1. Integrated science goal understandings that served as the focus of the assessment

Integrated Science Goal Understandings	Disciplinary Core Idea	Crosscutting Concept	Science Practice
Analyze data to identify values and patterns in temperature and precipitation values.	**ESS2.D Weather and Climate (Grades 3-5):** Climate describes patterns of typical weather conditions over different scales and variation. (p.47)	**Patterns (Grades 3-5):** Patterns can be used as evidence to support an explanation. (p.92)	**Analyzing and Interpreting Data (Grades 6-8):** Use graphical displays (maps) of large data sets to identify temporal and spatial relationships. (p.72)
Analyze data to support predictions about the cause of an observed pattern.	**ESS2.D Weather and Climate (Grades 3-5):** Climate describes patterns of typical weather conditions over different scales and variation. (p.47)	**Cause and Effect (Grades K-2):** Events have causes that generate observable patterns. (p.83)	**Analyzing and Interpreting Data (Grades 6-8):** Use graphical displays (maps) of large data sets to identify temporal and spatial relationships. (p.72)
Analyze data to make predictions about the habitat of species with given climate needs.	**LS4.C Adaptation (Grades 3-5):** Particular organisms can survive only in particular environments. (p.45)	**Cause and Effect (Grades K-2):** Events have causes that generate observable patterns. (p.83)	**Analyzing and Interpreting Data (Grades 6-8)**: Analyze and interpret data to provide evidence for phenomena. (p.57) **Argumentation (Grades 3-5):** Construct and/or support an argument with evidence, data, and/or a model. (p.63)
Analyze data to support predictions about the future location of a species' habitat based on given environmental change.	**LS4.D Biodiversity and Humans (Grades 3-5):** Populations of organisms live in a variety of habitats. Change in those habitats affects the organisms living there. (p. 45)	**Cause and Effect (Grades K-2):** Events have causes that generate observable patterns. (p.83)	**Analyzing and Interpreting Data (Grades 6-8):** Analyze and interpret data to provide evidence for phenomena. (p.57) **Argumentation (Grades 3-5):** Construct and/or support an argument with evidence, data, and/or a model. (p.63)

Note: Statements in columns 2-4 of this table are direct quotes of the elaborated dimensions found in *NGSS Volume 2: Appendixes*, page numbers refer to the page on which the text can be found. (NGSS Lead States, 2013)

Table 2. Assessment tasks and the dimensions integrated in the assessment task

	Question Text	Dimensions of Science Education
	Map 1	
Q1	Using the map above with the temperature layer turned on, answer question 1. Draw a border around the areas within the United States with the hottest average temperatures.	Analyzing and Interpreting Data + Earth's Systems
	Map 2	
Q2	Using the map ~ with the temperature layer turned on, answer question 2. On the map, draw a border around all areas within the United States that have average temperatures between 15°C and 19.9°C.	Analyzing and Interpreting Data + Earth's Systems
	Map 3	
Q3	Using the map above with the precipitation layer turned on, answer question 3. On the precipitation map, draw a border around all areas within the United States that have precipitation between 50cm and 99.9cm of annual precipitation.	Analyzing and Interpreting Data + Earth's Systems
	Map 4	
Directions	Use the map with the temperature layer turned on and the explanation of a pattern to answer questions 4-6. A pattern is when something is placed in a way that is not completely random. There is an order to the way things look.	
Q4	Draw a border around an area with a pattern.	Analyzing and Interpreting Data + Patterns + Earth's Systems
Q5	In a complete sentence, describe how the pattern looks.	Analyzing and Interpreting Data + Patterns + Earth's Systems
Q6	In complete sentences, describe what might cause that pattern?	Analyzing and Interpreting Data + Patterns + Cause & Effect + Earth's Systems
	Map 5	
Directions	Use the map with the precipitation layer turned on and the explanation of a pattern to answer questions 7-9. A pattern is when something is placed in a way that is not completely random. There is an order to the way things look.	
Q7	Draw a border around an area with a pattern.	Analyzing and Interpreting Data + Patterns + Earth's Systems
Q8	In a complete sentence, describe how the pattern looks.	Analyzing and Interpreting Data + Patterns + Earth's Systems
Q9	In complete sentences, describe what might cause that pattern?	Analyzing and Interpreting Data + Patterns + Cause & Effect + Earth's Systems
	Map 6	
Directions	Using the map above with the temperature ~ turned on, answer questions 10-13. The Southern Bog lemming likes temperatures between 10°C and 19.9°C.	
Q10	Draw a border around the areas where you would expect to find the Bog lemming in the United States, on the map above.	Analyzing and Interpreting Data + Earth's Systems
Q11	Draw a border around the areas where you expect to find the Southern Bog lemming if the United States were getting hotter, 5°C warmer.	Analyzing and Interpreting Data + Cause & Effect + Biological Evolution + Earth's Systems
Q12	Write a statement answering the scientific question: Where you would predict to find the	Analyzing and Interpreting Data + Cause & Effect

	Southern Bog lemming in the United States if the average temperature increased by 5°C?	+ Biological Evolution + Earth Systems + Argumentation
Q13	Backing: data or a scientific concept or definition that supports your answer to the scientific question. What two backings do you have to support your prediction? Describe them in complete sentences.	Analyzing and Interpreting Data + Cause & Effect + Biological Evolution + Earth Systems + Argumentation
	Map 7	
Directions	Using the map above with the precipitation layer turned on, answer questions 14-17. The Southern Bog lemming likes precipitation between 50 and 149.9 centimeters.	
Q14	Circle the area where you would expect to find the Bog Lemming in the United States, on the map above.	Analyzing and Interpreting Data + Earth's Systems
Q15	Circle the areas where you expect to find the Southern Bog lemming if the United States were getting drier, 50 centimeters less precipitation everywhere.	Analyzing and Interpreting Data + Cause & Effect + Biological Evolution + Earth's Systems
Q16	Write a statement answering the scientific question: Where would you predict to find the Southern Bog lemming in the United States if the average precipitation decreased by 50cm?	Analyzing and Interpreting Data + Cause & Effect + Biological Evolution + Earth's Systems + Argumentation
Q17	Backing: data or a scientific concept or definition that supports your answer to the scientific question. What two backings do you have to support your prediction? Describe them in complete sentences.	Analyzing and Interpreting Data + Cause & Effect + Biological Evolution + Earth's Systems + Argumentation
	Map 8	
Directions	Turn on both the temperature AND precipitation layers to answer questions 18 and 19. Use the borders you created on the last two maps, which are visible when you turn on the temperature and precipitation layers to answer the following questions.	
Q18	Write a statement answering the scientific question: Where would you expect. to find the Southern Bog lemming in the United States under the present temperature and precipitation conditions?	Analyzing and Interpreting Data + Cause & Effect + Biological Evolution + Earth's Systems + Argumentation
Q19	Backing: data or a scientific concept or definition that supports your answer to the scientific question. What two backings do you have to support your prediction? Describe them in compete sentences.	Analyzing and Interpreting Data + Cause & Effect + Biological Evolution + Earth's Systems + Argumentation

Note: Each Map signals a shift in webpages where the students are presented with a new map, the given directions, and the assessment items associated with the page. For Map 8, students had access to the circles they drew on Maps 6 and 7.

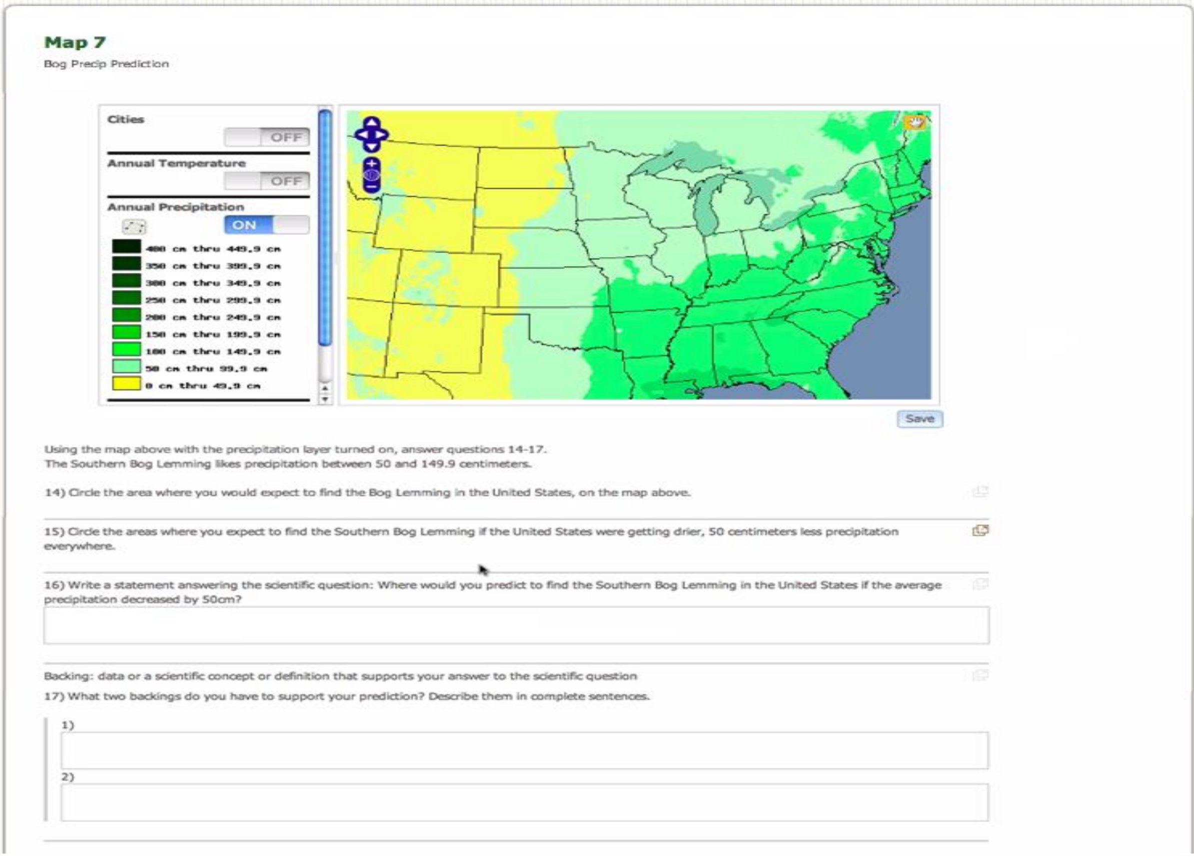

Figure 1. A precipitation map, with precipitation classified by 50cm bands of annual average precipitation. Below the map is an example of one of the question bundle that would accompany this type of map, in this case it is the question bundle associated with map 7

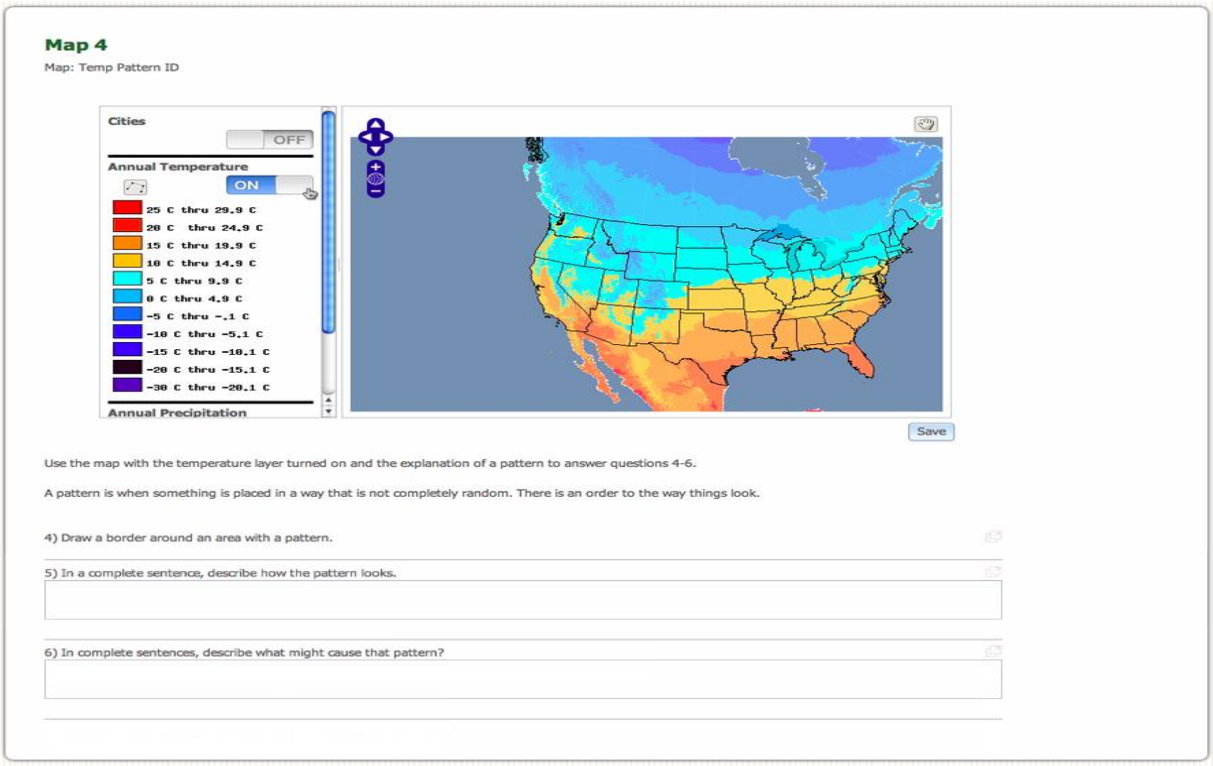

Figure 2. A temperature map, with temperature classified by 5 degree celsius bands of annual average temperature. Below the map is the question bundle that accompanied map 4

The second type of analysis task includes the adjustment of data values by a constant change to represent changing environmental conditions (Figure 2). After recognizing magnitude and direction of the change, students then adjust the values represented by the various colors to reflect the change, and circle the new areas satisfying the data range. Data adjustment was considered a scientific practice, because it requires students to visualize a constant change in the data.

Finally, the students were required to apply observations from a map as justification in support of a scientific prediction in answer to a scientific question (Table 2: Questions 13, 17, and 19). This required the student to select a supporting observation or pattern from the data represented on the map associated with the answer to a scientific question and to describe that observation or pattern in words as evidence. Predictions included a claim, and two justifications. The two justifications could include data, a scientific concept, or a definition that supports their answer to the scientific question. Because this task was intended to focus on interpretation and analysis, students' knowledge of scientific phenomena and political labels was intentionally kept to a minimum in the assessment task, but it was a component of all aspects of the process.

Implementation of the Assessment

Middle grade students have prior experience with maps in a variety of contexts and circumstances both in and out of the school environment. In addition, students might have experience with the disciplinary core knowledge related to human impacts on climate change, species' habitats, or climate change. These experiences and knowledge serve as foundational DCI knowledge that students draw on when demonstrated integrated science knowledge, such as the analysis of climate data or interpreting a climate model.

The assessment tasks utilized an online visualization tool (Peters & Songer, 2013) for the presentation of geographic visualizations. As shown in Figure 1 and Figure 2, the assessment questions were presented on the same webpage as the tool. The complete set of assessment items is presented in Table 2, and each change in webpage is represented by the row labeled with a map number. For each page of the assessment, a single question, or a set of questions was associated with a single map of temperature or precipitation data. When a student changed maps, or set of questions, the map would reset to the original settings thereby providing students with a blank map on which to begin the next question. The exception to this was for map 8, for this map, students were provided with the circles that they created when answering the questions for maps 6 and 7. Students completed the assessment tasks on a laptop during a free period. The assessment tasks were designed so that evidence of students' integrated science knowledge as well as the errors and incomplete integrated science knowledge could be demonstrated by requiring students to circle areas on a map that matched the given criteria, make predictions about future conditions, and to justify their predictions using any prior knowledge they had. For example, as seen in Figures 1 and 2, students used average temperature and average precipitation data as evidence in generating scientific predictions about where they might find specific environmental conditions. In addition to being aligned with the NGSS (Table 1; NGSS Lead States, 2013), these integrated knowledge tasks are aligned with standards recommendations from the National Council on Geographic Education (Bednarz et al. 1994).

Additional Considerations in Assessment Task Design

The amount of prior content knowledge related to climate, climate change, species habitat, and biological evolution required to be complete the assessment tasks was kept to a minimum by providing data within the task itself to serve as justification for the predictions, and by accepting any accurate response. Students did not need to know the names of states within the United States, but were expected to be able to pick out the border between the US and Canada, and the US and Mexico from lines on the map that outlined the individual states that make up the United States, since questions required students to "circle the areas within the United States".

Prior to the data collection with this group of students, the assessment tasks were given to a different group of students of a similar age and classroom to provide valuable information on the validity of the assessment tasks. These students were asked to think aloud during the process they used to complete the task. Based on challenges students had understanding and interpreting the assessment questions, several edits to the tasks were made to improve the tasks relative to the focal constructs.

Study Population

The students who completed the assessment consisted of six eighth-grade students in a science focused charter school in the urban center of a large Midwestern city. The school serves students living anywhere in the city district, which encompasses almost the entire city. The eighth-grade class that year was composed of 96.4% African-American students, the remaining <4% being made up of other races; 61% of the students were male, with only 39% female. Less than 10 students in the school were classified as English Language Learners.

The school was a charter school in a very low SES school district. Of the six students interviewed, two students were female, and one student was of an ethnicity other than African-American. The students were from different classroom sections, but they had the same science teacher. The teacher selected students who represented a range of abilities to participate in the study. Students' abilities were based on their performance in science class. Since the participants were at the very end of their eighth-grade year, they can be considered students transitioning from the middle grades (middle school) to upper grades (high school). All the students had been at the school for two or three years and therefore had experience with a research-based National Science Foundation sponsored curricular units focused on the development of integrated science knowledge in a variety of different disciplinary core ideas.

Data Collection

Students completed the assessment individually in their science classroom with the teacher present. The teacher was in a different part of the room focused on completing other tasks. The assessment consisted of 19 questions that took from 40 to 70 minutes to complete. The assessment was delivered through an interactive assessment format made up of clusters of tasks. For all questions, students could interact with the maps on the site by zooming in and zooming out, turning on and off the precipitation and temperature data layers, and circling areas on the map to identify particular locations. The assessment task began with an example question, that was focused on introducing the student to the tools and features of the maps, which asked students to locate and circle the state they lived in. The example was followed by 19 questions which are the focus of this research study.

For all pilot and research study interviews, the first author was present as students responded to the questions and a think aloud protocol (Ericsson & Simon 1993) was used. As students completed the task, the first author prompted the students to provide information about the process they were using to answer the questions, and why the students selected the particular answers. The assessment completion was recorded using ScreenFlow (Telestream 2011) software. ScreenFlow software stores a continuous record of the screen of the computer with a coordinated record of the ambient noise in the room. Recordings consisted of a continuous screenshot of the students' screen activities accompanied by audio of the students' described responses, the think aloud description of the process they used for answering the question, and the written responses students provided for the assessment questions.

Data Analysis

Students' verbal and written responses were initially transcribed. This process of transcription used both the audio recording and the coordinated screenshots to determine any context specific verbal responses, such as "it's right here," where the student indicated a location with their cursor. In examining students' responses to the assessment tasks, iterative rounds of coding (Miles & Huberman 1994) initially characterized written responses as correct or incorrect.

The coding was based on a pre-established notion of what were correct and incorrect representations of the DCI, CCC, and SEP based on preliminary trials of the assessment item with a different group of students. Subsequent coding used incorrect responses as the basis for the development of codes to characterize type and level of difficulty that the student has with the assessment task, using grounded theory based coding (Patton 2002). The codes were grouped into broad categories that reflected the types of AISK represented in the students' responses. These types of error were then sorted into the categories of errors shown in Table 3. At the end of the description of the types of errors in Table 3 is a reference to the codes in the codebook (supplemental material) that make up that code.

Results

Types of Errors

The integrated science knowledge errors that students demonstrated consisted of different combinations of the DCI, CCC, and SEP, thus resulting in new types of AISK. The errors were categorized into one of five types:

- Error Type 1: Climate Data Interpretation and Analysis: Earth's Systems + Analyzing and Interpreting Data.
- Error Type 2: Identifying Climate Patterns: Earth's Systems + Pattern + Analyzing and Interpreting Data.
- Error Type 3: Identifying Causes of Climate Variation: Earth's Systems + Cause and Effect + Analyzing and Interpreting Data.
- Error Type 4: Justifying Species Range Predictions: Earth's Systems + Biological Evolution + Analyzing and Interpreting Data + Argumentation.
-

Each type of error was associated with several observed categories of error (Table 3). Each category of error could be ranked on a hierarchy describing the level of the problem (Table 3, right column). The hierarchies were determined based on whether there was sufficient information to judge the response, and subsequently whether the student used appropriate information in generating that response. The types of error, and categories of error, are elaborated with examples from students' responses. It is important to note that certain types of errors were only possible on certain questions (see Table 4). For example, students never made an error in pattern identification when circling on the map.

Students' Errors When Making Climate Change Predictions

This paper is focused on the types of errors that students in their attempts to demonstrate integrated science knowledge, e.g., knowledge statements that include both DCI and SEPs or DCI, SEPs and CCCs in an integrated statement. Since it is difficult to determine the cause of the error, the sections below focus on describing the errors, not the cause. The errors selected below focus on the difficulties that students had with making integrated predictions. By focusing on the errors associated with justifying climate change predictions, we can concentrate on the ways in which we might support students to develop integrated knowledge.

Error Type 1: Climate Data Interpretation and Analysis: Earth's Systems (DCI) + Analyzing and Interpreting Data (SEP)

These errors are associated with interpreting and analyzing the data represented in the maps. These were errors in which students had difficulty coordinating the DCI and the SEP of data analysis to communicate the information presented. For example, students circled areas that were smaller or larger than the area with the specified data or they demonstrated errors in interpreting the climate data represented in the maps.

The early part of the assessment focused on identifying climate values on the map. These assessment items asked students to identify locations with specified conditions ("Analyzing and Interpreting Data + Earth's Systems", Table 1). In students' responses, they needed to circle the areas that met the specified conditions. Often students were inexact in their circling, including other data values in with the correct ones (e.g. Figure 3). At other times the students circled part of the correct response but did not include all the data in their response (e.g. Figure 4). These responses were a level 2 error (Table 3), because they included correct areas, but also included incorrect areas, or were missing some correct areas. All the students who participated in the study did this at least once (Table 4: Error Type 1, Level 2). A third variation within this error type are the instances where the students circled areas that did not include the correct values (e.g. Figure 5). There were several different ways that students might do this. The initial comparison between the key and the map might result in the student picking the wrong color, a level 1 error (Table 4: Error Type 1, Level 1), or the question might ask a student to do a data adjustment that resulted in the student picking the wrong color to represent the adjusted data values, a level 3 error (Table 4: Error Type 1, Level 3).

The climate interpretation and analysis tasks revealed the challenges that students had using the information and clues in the data to assist them to find the correct areas. The initial tasks, questions 1-3, 10, and 14, asked students to identify values within a given range. Students were challenged by these initial tasks to identify values (Table 4: Error Type 1), while most students included some of the correct values, many students missed part of the range. It was more common for students to circle some of the correct results than none as shown by a comparison of rows 1 and 2 in Table 3. There was one student who answered more than half of these questions correctly, student 6.

Error Type 2: Identifying Climate Patterns: Earth Systems (DCI) + Pattern (CCC) + Analyzing and Interpreting Data (SEP)

These errors focused on students having difficulty describing a pattern they identified in the data. Many students referred to the data without reference to locations. Two questions required students to describe the patterns they identified on the map (Table 2, Questions 5 & 8). The students' descriptions clarified what the student selected as being a pattern. In their descriptions, students frequently referred to the colors observed in the maps without reference to geographic information (Table 3: Incomplete Description of Climate Pattern). Since it was difficult to determine exactly what part of the data the students were describing, these errors were coded as incomplete descriptions of the climate pattern, a level 1 error (Table 4: Error Type 2, Level 1). For example, student stated:

> The pattern looks like its going from blue orange blue orange – Student 2 (Question 5)
> The pattern looks like the readings turned to the right, or laid on their right side. – Student 3 (Question 8)

Based on the descriptions provided by the students, it was difficult to determine to what extent their observations reflected a pattern as defined in the task: *"A pattern is when something is placed in a way that is not completely random. There is an order to the way things look." (The definition of a pattern included in the assessment).* While students often accurately described something that could be a pattern, their responses often lacked connection to the data presented or the disciplinary core knowledge that could be integrated into the response to support their observation.

Error Type 3: Identifying Causes of Climate Variation: Earth's Systems (DCI) + Cause and Effect (CCC) + Analyzing and Interpreting Data (SEP)

There were several responses that indicated a lack of accurate knowledge about the causes of climate variation (Table 4: Error Type 3). These answers were in response to questions that asked students what might be a cause of the pattern they observed. In these cases, students' lack of knowledge about climate became apparent in their difficulty being able to describe the cause of a pattern. These items asked students to, "in complete sentences, describe what might cause the pattern" (see Questions 6 and 9, Table 2). This phrasing, including "might", was intended to allow students unfamiliar with the cause room for speculation, engaging their prior knowledge. These responses that showed AISK about what causes variation in climate were level 2 errors (Table 3: Inaccurate Description of Pattern Cause). Some examples of these responses are:

> I think that different types of time zones/dates cause different temperatures. – Student 2 (Question 6)
> The air pressure as your higher in the atmosphere rather than going lower. – Student 4 (Question 6)

These responses make clear students' AISK about things that can be classified as a cause of varying climates. Student 2 seemed to have alternative science knowledge about a places' positioning on the globe being related to the temperature, and the reason why we have time zones. Some additional probing of the student's understanding would clarify the students' meaning here. This was the most common difficulty with this question type (Table 4: Error Type 3, Level 2).

Other students did not sufficiently describe the cause enough to understand whether they were relying on an alternative science idea (Table 4: Error Type 3, Level 1). For example, for question 6, which asked about the possible cause of temperature patterns, student 1 wrote, "The higher you go the colder it will get." In this response, it is unclear what the student means by "higher". If they meant further north on the map, then their response was accurate, but if they meant altitude then that information was unrelated to the task. In this example, additional information from the student would have clarified the response.

Table 3. The types categories, and difficulty levels of errors observed on the integrated assessment

Type of Error	Dimensions	Category	Description (Codes from Analysis Codes)	Difficulty Level
Error Type 1: Climate Data Interpretation and Analysis	Earth Systems + Analyzing and Interpreting Data	Circled Incorrect Values	The circled area does not include the correct values. (OFF)	1
		Circled Correct and Incorrect Values	The circled area includes correct values, but is either missing values or includes extra values. (INC)	2
		Transformation Error	Inaccurate transformation of temperature or precipitation bands to account for prediction. (TRANS)	3
Error Type 2: Identifying Climate Patterns	Earth Systems + Analyzing and Interpreting Data + Patterns	Incomplete Description of Climate Pattern	Does not completely describe the pattern. There is insufficient information present to determine what pattern was identified.	1
Error Type 3: Identifying Causes of Climate Variation	Earth Systems + Analyzing and Interpreting Data + Patterns + Cause & Effect	Incomplete Description of Pattern Cause	Does not describe the cause of the pattern. There is insufficient information present to make a judgment about the accuracy of the statement. (INC-D)	1
		Inaccurate Description of Pattern Cause	The statement is a description of an inaccurate scientific process or geography that caused the pattern, uses the wrong word to describe the scientific phenomenon, or provides an unrelated fact. (PC)	2
Error Type 4: Justifying Species Range Predictions	Earth Systems + Biological Evolution + Analyzing and Interpreting Data + Argumentation	Incomplete Description of Claim	Student stops short of making a complete claim for their prediction. There is insufficient information presented to make a judgement about the accuracy of the statement.	1
		Prediction Mismatch	The prediction does not match the area identified on the map as the answer to the question. There is a mismatch between the students' data analysis and the claim they are making. (MAT)	2
	Earth Systems + Biological Evolution + Analyzing and Interpreting Data + Argumentation	Incomplete Description of Justification	Student does not completely describe the prediction or justification in writing. There is insufficient information present to make a judgment about the accuracy of the statement. (INC-J)	1
		Unrelated Info Used for Prediction	Student uses unrelated fact as a claim and/or justification for a prediction. (URF)	2
		Prediction as Justification	Student uses another prediction as justification for a prediction. (PRE)	3
		Inaccurate Description of Science Process	The statement is a description of an inaccurate scientific process to justify the prediction, or uses the wrong word to describe the justification.	4

Table 4. Results of the integrated assessment showing the level of error by error type and by student

Type of Error	Error Type 1: Climate Data Interpretation and Analysis	Error Type 2: Identifying Climate Patterns	Error Type 3: Identifying Causes of Climate Variation	Error Type 4: Justifying Species Range Predictions
Question #	1, 2, 3, 10, 11, 14, 15	5, 8	6, 9	12, 13, 16, 17, 18, 19
Difficulty Levels	1, 2, 3	1	1, 2	1, 2, 3, 4
Student 1	1 – 4 2 – 3 3 – 0 Correct – 0	1 – 1 Correct – 1	1 – 2 2 – 0 Correct – 0	1 – 2 2 – 7 3 – 0 4 – 0 Correct – 0
Student 2	1 – 1 2 – 3 3 – 1 Correct – 2	1 – 2 Correct – 0	1 – 0 2 – 2 Correct – 0	1 – 6 2 – 1 3 – 1 4 – 0 Correct – 1
Student 3	1 – 0 2 – 4 3 – 0 Correct – 3	1 – 2 Correct – 0	1 – 0 2 – 1 Correct – 1	1 – 0 2 – 1 3 – 0 4 – 1 Correct – 6
Student 4	1 – 0 2 – 4 3 – 0 Correct – 3	1 – 0 Correct – 2	1 – 0 2 – 2 Correct – 0	1 – 3 2 – 0 3 – 2 4 – 2 Correct – 2
Student 5	1 – 1 2 – 3 3 – 0 Correct – 3	1 – 1 Correct – 1	1 – 0 2 – 1 Correct – 1	1 – 7 2 – 0 3 – 0 4 – 1 Correct – 1
Student 6	1 – 1 2 – 1 3 – 1 Correct – 4	1 – 0 Correct – 2	1 – 1 2 – 0 Correct – 1	1 – 1 2 – 1 3 – 0 4 – 0 Correct – 7

Note: The shading represents frequency and level of the error. Those cells shaded in green include an equal number of correct and incorrect or more correct. Those in shades of yellow include more incorrect than correct, but include some correct answers. Those in shades of blue include no correct answers, the lighter shades are higher levels of difficulty, while darker shades are lower levels of difficulty.

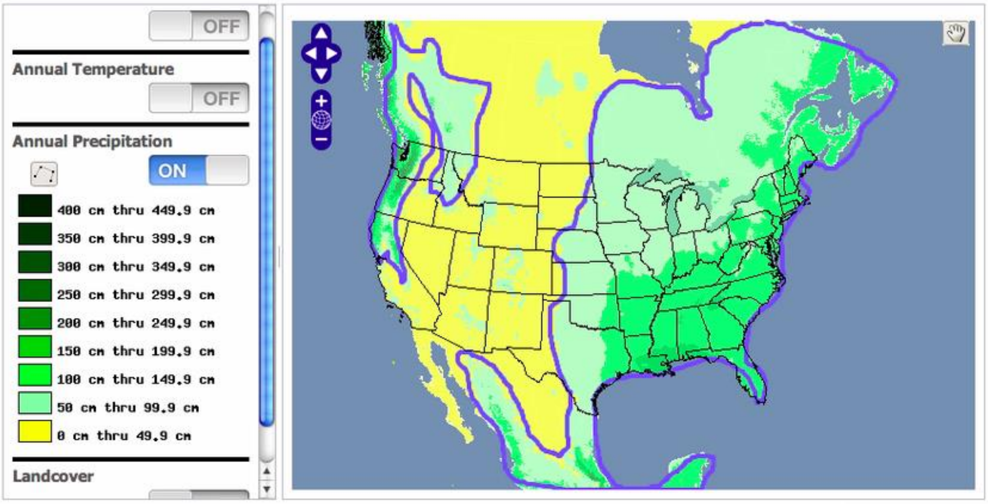

Figure 3. Map of student 3's response to question 14. The area that the student circled includes many different precipitation values, particularly in the area identified in the Pacific Northwest. This is also the case for the area identified in the Southeast though, since there are three different precipitation values in the area identified

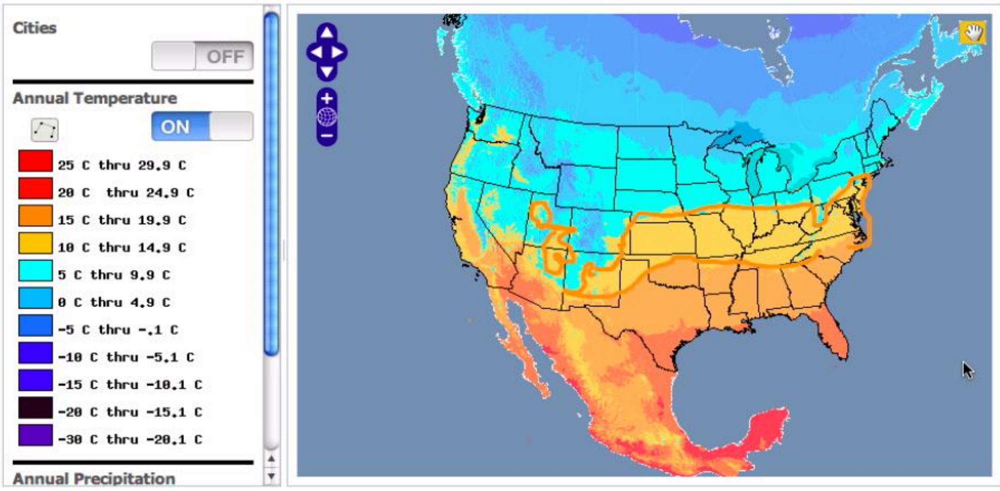

Figure 4. Map of student 4's response to question 10. The area that student 4 circled represents one of two temperature bands that were specified by the question. This error was continued as the student transformed the data to represent a changing climate in question 11.

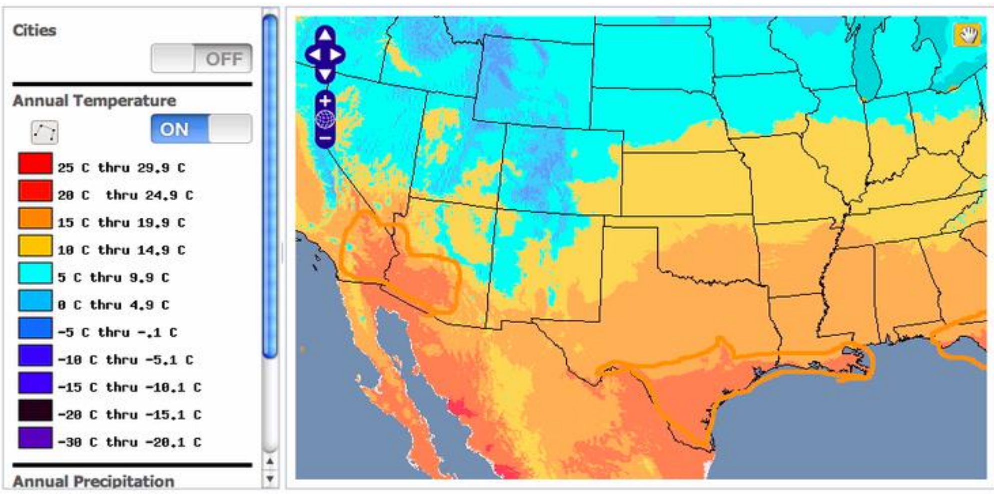

Figure 5. A map showing student 6's response to question 2. The area that student 6 circled is one temperature band away from the values specified by the question (15°C to 19.9°C). The student's response does not include the correct values.

Error Type 4: Justifying Climate Claims: Earth's Systems (DCI) + Argumentation (SEP)

Students also made errors when justifying their climate predictions. These errors were demonstrated when students provided an incomplete description of their justification (level 1), used unrelated information to support their prediction (level 2), made a prediction statement as justification (level 3), or an alternative idea about the DCI material included in their justifications (level 4). In other words, students often used something other than relevant DCI evidence to support their claim. Many students had difficulty relating the DCI associated with earth systems with the SEP of argumentation to generate justified predictions based on climate data or in providing sufficient and accurate justification that was scientific and not personal. For example, students made a variety of errors in supporting their predictions with accurate DCI climate change knowledge for justification. Students did not receive instruction about constructing predictions supported by justification, and correspondingly many of the errors were based on the kinds of DCI information that students provided as justification. It is possible that some of these errors could be attributed to lack of prior knowledge or insufficient DCI knowledge to identify appropriate support.

Some students used unrelated personal knowledge as justification for their predictions (Table 4: Error Type 4, Level 2). One example was: *"The areas where tornados are most common." – Student 6 (Question 17)*
Neither tornados nor, more generally, natural disasters were discussed in the task. Weather and climate phenomena were presented in terms of annual average temperature, and the potential for change in those averages was presented. Another example demonstrates that, if a student referenced information insufficiently, it was unclear if the student based their reasoning on personal knowledge or information provided in the task. For example, in this level 1 answer, the student uses vague terms, making it unclear whether the information used is from the task: *"For the [justification] the bog lemming likes the heat so with less rain level and in dry spots it would like to stay there." – Student 5 (Question 17).* In this example, the student refers to conditions the animal prefers such as "likes the heat" and "dry spots." These phrases are referential to a standard level of temperature, a normal, which is not clearly defined. In this case, "likes heat" refers to an undefined range of temperatures. While this may appear to focus on minute details, the students were given ranges of values that the bog lemming preferred which corresponded to specific colors on the temperature and precipitation map. This student translated those ranges into a personal value system, not clearly specified, and used that system as a justification for the prediction. Some students used a claim as justification for a different claim, a level 3 error. An example from a students' work is:

> The plants and animals would die and travel further like the bog lemming to find food. – Student 4 (Question 17).

This student further provided information about what might happen to other animals, after having made a claim about what they expected to happen to the bog lemming.

Three students made a level 4 error, an inaccurate description of the science process (Table 4: Error Type 4, Level 4). In response to question 13, student 4 wrote:

> if it became hotter, (5 degrees) the [sic] would travel up to a warmer habitat.

This response uses all the correct principles, except that the student adjusted the temperature inaccurately. If the average temperature were getting warmer, then the location of the animal's preferred habitat would be where it had been previously cooler. This error in adjustment is a scientifically based error (Table 3: Inaccurate Description of Science Process).

Justifications frequently took the form of a description of the process used, a claim, or personal knowledge. This could indicate the students' lack of integrated disciplinary core knowledge related to climate change's impact on species habitats, although the species' habitat preferences were provided as were the climate changes (see "Directions" in Table 2; or see full assessment in supplemental material). Alternatively, it could be that students struggled to understand the type of information needed to support their claims when drawing from information on a map and in the item itself.

Patterns across Students

In looking across student responses as represented in table 4, there are no clear patterns in the level of error that a student made across the questions. The errors that student 1 made primarily fall in the category of incorrect or imprecise identification, which speaks to the necessity of basic identification skills for beginning the assignment. For most students, there was one level of error that was most common for each error type. There were several students who got 50% or more questions right for a particular type of question, but for the questions that they got wrong, there was not a distinguishable pattern in the level of error made.

Discussion

This research shows examples of assessment items and student responses that represent students' progress on integrated science knowledge. By asking questions that asked students to analyze data to find patterns and make predictions about the cause and effect of changing climate, these assessment tasks revealed many different AISK that students held about the cause of climate change and the effects of these changes on species. A review of the results across all students and tasks reveals these general patterns:

- The use of maps that showed variation in temperature and precipitation seemed to make the task more complex, increasing the level of difficulty of the associated tasks.
- While most students were successful with the basic identification tasks with this representation, some struggled with the introductory questions. Those who were successful with identification were generally challenged by the questions that required them to make an adjustment, describe a pattern, make a prediction, or describe a possible cause.
- The application questions were frequently more challenging for the students. As a result, these tasks elicited a wider range of students' AISK about climate change, its causes and its associated impacts on species.
- Students' errors did tend to clump around a single level or two within an error type, but the level in one error type did not appear associated with whether a student was successful in a different error type.

A common theme across several types of errors was that students' responses indicated confusion about the cause of climate variation as an underlying principle, such as differences in latitude being associated with variation in the range of temperatures typically experienced. Many students in this study struggled with both the application of and the mechanism for this information. This kind of foundational knowledge, often initiated at the elementary levels, is one that teachers might want to use to build a knowledge of climate change. These findings do more than that, they show us several more specific areas where students demonstrated various alternative science knowledge about how the science content was visually presented, what the science content represented, and how to use that information to answer complex questions. Each of these areas is a possible place where a student might need specific scaffolding (Reiser & Tabek, 2014) to develop deep knowledge related to climate change. The format of these assessment tasks facilitated seeing the challenges that students faced to express integrated science knowledge about this content.

This research also characterized the types of AISK that students demonstrate about the interpretation and analysis of climate data, the identification and explanation of climate patterns using data, and the use of data justifying predictions. This AISK is different from those described by Driver and colleagues (2008) because they incorporate content and practices together to reveal deeper challenges that students have using their knowledge of the DCI than might be represented on an assessment item focused on the DCI alone.

Need Assessment Tasks that Characterize Alternative Integrated Science Knowledge (AISK)

The tasks presented here required students to demonstrate their knowledge of disciplinary core idea and crosscutting concepts through the science practices and therefore students' progress towards achieving complete integrated science knowledge. In several of the questions, students were asked to find patterns and make predictions about the cause and effect of those patterns. These questions proved difficult for students, and as a result we were able to generate new typologies of AISK that students demonstrate about climate, climate change, and species habitat that students expressed during the assessment.

These tasks also provided evidence that while some students are able to draw on appropriate DCI knowledge of climate, climate change, and species' habitat to justify their predictions, many students demonstrated a range of types of errors that fell short of these ideals. Characterizing these errors is the first step in both understanding students' progress towards integrated knowledge and in crafting new teaching and learning strategies to help students become more successful. Though there has been prior work developing and evaluating integrated assessments (e.g. Gotwals & Songer, 2013), thus far, the focus has not been on characterizing students' alternative knowledge relative to a standard (Songer & Kali, 2014).

These findings build on the work of others (e.g. Driver et al., 2008; Keeley & Tucker, 2016) in supporting teachers to identify common alternative science knowledge that students might hold related to core content. Driver and Keeley and colleagues (e.g. Keeley & Tucker, 2016; Driver et al., 2008) provided information about challenges that students demonstrate with disciplinary core ideas and provided valuable assessment tasks for diagnosing students' alternative science content knowledge. One conclusion that can be taken away from Keeley's formative assessments is the value of a clearly written diagnostic tool that explains students' responses. Building on that work, these results provide useful information so that teachers can more easily identify and address students' AISK when developing and demonstrating integrated knowledge. In addition, this work presents the analysis tools used to interpret the alternative integrated knowledge represented in students' responses. These analysis tools can serve as a model for diagnosis tools that describe the possible answers you might receive to these constructed response questions. Building on the work that Keeley has done in developing formative assessment probes to understand students' misconceptions and making them available and useful for teachers, this work suggests the value of an additional type of formative assessment probe that reveals a range of integrated alternative science knowledge.

Moving Forward

The examples presented here show the need for formative assessments that support teachers to identify the challenges that students have developing integrated knowledge. This research also shows that students can express integrated knowledge even when the disciplinary core ideas are challenging for students. When content is more complex, such as climate change, students' ability to draw from that content knowledge towards the creation of integrated knowledge products is considerably more challenging. In such difficult content areas, asking students to create integrated predictions can be a tool for revealing students' challenges in successfully combining the content with science and engineering practices.

These findings also provide examples of AISK that middle grade students demonstrate in response to integrated assessment items. The work presents a first attempt at an integrated science knowledge continuum to which the students' progress can be compared. This work has potential to be used for the development of formative assessments and teaching strategies to support students' developing integrated understandings.

References

American Association for the Advancement of Science (AAAS). (1993). Benchmarks for science literacy. New York: Oxford University Press.

Arias, A. M., Davis, E. A., Marino, J.-C., Kademian, S. M., & Palincsar, A. S. (2016). Teachers' use of educative curriculum materials to engage students in science practices. *International Journal of Science Education, 38*, 1504–1526.

Bednarz, S. W., Bettis, N. C., Boehm, R. G., deSouza, A. R., Downs, R. M., Marran, J. F., et al. (1994). Geography for Life: National Geography Standards 1994. Washington, D.C.: National Geographic Research & Exploration.

College Board. (2009). Science: College Board Standards for College Success. Princeton, NJ: College Board.

Davis, E. A., & Linn, M. C. (2000). Scaffolding students' knowledge integration: Prompts for reflection in KIE. International Journal of Science Education, 22(8), 819-837.

Driver, R., Guesne, E., & Tiberghien, A. (2008). Children's Ideas and the Learning of Science. In R. A. Driver, E. Guesne, & A. Tiberghien (Eds.), *Children's Ideas in Science* (pp. 1–9). Glasgow: Bell & Bain Ltd.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (2007). Taking science to school: Learning and teaching science in grades K-8. Washington, DC: National Academy Press.

Ericsson, K. A., & Simon, H. A. (1993). Protocol Analysis: Verbal Reports as Data. Cambridge, MA: MIT Press.

Gordin, D. N., Polman, J. L., & Pea, R. D. (1994). The Climate Visualizer: Sense-Making Through Scientific Visualization. Journal of Science Education and Technology, 3(4), 203-224.

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contributions of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. (Core Writing Team, R. K. Pachauri, & L. A. Meyer, Eds.). Geneva, Switzerland: IPCC.

Keeley, P., & Tucker, L. (2016). *Uncovering Student Ideas in Earth and Environmental Science*. Arlington, VA: NSTA Press.

Lee, H. S., & Songer, N. (2003). Making authentic science accessible to students. *International Journal of Science Education*, *25*(8), 923–948.

Linn, M. C. (2006). The knowledge integration perspective on learning and instruction. In R. K. Sawyer (Ed.), The Cambridge Handbook of the Learning Sciences (pp. 243-64). Cambridge University Press New York.

McNeill, K. L., Lizotte, D. J., Krajcik, J., & Marx, R. W. (2006). Supporting Students' Construction of Scientific Explanations by Fading Scaffolds in Instructional Materials. Journal of the Learning Sciences, 15(2), 153-191.

McNeill, K. L., & Krajcik, J. (2007). Middle school students' use of appropriate and inappropriate evidence in writing scientific explanations. In M. C. Lovett & P. Shah (Eds.), Thinking with data. (pp. 233-65). New York, NY: Lawrence Erlbaum Associates

Miles, M. B., & Huberman, A. M. (1994). An Expanded Sourcebook: Qualitative Data Analysis (2nd ed.). Thousand Oaks, CA: Sage Publications.

Minstrell, J. (2001). Facets of students?' thinking: Designing to cross the gap from research to standards-based practice. In K. Crowley, C. D. Schunn, & T. Okada (Eds.), *Designing for science: Implications from everyday, classroom, and professional settings* (pp. 415–443). Mahwah, NJ: Erlbaum.

National Curriculum Board. (2009). Shape of the Australian Curriculum: Science. Commonwealth of Australia. Retrieved from http://www.acara.edu.au/_resources/Australian_Curriculum_-_Science.pdf

National Research Council. (2012). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, DC: The National Academies Press.

National Research Council. (2014). *Developing Assessments for the Next Generation Science Standards.* Committee on Developing Assessments of Science Proficiency in K-12. Board on Testing and Assessment and Board on Science Education, J.W. Pellegrino, M.R. Wilson, J.A. Koenig, and A.S. Beatty, *Editors.* Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Research Council. (2005). How students learn: History, mathematics, and science in the classroom. Washington, DC: National Academies Press.

National Research Council. (1996). National Science Education Standards. Washington, DC: The National Academies Press.

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Washington, D.C.: The National Academies Press.

NGSS Lead States. (2013b). Next Generation Science Standards: For States, By States. Volume 2: Appendixes. Washington, D.C.: The National Academies Press.

Patton, M. Q. (2002). Qualitative research & evaluation methods (3 ed.). Thousand Oaks: Sage Publications.

Peterman, K., Cranston, K. A., Pryor, M., & Kermish-Allen, R. (2015). Measuring Primary Students' Graph Interpretation Skills Via a Performance Assessment: A case study in instrument development. *International Journal of Science Education*, *37*(17), 2787–2808.

Peters, V. L., & Songer, N. B. (2013). Evaluating the Usability of a Professional Modeling Tool Repurposed for Middle School Learning. *Journal of Science Education and Technology*, *22*(5), 681–696.

Piaget, J., & Inhelder, B. (1969). The Psychology of the Child. (H. Weaver, Trans.). New York City: Basic Books.

Pielke, R. A., & Conant, R. T. (2003). Best practices in prediction for decision-making: lessons from the atmospheric and earth sciences. *Ecology*, *84*(6), 1351–1358.

Ruiz-Primo, M. A., Li, M., Tsai, S.-P., & Scheider, J. (2010). Testing One Premise of Scientific Inquiry in Science Classrooms: Examining Students' Scientific Explanations and Student Learning. Journal of Research in Science Teaching, 47(5), 583-608.

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. Journal of Research in Science Teaching, 41(5), 513-536.

Sadler, T. D., Chambers, F. W., & Zeidler, D. L. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. International Journal of Science Education, 26(4), 387–409.

Shah, P., Mayer, R. E., & Hegarty, M. (1999). Graphs as Aids to Knowledge Construction: Signaling Techniques for Guiding the Process of Graph Comprehension. Journal of Educational Psychology, 91(4), 690-702.

Songer, N. B. (2006). BioKIDS: An animated conversation on the development of curricular activity structures for inquiry science. In R. K. Sawyer (Ed.), *The Cambridge Handbook of The Learning Sciences* (pp. 355–371).

Songer, N. B., & Kali, Y. (2014). Science Education and the Learning Sciences as Coevolving Species. In R. K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (2nd Edition). New York, NY: Cambridge University Press.

Songer, N. B., Kelcey, B., & Gotwals, A. W. (2009). How and when does complex reasoning occur? Empirically driven development of a learning progression focused on complex reasoning about biodiversity. *Journal of Research in Science Teaching*, *46*(6), 610–631.

Telestream, Inc. (2011). ScreenFlow Software (Version 3.9) [Software]. Available from http://www.telestream.net/screen-flow/overview.htm

Toulmin, S. (1958). The Use of Argument. Cambridge, England: Cambridge University Press.

United Kingdom Department of Education. (2015). National Curriculum in England: Science Programmes of Study. United Kingdom Department of Education. Retrieved from https://www.gov.uk/government/publications/national-curriculum-in-england-science-programmes-of-study/national-curriculum-in-england-science-programmes-of-study

Vekiri, I. (2002). What is the value of graphical displays in learning? Educational Psychology Review, 14(3), 261-312

Vygotsky, L. S. (1978). Mind In Society. Cambridge, MA: Harvard University Press.

White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. Cognition and Instruction, 16(1), 3-118

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education*, *92*(5), 941–967. https://doi.org/10.1002/sce.20259

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Preservice Teachers' Perception Levels Concerning Consumer Environmental Consciousness

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Abstract

People who strive to prevent harm to the environment while utilizing it and to maintain a livable environment is related to educational and cultural values. If we want the next generation to live in an environment as undisturbed as we live in now, environmentally friendly products should be consumed and waste should be prevented. Thus, raising an environmental consciousness among consumers is of vital importance. Environmental consciousness is shaped by individuals' knowledge, attitudes, sensitivity and beneficial behavior towards environment. In this sense, the primary aim of this study is to determine preservice teachers' perception levels of consumer environmental consciousness in terms of different variables. The sample of the study consists of 396 preservice teachers from various departments in the Faculty of Education in Ahi Evran University between the 2015-2016 academic years. 70.2% of the sample is female while 29.8% is male. The Consumer Environment Consciousness Scale (CESS) which was developed by the researcher, and contains 28 items, 20 of which are positive and 8 of which are negative, was used for data collection. The gathered data was analyzed using SPSS 17 software. The study findings suggest that the participant preservice teachers have a medium level of consumer environment consciousness and this consciousness differs significantly in terms of gender, income level and whether or not they have had environment lessons before. Additionally, there was found to be no meaningful difference in perception levels in terms of residential area the participants live in.

Introduction

Environment is defined as the place in which living and non-living things coexist, including both natural and manmade elements in constant change and transformation, and is of an interacting nature. In this interacting process, the dominant role belongs to humans. Humans have the desire and skills to change the environment for living and non-living creatures for their own sake, and have historically tried to fulfill their desires without considering the future (Yücel, Uslu, Altunkasa, Güçray and Say, 2008).

Although nature has the ability to renew itself, this ability is limited. Since humans started to live on Earth, the relationship between nature and humans has been based on humans' utilizing natural sources. With the development of science, humans have dominated nature (Türküm, 1998). Humans have utilized nature insensibly, which in turn has become a major environmental issue of today and a threat for all living creatures (Seçkin, Yalvaç and Çetin, 2010). Therefore, the environment has become a problem which needs to be dealt with both on a national and international level. That humans learn to live in harmony with nature and to prevent any disturbance of ecological balance are of great importance to maintain humanity (Kahyaoğlu, Daban and Yangın, 2008).

Education is the most influential way to overcome the problems society faces or will face and to construct the future (Hoody 1995). Environmental education addresses individuals' cognitive, affective and kinetic learning fields. It is the process of developing attitudes, norms, knowledge and skills. It is also the process of cultivating their results (Erten, 2004). Environmental education is a lifelong issue surrounding the whole society and producing vital long term results (Kaya and Gündoğdu, 2007). The significance, necessity and effects of environmental education, and the inadequate training about environmental consciousness for students at schools has recently become a heavily discussed topic at many schools around the world (Aydın, Coşkun, Kaya and Erdönmez, 2011; Bonnett and Williams, 1998; Cheng and Monroe, 2010; Meydan and Doğu, 2008; Tahiroğlu and Çetin, 2013). The general outcomes of researches related to environmental education suggest that environmental consciousness, knowledge and sensibility rise when education is delivered at an early age with visual, audio and practical methods (Tahiroğlu, Yıldırım and Çetin, 2010).

Geography plays a special part in environmental education as its content is the interactions between humans and the environment. Since geography interacts with both natural and social sciences, it has advantages to deal with environmental problems in an objective and integrative perspective (Arslan, 2009). Also, values education at schools aiming to develop environmental consciousness has positive effects on raising awareness among students (Tahiroğlu, Yıldırım, and Çetin, 2010). If an individual does not try to decrease waste, does not save energy and water, does not prefer buying recyclable products, does not regularly check the potential harms of a product he buys, does not actively protect the environment and keeps his silence when he sees somebody polluting the environment, he cannot be said to have environmental consciousness. Additionally, there is no meaning in what these people know about the environment (Erten, 2004). In this sense, environmental consciousness can be defined as developing sensitivity towards the environment among individuals for a sustainable life.

As environmental consciousness and education involve lifelong knowledge, attitudes, behaviours and skills, teaching programs which focus on an intense interaction with the environment should be designed and practiced (Bonnett and Williams, 2006). According to international studies concerning environmental education, the optimal education level for delivering environmental education is secondary education, and teachers play critical roles in attaining the goals of environmental education. Thus, secondary education teachers should be trained so that they can deliver environmental education and consciousness (IEEP, 1994; Ünal and Dımışkı, 1998).

In recent years in Turkey, it has been observed that the number of consumers with environmental consciousness and concerns has risen, and the consumption of environmentally friendly products has reflected this increase in consciousness (Çabuk and Nakıboğlu, 2003). Since the 1980s, environmental consciousness and concern has increased among consumers, which results in them demonstrating environmentalist behaviours in their buying decisions, during and after the consumption process. However, the number of environmental disasters occurring with human's effects has increased despite all those things. So, it is a must that consumers develop more environmental and consumption consciousness (Horton, 2003).

As geography focuses on the interaction between human and environment, it dwells on environmental issues. For this reason, it is aimed that the students learn the ecology and environmental issues in the field of environmental and community learning within the Geography Course Curriculum and gain attitudes and values in this subject. The knowledge, skill and attitude of mankind are very important in determining the mutual interaction with the environment. For this reason, all individuals have to be aware of the impacts and effects on the environment. It is also the responsibility of the geography educators to equip society with values and attitudes, such as to equip them with "ethical values" that will guide them in carrying out their vital activities and to make them aware of the environment (Artvinli, 2007).

In a review of the literature, a number of studies about consumer environmental consciousness have been found, but the number of these studies in the field of geography are quite low, and studies conducted in other fields have their own field limitations (Yeniçeri, 2009; Aracıoğlu and Tatlıdil, 2009; Köse and Gül, 2014). Additionally, these studies were observed to be limited to the fields of marketing, in terms of the consumer dimension, and science education, in terms of the environmental consciousness dimension. However, in Geography Course Teaching Program (MEB, 2015) environmental consciousness is adopted as an essential principle, and protecting the environment is determined to be of geographic merit, which makes this study to be of more importance for the field of geography. This study aims to measure consumer environmental consciousness levels of preservice teachers, and it is believed that this study would highly contribute to the geography field.

Method

This study is an ex-post facto study which means not controlling the variables and investigating the phenomena after it had occurred. The demographic background form and the CESS were administered to voluntary preservice teachers in the spring semester of the 2015-2016 academic year. The study aims to analyze preservice teachers' consumer environmental consciousness, and demographic factors' influence on it. The dependent variable was consumer environmental consciousness. The independent variables were gender, settlement, SES, and attending a course relating to the environment.

Sample

The convenience sampling method was used in this study. Convenience sampling refers to a group of individuals who are available for the study (Fraenkel and Wallen, 2012). The sample consisted of 642 preservice teachers. The data was collected in the 2015-2016 Spring semester at the Faculty of Education, Ahi Evran University. Demographic background information of the sample is summarized in Table 1.

Table 1. Demographic characteristics of the sample (n=642)

Gender		*Attending A Course*		*Settlement*	
Male	23.1%	Yes	58.9%	Rural	17.6%
Female	76.9%	No	41.1%	Urban	82.4%
Ranking		*Socio-economic Status*			
Freshman	26.6%	Low	19.9%		
Sophomore	26.8%	Middle	65.1%		
Junior	23.5%	High	15%		
Senior	23.1%				

As seen above, nearly one-fourth of the sample was male, and the rest were female. More than half of the sample had a middle socio-economic status (SES) background. 82.4% of preservice teachers were from urban areas of Turkey, and 17.6% were from rural areas. Rankings of preservice teachers were approximately equally divided. Furthermore, more than half of the preservice teachers had attended a course concerning the environment.

Data Collection and Analysis

A demographic background form was used to collect information about gender, settlement, SES, and rankings of preservice teachers. Whether preservice teachers had attended a course relating the environment was also asked, The Consumer Environment Consciousness Scale (Dikmenli and Konca, 2016) was used to investigate preservice teachers' environmental consciousness. The Consumer Environment Consciousness Scale (CESS) is a five point scale and consists of 28 items (8 items are negative, and 20 items are positive). The items are divided under four factors; Susceptible Consciousness (10 items), Behavioral Consciousness (9 items), Social Pressure (5 items), and Bias (4 items). The Cronbach's alpha coefficients of the sub-scales was calculated as .767, .823, .779, and .753, respectively. For the current study, the Cronbach's alpha coefficients of the sub-scales were found to be .777, .815, .769, and .756, respectively. To interpret the scores obtained from the scale, the range of the scale was divided by three, and the scores are categorized as low (1.00-2.33), middle (2.34-3.66), and high (3.67-5.00).

Frequency, percentage, mean, standard deviation, and multiple regression analysis were used in data analysis process. Demographic characteristics of the sample were descriptively analyzed by using frequency and percentage. Multiple regression analysis was conducted to investigate the relationship between the independent variables, and the dependent variable. Before conducting multiple regression analysis, the assumptions (Tabachnick and Fidell, 2007) were checked. It was seen that the assumptions were met, so the analysis was done.

Results

Table 2 presents a descriptive summary of preservice teachers' scores obtained from the CESS and sub-scales. As seen in the table, on a five-point scale, preservice teachers appear to have high levels of consumer environmental consciousness. When the minimum and the maximum scores are analyzed, it can be seen that scores of preservice teachers were spread from minimum points of sub-scales to maximum points. While preservice teachers had the highest mean score on susceptible consciousness, they had the lowest mean score on bias. While the mean score of susceptible consciousness sub-scale represents a high level of consciousness, the other three sub-scales and total score of the CESS point middle level of consciousness.

When the attitudes of preschool teachers towards technological tool and material use participating to the research were examined on the basis of sample, the mean was 4.21 which refers to high attitude. Additionally, %90.26 of teachers have a high attitude and %8.74 of teachers have a moderate attitude. In the light of these findings, it can be concluded that preschool teachers have quite a positive attitude towards technological tool and material use.

Table 2. Description of preservice teachers' scores obtained from the CESS

	Min	*Max*	*Mean*	*Std. Dev.*
Susceptible Consciousness	1.60	5.00	3.72	0.55
Behavioral Consciousness	1.00	5.00	3.23	0.68
Social Pressure	1.40	4.80	3.11	0.59
Bias	1.00	5.00	3.09	0.74
Total	2.07	4.46	3.36	0.41

In order to examine how well gender, settlement, SES, and attending a course relating to the environment predicts preservice teachers' environmental consciousness, multiple linear regression analysis was conducted and presented in Table 3. Results of the analysis showed that the linear combination of predictor variables significantly predicted the dependent variable (*R*=.332, *F*=13.90, *p*<0.05).

Table 3. Results of multiple regression analysis between the predictor variables and environmental consciousness

Multiple Regression	**Analysis of Variance**				
R=.332	Source	*df*	*SS*	*MS*	*F-ratio*
R^2=.1102	Regression	4	4556.82	1139.206	8.900*
S.E.=11.31379	Residual	636	81409.165	128.002	

*p<0.05

Specifically, preservice teachers' gender, SES, and attending a course relating environment each made a significant contribution to the prediction of preservice teachers' consumer environmental consciousness (*p*<.05), as seen in the Table 4. However their settlement did not predict their environmental consciousness (*p*>.05). Table 4 also presents b values, standard error of b values, beta values, t values, and p values of the constant and the independent variables. It can be seen that the beta values for gender (*B*=.082, *t*=2.118), SES (*B*=.122, *t*=3.011), and attending a course (*B*=.163, *t*=4.162) were significantly high. However, the beta values for settlement (*B*=.007, *t*=.187) pointed to an insignificant effect of settlement of preservice teachers on their consumer environmental consciousness.

Table 4. The beta values of the predictor variables

	B	**SEB**	**Beta**	**t**	**p**
Constant	94.226	1.646		57.256	.000
Gender	2.262	1.068	.082	2.118	.035
Settlement	-.228	1.217	.007	.187	.851
SES	-1.289	.428	.122	3.011	.003
Attending a course	3.835	.922	.163	4.162	.000

p<0.05

Conclusion

According to study results, preservice teachers have a medium level of consumer environmental conscious. Regarding the sub-scales, they also have medium levels in behavioural consciousness, social pressure and bias. However, they demonstrate a high level of susceptible consciousness. Consumer environment consciousness is the dimension in which environmental knowledge transforms into skill fairly. However, the levels of skill and perception among participant preservice teachers were not high.

Thus, in the framework of Geography Course Teaching Program and Principles (2015), environmental consciousness is adopted; protecting the environment is accepted as a geographic value, and additionally, the statement "Humans have to adopt a lifestyle in harmony with environment" is included in theme Geography's Agent: Human. In this sense, it can be understood that in the last version of the geography teaching program aims to constitute environmental consciousness and knowledge among students through various ways. It was also determined that environmental consciousness does not influence environmentalist behaviours directly, but the those developing environmentalist attitudes also reflect it in their behaviours and buy ecological products

(Roberts and Bacon, 1997; Yılmaz, Çelik and Yağızer, 2009). In their study with university students, Dono, Webb and Richardson (2009) found significant relationships between environmental attitudes and behaviours. As Straughan and Roberts (1999) claim, although individuals worry about environmental issues, if they do not believe that they cannot contribute to fight against environmental problems, they do not reflect their concerns in their behaviours. Hence, it can be inferred that students are mostly in the level of knowledge and attitude but are not sufficiently on the level of behaviour and competency yet.

The consumer environmental consciousness levels of preservice teachers were found to differ significantly in terms of gender. Some studies (Kahyaoğlu, 2014; Timur and Yılmaz, 2011) addressed the lack of any effect of gender on environmental consciousness while many other studies revealed that females' consciousness levels towards the environment are higher than males (Torlak, 2001; Ay and Zümrüt, 2005; Alp, Ertepınar, Tekkaya, and Yılmaz, 2006; Dibgy, 2010; Yılmaz and Anderson, 2004; Gökçe, Kaya, Aktay and Özden, 2007; Çabuk, Nakıboğlu and Keleş, 2008; Arabacıoğlu and Tatlıdil, 2009; Yeniçeri, 2009; Yaraş, Akın and Şakacı, 2011, Özgen and Kahyaoğlu, 2013). Considering these researches, it can be concluded that female students are more interested in environmental issues than male students.

The consumer environmental consciousness levels of preservice teachers were found to show no meaningful differences in terms of settlement places. Similarly, in his study Öztürk (2013) revealed no meaningful difference based on settlement place, which indicates that both study findings are in accordance with each other. However, some other researches demonstrated that urban people have more environmental attitudes and consciousness than rural people (Straughan and Robert, 1999; Ek, Kılıç, Öğdüm, Düzgün and Şeker, 2009; Şama, 2003). This study's findings suggest that whether coming from urban or rural does not have any effect on consumer environmental consciousness, which can be explained by the fact that preservice teachers have the same educational levels, because it is believed that in creating environmental consciousness in society, even individual consumption contributes to protecting the environment and maintaining this understanding is only possible with education.

Another finding in this study indicates significant differences between consumer environmental consciousness and family incomes. In related studies, it is observed that the higher income families have, the higher level of consumer environmental consciousness they demonstrate (Soonthonsmai, 2001; Çabuk, Nakıboğlu and Keleş, 2008; Yeniçeri, 2009; Yaraş, Akın and Şakacı, 2011). According to post materialist theory (Abramson and Inglehart, 1995), individuals coming from middle/high income families are more sensitive to environmental issues than low/ high income families. In the light of these results, it can be inferred that as the income increases, consumers would gain economic power to buy more expensive but less environmentally harmful products, which in turn refers to an increase in their environmental consciousness.

Lastly, meaningful differences in preservice teachers' consumer environmental consciousness and whether they have had any lectures about environmental issues before were found. Similar results were obtained from many related researches, too (Kahyaoğlu, 2014; Özden, 2008; Tuncer, Tekkaya, Sungur, Çakiroglu, Ertepinar and Kaplowitz, 2009). Also, educational trainings and projects about the environment were revealed to have a positive effect to cultivate environmental consciousness among preservice teachers (Carroll, 2015; Keleş, Uzun and Varnacı Uzun, 2010). However, some studies showed that although students have had lectures about environmental issues, the participation rate to activities related to environment is low (Sağır, Aslan and Cansaran, 2008). Additionally, many studies also mention inadequate environmental trainings in Turkey (Armağan, 2006; Bozkurt, Akın and Uşak, 2004; Atasoy and Ertürk, 2008; Maskan, Efe, Gönen and Baran, 2006; Sülün and Kozcu, 2005). Considering these findings, it can be generally concluded that having lectures about environment increases environmental consciousness, but just lectures are not enough as they do not always bring environmental consciousness to individuals.

Recommendations

In order to cultivate customer environmental consciousness with its all dimensions among preservice teachers, lectures related to environment should be added to other departments apart from science, social and classroom teacher trainings departments. In fact, these lectures should be included into the whole educational grades so as to cultivate nature love and environment consciousness even at later ages. Teachers who volunteer to manage this duty are thought to be able to raise individuals with consumer environmental consciousness and environmentally friendly and sensitive. Thus, firstly cultivating environmental consciousness among preservice teachers becomes important. With this aim, cooperation among geography courses and other courses should be established, and provide students with opportunities to practice these abilities, because it is difficult that knowledge learnt in vitro can transform into behaviours in real life. Also, families should be absolutely included in this process, and engage in activities together with their children so that they may internalize related knowledge, skill and values given at schools. Thus, it is possible to raise individuals endowed with conceptual knowledge about the environment and consumer environmental consciousness.

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References

Abramson, P. R. & Inglehart, R. (1995). Value change in global perspective. Ann Arbor, MI: University Of Michigan Press.

Alp, E., Ertepınar, H., Tekkaya, C. & Yılmaz, A. (2006). İlköğretim öğrencilerinin çevreye yönelik tutum ve bilgileri üzerine bir çalışma, 7. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi. Ankara.

Aracıoğlu, B. & Tatlıdil, R. (2009).Tüketicilerin satın alma davranışında çevre bilincinin etkileri. Ege Akademik Bakış / Ege Academic Review, 9 (2),435-461

Armağan, F. (2006). İlköğretim 7. ve 8. Sınıf öğrencilerinin çevre eğitimi ile ilgili bilgi düzeyleri. Yayınlanmamış Yüksek Lisans Tezi. Gazi Üniversitesi Eğitim Bilimleri Enstitüsü. Ankara

Artvinli, E. (2007). 2005 Yılı 9. Sınıf coğrafya öğretim programı: Öğretmenler açısından uygulanabilirlik düzeyi. (Yayımlanmamış Doktora tezi) Atatürk Üniversitesi Sosyal Bilimler Enstitüsü Ortaöğretim Sosyal Alanlar Eğitimi Anabilim Dalı. Erzurum.

Aslan, A. (2009). Ortaöğretim coğrafya dersi programındaki çevre konularının analizi. Yayınlanmamış Yüksek Lisans Tezi. Marmara Üniversitesi Eğitim Bilimleri Enstitüsü. İstanbul.

Atasoy, E., & Ertürk, H. (2008). İlköğretim öğrencilerinin çevresel tutum ve çevre bilgisi üzerine bir alan araştırması. Erzincan Eğitim Fakültesi Dergisi. 10(1),105-122

Ay, C. & Zümrüt E. (2005). Çevre bilinçli tüketiciler. Akdeniz İİBF Dergisi, 10,238-263.

Aydın, F. Coskun, M. Kaya, H. & Erdönmez, İ. (2011). Gifted students' attitudes towards environment: A case study from Turkey. African Journal of Agricultural Research, Vol. 6(7),1876-1883.

Bonnett, M. & Williams, J. (1998). Environmental education and primary children's attitudes towards nature and the environment. Cambridge Journal Of Education. 28(2),159-174.

Bozkurt,O., Akın, B. & Uşak, M. (2004). İlköğretim 6. 7.ve 8. sınıf öğrencilerinin erozyon hakkındaki ön bilgilerinin ve kavram yanılgılarının tespiti. Gazi üniversitesi Kırşehir Eğitim Fakültesi Dergisi. 5(2),277-285.

Carroll, K. N. (2015). Mississippi teachers' environmental awareness and usage of the project learning tree curriculum within traditional classrooms. Mississippi State University Department of Foresty. Mississippi.

Çabuk, S.M.A. & Nakıpoğlu, B. (2003). Çevreci pazarlama ve tüketicilerin çevreci tutumlarının satın alma davranışlarına etkileri ile ilgili bir uygulama. Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 12(12), 39-54.

Çabuk, S., Nakiboğlu, B., & Keleş, C. (2008). Tüketicilerin yeşil (ürün) satın alma davranışlarının sosyo-demografik değişkenler açısından incelenmesi. Journal Of The Cukurova University Institute Of Social Sciences, 17(1),85-102

Chen-Hsuan Cheng, J., & Monroe, M. (2010). Connection To Nature: Children's Affective Attitude Toward Nature. Environment and Behavior, 44(1),31–49.

Dibgy B. L. C. (2010). An examination impact of non-formal and informal learning on adult environmental knowledge, attitudes, and behaviors, *Unpublished Doctoral Dissertation*, *University of Minnesota*, USA

Dikmenli, Y., & Konca, A. S. (2016). Validity and reliability study of envıronmental consciousness scale/Tüketici çevre bilinci algı ölçeği geçerlik ve güvenirlik çalışması. *Eğitimde Kuram ve Uygulama*, *12*(6),1273-1289.

Dono, J., Webb, J., & Richardson, B. (2009). The relationship between environmental activism, pro-environmental bahaviour and social identity. Journal Of Environmental Psychology (Article İn Press):1-9.

Ek, H. N. Kılıç, N., Öğdüm, P., Düzgün, G., & Şeker, S. (2009). Adnan menderes üniversitesinin farklı akademik alanlarında öğrenim gören ilk ve son sınıf öğrencilerinin çevre sorunlarına yönelik tutumları ve duyarlılıkları. Kastamonu Eğitim Dergisi, 17:(1),125-136

Erten, S. (2004). Çevre eğitimi ve çevre bilinci nedir, çevre eğitimi nasıl olmalıdır? Çevre ve İnsan Dergisi, Çevre ve Orman Bakanlığı Yayın Organı, 65/66: 2006/25.

Fraenkel, Wallen & Hyun (2012). How to design and evaluate research in education. New York: McGraw-Hill.

Gökçe, N., Kaya, E.,Aktay, S. & Özden, M. (2007). İlköğretim öğrencilerinin çevreye yönelik tutumları. İlköğretim Online, 6(3),452-468.

Hoody, L. (1995). The educational efficacy of environmental education (interim report). San Diego, CA: State Education and Environment Roundtable.

Horton, D. (2003). Green distinctions: The performance of identity among environmental activists. The The Sociological Review, 51(2),63-77.

IEEP (1994). An environmental education curriculum for pre-service education of secondary level teachers. UNESCO-UNEP-IEEP: Environmental. Education Series (43).

Kahyaoğlu, M. (2014). The research of the relationship between environmentally aware prospective teachers' qualities and self efficacy beliefs towards environmental education. Procedia-Social and Behavioral Sciences, 116,4493-4497.

Kahyaoğlu, M. Daban, Ş. & Yangın, Y. (2008). İlköğretim öğretmen adaylarının çevreye yönelik tutumları. D.Ü. Ziya Gökalp Eğitim Fakültesi Dergisi, 11,42-52.

Kaya, İ. & Gündoğdu, Y. (2007). Coğrafya öğretmenlerinin çevre bilincini oluşturma ve geliştirmedeki rolü: Diyarbakır örneği. Doğu Coğrafya Dergisi, 18,187-204

Keleş, Ö., Uzun, N. & Varnacı-Uzun, F. (2010). Öğretmen adaylarının çevre bilinci, çevresel tutum, düşünce ve davranışlarının doğa eğitimi projesine bağlı değişimi ve kalıcılığının değerlendirilmesi, Elektronik Sosyal Bilimler Dergisi, 9(32),384-401

Köse, E. Ö.,& Gül, Ş. (2014). Öğretmen adayları için çevre sorumluluğuna bağlı tüketim bilinci ölçeğinin geliştirilmesi. *Journal Of Educational Sciences & Practices*, *13*(26),257-277

Maskan, A. K., Efe, R., Gönen, S., & Baran, M. (2006). Farklı branşlardaki öğretmen adaylarının çevre sorunlarının nedenleri, eğitimi ve çözümlerine ilişkin görüşlerinin değerlendirilmesi üzerine bir araştırma. *Çukurova Üniversitesi Eğitim Fakültesi Dergisi*. *3*(32),1-12.

MEB (2015). Ortaöğretim coğrafya dersi taslak öğretim programı. Millî Eğitim Bakanlığı Talim Ve Terbiye Kurulu Başkanlığı, Ankara

Meydan, A. & Doğu, S. (2008). İlköğretim ikinci kademe öğrencilerinin çevre sorunları hakkındaki görüşlerinin bazı değişkenlere göre değerlendirilmesi, Selçuk Üniversitesi Ahmet Keleşoğlu Eğitim Fakültesi Dergisi, 26, 267-277.

Ozden, M. (2008). Environmental awareness and attitudes of student teachers: An empirical research. International Research İn Geographical And Environmental Education, 17(1),40-55.

Özgen, N. & Kahyaoğlu, M. (2012). Öğretmen adaylarının çevre sorunlarına yönelik tutumlarının çeşitli değişkenler açısından incelenmesi. Kuramsal Eğitimbilim Dergisi, 5(2),171-185

Öztürk, E. (2013). Uluslararası bir çevre eğitimi projesinin fen ve teknoloji öğretmen adaylarının çevre bilincine etkisi. Yayınlanmamış Doktora Tezi. Hacettepe Üniversitesi Eğitim Bilimleri Enstitüsü İlköğretim Anabilim Dalı. Ankara

Roberts, J. A.,& Bacon, D. R. (1997). Exploring the subtlerelationships between environmental concern and ecologically conscious consumer behavior. *Journal Of Business Research*, *40*(1),79-89.

Sağır, S., Aslan O. & Cansaran, A. (2008). İlköğretim öğrencilerinin çevre bilgisi ve çevre tutumlarının farklı değişkenler açısından incelenmesi. İlköğretim Online E-Dergi, 7(2), 496-511.

Seçkin, F., Yalvaç, G., & Çetin, T. (2010). İlköğretim 8. sınıf öğrencilerinin karikatürler aracılığıyla çevre sorunlarına ilişkin algıları, International Conference on New Trends in Education and Their Implications, 11(13), 391-398.

Soontonsmai, V. (2001). Predicting intention and behavior to purchase environmentally sound or green products among Thai consumers: An application of the Theory of Reasoned Action, Unpublished Doctor of Philosophy, Nova Southeastern University. USA

Sülün, Y. & Kozcu , N. (2005). İlköğretim 8. sınıf öğrencilerinin lise girişi sınavlarındaki çevre ve popülasyon konusuyla ilgili grafik sorularını algılama ve yorumlamalarındaki yanılgıları. Erzincan Eğitim Fakültesi Dergisi. 7 (1) , 25-33

Straughan, R. D., & Roberts, J. A. (1999). Environmental segmentation alternatives: a look at green consumer behavior ın the new millennium. Journal of Consumer Marketing. 16(6), 558-575.

Şama, E. (2003). Öğretmen adaylarının çevre sorunlarına yönelik tutumları. Gazi Eğitim Fakültesi Dergisi, 23(2),99-110

Tabachnick, B. C., & Fidell, L. S. (2007). Using multivariate statistics (5th ed.). Boston, MA: Pearson Education, Inc. USA

Tahiroglu, M., Yıldırım, T. & T. Çetin, T. (2010). Değer eğitimi yöntemlerine uygun geliştirilen çevre eğitimi etkinliğinin, ilköğretim 7. Sınıf öğrencilerinin çevreye ilişkin tutumlarına etkisi. Selçuk Üniversitesi Ahmet Keleşoğlu Eğitim Fakültesi Dergisi Sayı 30,231-248

Tahiroglu, M. & T. Cetin, T. (2013). The effect of the activity based education on teaching the love of nature value in social studies course and the gain and the attitude levels of the students. International Journal of Academic Research Part B, 5(1), 226-236.

Timur, S. & Yılmaz, M. (2011). Fen bilgisi öğretmen adaylarının çevre bilgi düzeylerinin belirlenmesi ve bazı değişkenlere göre incelenmesi, Gazi Üniversitesi Gazi Eğitim Dergisi, 31(1), 303-320.

Torlak, Ö. (2001). Pazarlama ahlakı, Beta Basım, 1. Baskı. İstanbul.

Tuncer, G., Tekkaya, C, Sungur, S., Cakiroglu, J., Ertepinar, H., &Kaplowitz, M. (2009). Assessing pre-service teachers' environmental literacy in turkey as a mean to develop teacher education programs. International Journal of Educational Development, 29(4), 426-436.

Türküm, A.S, (1998). Çağdaş toplumda çevre sorunlari ve çevre bilinci. (Editör. G. Can) Çağdaş Yaşam Çağdaş İnsan. Eskişehir: Anadolu Üniversitesi Açık Öğretim Fakültesi İlköğretim Öğretmenliği Lisans Tamamlama Programı, 165-181.

Ünal, S. & Dımışkı, E. (1999). UNESCO UNEP himayesinde çevre eğitiminin gelişimi ve türkiye'de ortaöğretim çevre eğitimi. Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 17,142-154.

Yaraş, E., Akın, E. & Şakacı, B. A., (2011) Tüketicilerin çevre bilinci düzeylerini belirlemeye yönelik bir araştırma. Öneri Dergisi, 9(35), 117-126.

Yeniçeri, T. (2009). Tüketicilerin çevre bilinci ve çevreye duyarlı satın alma davranışlarına yönelik bir pilot araştırma. *Sosyal Ve Ekonomik Araştırmalar Dergisi*, *11*(17), 311-326.

Yılmaz, Ö. & Anderson, H.O. (2004). Views of elementary and middle school Turkish students toward environmental issues. International Journal of Science Education, 26, 1527-1546.

Yılmaz, V., Çelik, H. E. & Yağızer, C. (2009). *Çevresel duyarlılık ve çevresel davranışın ekolojik ürün satın alma davranışına etkilerinin yapısal eşitlik modeliyle araştırılması,* Anadolu Üniversitesi Sosyal Bilimler Dergisi 9(2), 1-14.

Yücel, M., Uslu, C., Altunkasa, F., Güçray, S.S., Say, N.P., (2008). Adana'da halkın çevre duyarlılığının saptanması ve bu duyarlılığı arttırabilecek önlemlerin geliştirilmesi. Adana Kent Sorunları Sempozyumu, 9– 10 Mayıs, , 363–382. Adana.

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Broad-based Participatory Inquiry into the Definition and Scope of Disaster

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Abstract

Understanding what disaster means will not only raise our awareness but will also bring us closer to knowing how to protect ourselves in the face of their destructive effects. The aim of this study is to understand how the concept of disaster is perceived in different demographics/subgroups of the population and by defining the term, to determine its scope and contribute in the long term to the content and effectiveness of the disaster education in the school settings. The sample for the study, which was of survey design, comprised 1600 individuals. A "Disaster Definition and Scope Scale [DDSS]" developed by the researchers to inquire into the definition and scope of disasters was used as a data collection instrument. The Cronbach Alpha reliability coefficient for the internal consistency of the scale is .83. The frequency analysis method of statistical analysis was used to examine the participants' demographic features. The responses of the participants to the open-ended questions on the definition of disaster were examined under 4 main themes that categorized the responses as nature-based, people-based, belief-based and outcome-based. The third section made up of 25 items on the scope of the term disaster was analyzed using the one-way analysis of variance and the Scheffe's test was employed to ascertain the source of the significant differences between the groups in an inter-group post-hoc comparison. The conclusion of the study is that the concept of disaster is generally confused with natural phenomena in every aspects of the population and that the participants in the research were not even aware of the existence of institutions, associations and civil defense organizations that conduct disaster emergency operations. The media tools occupy an important place in providing the public with right disaster understanding.

Introduction

Generally, people have combined their beliefs and curiosity about natural phenomena with science and technology and it is thought that each step that has been taken has brought us closer to the truth. While there is so much knowledge still waiting to be discovered and as the concentration of this knowledge becomes more and more complex with every passing second, people still desires to expand the boundaries of their understanding. Because the reason of the existence of extensive unexplored knowledge in nature has evoked curiosity, and worse, even fear in many people. As questions form in people's minds when science and curiosity join together, it also becomes clearly evident that no scientific facts can differ from person to person or according to different cultures. An example of this is the concept of "disaster." By the same token, the concept of "disaster" should not be different depending upon country or culture. The difference lies in the degree of its impact.

Through the human history, there have been many natural phenomena which have had an impact on the world (e.g., Herodotos, 1, 74; Strabon, 12, 8, 17; Herodotos, 5, 82-85; Strabon, 12, 8, 18; Higgins 2009; Tacitus, Annales, 2, 47; Plinius, Nat. Hist. 2, 200; Ünver, 2012; Şahin, 2012). Natural phenomena have always existed and played a part in people's lives all through history. For tens of thousands of years, countless natural phenomena have occurred in any one year and evidence of these, particularly of earthquakes, has reached us in archeological ruins and in the works of literature that have survived since antiquity. Many accounts of earthquakes, along with related data and narratives (e.g., Capelle, 2006, 62, 81) exist but the description of a tsunami that occurred along the shores of the Mediterranean is a unique account that is of particular significance. In his work, Cassius Dio (63, 26, 5) relates in the middle of the first century A.D. how giant waves rising from Egypt wreaked havoc over the coast of Lycia. It is without doubt that as a result of the way human beings in antiquity were caught in a perception of the world that stood between myth and religion; many acts of nature were thought to be reflections of the wrath of the gods. Hesiod describes how the glorious Zeus could send down punishment so severe that it could demolish an entire city (Hesiod, 239-240) and how earthquakes are created by Poseidon, God of the Seas (Hesiod, 667-668).

The disasters of more recent times that have been imprinted in our memories are the eruption of the volcano Mt. Tambora in Indonesia in 1815, the Texas hurricane of 1900, the San Francisco earthquake of 1906, the earthquake in Chile in 1960, the landslide in Yungay, Peru in 1970, the Kocaeli earthquake of 1999, the floods in Pakistan in 2010, the earthquake and ensuing tsunami in Japan in 2011 (The International Disaster Database [EM-DAT], 2012) and the 2011 Van earthquake (Sever & Kazancıoğlu,2012).

Defining Disaster

One continues its attempt to assign some kind of meaning to events such as these that create such an impact and cause so much destruction. To define the concept of disaster, the following table has been set up, drawing from definitions of the word by the Turkish Language Association and the terminology of other organizations for which the term is of significance (Table 1).

Table 1. Definitions of disaster

Turkish Language Association	The meaning of the word disaster (afet) is described as: *a. (n.)*1. Destruction caused by various natural phenomena: *That year, the floods were like a disaster.* 2. Cataclysm. 3. *adj. fig. (figurative)* Dire: *I now understand how fame can be a dire [disastrous]type of wealth.* -R. N. Güntekin 4. *Medicine* A disorder caused in tissues by diseases, natural phenomena (Turkish Language Association [TDK], 2013).
American College of Emergency Physicians	Situations where "the destructive effects of natural or man-made forces overwhelm the ability of a given area or community to meet the demand for health care (American College of Emergency Physicians [ACEP], 2012).
World Health Organization	A fulminant and major ecologic phenomenon that develops with such intensity that it necessitates external intervention. A state of emergency that seriously disrupts the functioning of a community causing widespread administrative and traumatic distress that exceeds the ability of the affected community or society to cope with routine interventions using its own resources (World Health Organization [WHO], 2012).
Pan American Health Organization	A disaster is "an event or occurrence − usually sudden and unexpected − that intensely alters the beings, objects and localities under its influence (Pan American Health Organization [PAHO], 2012)."

It can be seen from the table that the definition of disaster varies from organization to organization. In some definitions, disaster is treated as a natural phenomenon. In a study by Cannon (1994), it is stressed that there must be a differentiation made in English between the term *hazard*, meaning danger or risk, and the term *disaster*, which pertains to a natural disaster or catastrophe. In the light of this information, then, the definition that has been adopted in this work shall be as described below.

> The general term used to describe the consequences of natural or man-made events and/or occurrences that halt or disrupt the normal life functions of communities by causing human beings physical, economic, social, cultural, natural and environmental losses, such that the community affected cannot cope using local resources and interventions." (Kadıoğlu, 2011).

Studies on Defining Disaster and its Scope in the Fields of Natural Sciences and Medicine and Management

The negative effects disasters have on the daily lives of individuals have given rise to a need to study why disasters occur. An attempt is being made to explore the reasons for disasters through research in the field of natural sciences. It can be seen that these studies are more concentrated in the areas of geology, health sciences, meteorology and engineering.

Related literature in geology reveals that the focus of studies is generally earthquakes (e.g., Arslan, 2003; Ersoy, 2013; Fuse, Igarashi, Tanaka, Kim, Tsujii, Kawai & Yokota, 2011; Kayrancıoğlu, 2007; Uzunçıbuk, 2005; Ünalan, 2010). In natural sciences, studies on disasters appear to be on the scope of disasters, the disasters that have occurred, and the regions that present disaster risk (e.g., Aydın, 2012; Aycan, Toprak, Yüksel, Özer & Çakır, 2002; Altıntaş, 2005; Uğurlu, Bakım, Güveli, Karamustafalıoğlu, Soydal & Ergüder, 2003; Işık, Aydınlıoğlu, Koç, Gündoğdu, Korkmaz & Ay, 2012).

When studies in the medical field are reviewed, one encounters studies on the psychological trauma in the aftermath of disasters (e.g., Alkan, Elmas, Karakuş & Akkay, 2001; Nakajima, 2012; Aydın, 2012; Aycan, Toprak, Yüksel, Özer & Çakır, 2002; Altıntaş, 2005; Uğurlu, Bakım, Güveli, Karamustafalıoğlu, Soydal & Ergüder, 2003; Işık, Aydınlıoğlu, Koç, Gündoğdu, Korkmaz & Ay, 2012). A look into research on disaster management reveals that the subjects treated are preparations for disaster and state of emergency management (e.g., Akdur, 2005; Battal, 2007; Bengtsson et al., 2011; Güler & Çobanoğlu, 1994; Kadıoğlu, 2011; Kayrancıoğlu, 2007; Uzunçıbuk, 2005).

In short, although it is apparent that studies on disaster encompass a broad framework in terms of the fields the subject involves, it is also true that apart from the evaluation of the impact of disasters on nature and on living beings, studies on raising awareness about the implications of disaster and on disaster management, there is no reference to other types of research in the literature. Moreover, while there are studies on disasters caused by nature and also mention of natural disasters in the context of preventing disasters, the topics covered are limited to traffic accidents, war, attacks, nuclear power and other activities, and the work of civil organizations. The framework of studying disasters is however quite broad, both in terms of impact and in terms of meaning.

Studies on Defining Disaster and its Scope in the Field of Education

In the field of education, it can be seen that instead of defining disaster and seeking to create public awareness about its implications, studies focused on outcomes and disasters caused by natural phenomena are in the majority. In this sense, the studies that stand out are on the subject of earthquakes (e.g., Ault,1982; Aydın, 2010; Blake, 2005; Barrow & Haskins, 1996; Başıbüyük, 2004; Dal, 2009; King, 2000; King & Tarrant, 2013; Leather, 1987; Nakamura, 2007; Öcal, 2005; Öcal, 2010; Ross & Dargush, 1992; Şimşek, 2007). In a review of these studies, the main research focus is the surveys that were conducted in the elementary and middle schools (e.g., Ault, 1982; Buluş Kırıkkaya, Çakın, İmalı & Bozkurt, 2011; Buluş Kırıkkaya, Oğuz Ünver & Çakın, 2011; Fetihi & Gülay, 2011; King & Tarrant, 2013; Oğuz, 2005; Özgüven, 2006), in the high schools (e.g., Leather, 1987), the universities (e.g., Barrow & Haskins, 1996; Dal, 2009; Öcal, 2010) and with adults (e.g., Başbuğ Erkan, Özmen & Güler, 2011; Başıbüyük, 2004; Buluş Kırıkkaya & İmalı, 2013; King, 2000; Ross & Dargush, 1992).

When studies on education related to disasters are examined, it is seen that earthquakes, which are natural phenomena, are directly defined as disasters and most of the studies on this topic have been designed on the basis of this premise. In geology, however, an earthquake is one of the most extraordinary and miraculous natural phenomena, a force that has caused the shaping and formation of the earth and one that is necessary to release the earth's built-up energy. The fact that such a miraculous natural event can be referred to as a disaster is a consequence of the failure to take necessary precautions. It is for this reason that to create awareness about the concept of disaster, the definition of a disaster is necessary and important. In this context, the fact that earthquakes occur through natural processes and their conversion into disasters is a outcome-based result requires defining earthquakes first as natural phenomena. Starting from this point, in the realization that a differentiation between natural phenomena and the concept of disaster is not definitively made in the literature, the related studies in the wide spectrum of different fields has led to certain fundamental conclusions. These conclusions are the following:

1) The research on disasters covers a broad span of different fields of discipline (e.g., geology, medicine, management, education, etc.).
2) When the research is examined, it is seen that most of the studies are on the consequences of disasters and the measures that must be taken.
3) Despite the fact that disaster studies concentrate on a vast outcome-oriented impact, there is limited interdisciplinary research available.

4) A review of the literature also shows that the studies in the field of education are limited to natural disasters (e.g., earthquakes, floods, landslides, erosion, etc.).
5) The studies in the field of education are more concentrated on a survey type of research and these surveys are generally limited to earthquakes.
6) There is a limited number of studies on defining disaster and creating public awareness.

Purpose of the Research

The raising of population and the fact that the increasing number of people are distanced from science leads to a substantial lack of awareness in the general public about natural phenomena and as a consequence, to senseless over-growth and development (Kadıoğlu, 2007). While this is the case, it is inevitable that most natural phenomena will bring about devastating material and moral damage. Keeping this destruction and loss at a minimum can only be accomplished by becoming acquainted with and understanding nature through a scientific approach to disaster education. Understanding disaster will not only create awareness but will also bring us closer to knowing how to protect ourselves from it.

Becoming aware of what disaster is can therefore only be possible by first defining the term. It is a fact however that the textbooks students follow in the schools that are designed to promote this awareness do not provide a scientific definition of disaster. This is why studies should be produced in this context and disaster education should be based on this basic function. This is how the concept of disaster can be saved from being trivialized to encompass only the concept of earthquakes. The aim of this study from this perspective is to examine how the concept of disaster is perceived in different aspects of the population and by defining the term, to determine its scope and contribute in the long term to the content and effectiveness of the disaster education provided at the schools. In the light of this aim, some of the sub-goals of the study were to develop a scale to measure the knowledge of the various aspects of the population (the middle school students, high school students, university students, and other adult peoples) about disaster as well as their ability to differentiate between disasters and natural phenomena, and in addition, to explore how the different aspects of society define the concept and its scope.

Method

Research Model and Participants in the Study

This study was designed within the framework of survey research design. The participants were chosen in terms of convenience sampling that uses participants from target population available at the time and willing to take part (Patton 1987). Furthermore, convenience sampling is used in exploratory research where the researcher is interested in getting an inexpensive approximation of the truth. The reason chosen this method for the current study is that nonprobability method is often used during preliminary research efforts to get a gross estimate of the results, without incurring the cost or time required to select a random sample. Even though it may not provide a representative sample, this is a quick way choosing participants and had general knowledge for further studies.

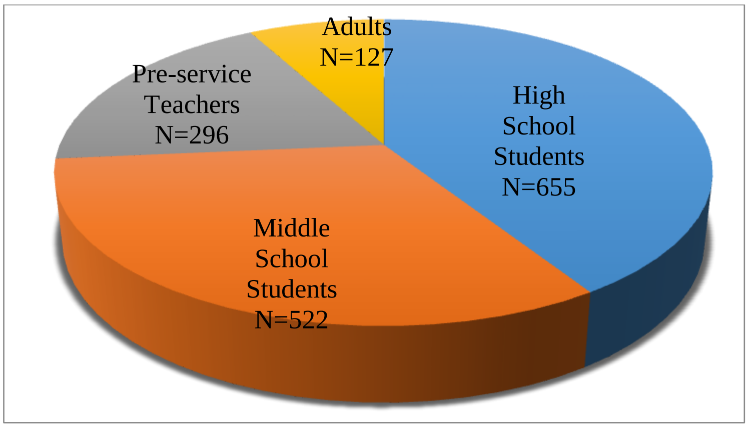


Figure 1.Distribution of participants in research

The sample for the study comprised 1600 individuals made up of 7th and 8th grade (middle school) (N=522), 11th and 12th grade (high school) (N=655), and last-year university students (N=296), and adults (N=127) in the metropolitan area of a city in western Turkey. The university participants were last-year pre-service teachers enrolled in the Science Teaching, Social Studies Teaching, Classroom Teaching and Pre-school Teaching Departments. The adults were individuals belonging to different professional groups in the community, having different levels of education. The distribution of the participants in the research is shown in Figure 1.

Data Collection Instrument

A "Disaster Definition and Scope Scale (DDSS)" developed by the researchers to inquire into the definition and scope of disaster was used as a data collection tool. The scale was developed in three stages.

Stage 1 (A pilot application to analyze related literature and determine student ideas)

In this first stage, an analysis was made of the course contents and scholastic tests reported in the literature for Science, Life Sciences and Social Sciences Programs and for undergraduates in relevant departments. At the end of the analysis, it was concluded that the concepts of disaster and natural phenomena were not distinctly differentiated from each other. To understand how these concepts were constructed in the minds of the participants, the following open-ended questions were composed:

What is a disaster? Explain.
Is a disaster a natural phenomenon? Explain.
What are some disasters that take place on earth?

The open-ended questions were asked of the 3rd-year students of Elementary School Science Teaching (N: 76), and the participants' views were taken in writing (Oğuz Ünver & Öztürk 2012). The responses of the participants to each question were gathered together under specific themes. While the participants offered descriptions of the concept of disaster as destruction, loss, earthquakes, death, they described the scope of a disaster as, among others, an earthquake (N: 69), floods (N: 62), avalanches (N: 34), landslides (N: 11), tsunamis (N: 34). To the question, "Is a disaster a natural phenomenon?" 89.47% of the participants responded as "Yes." The statements in the last section of the tool were formulated in the light of the events and occurrences described as being within the scope of a disaster by the participants in the pilot study and in with the light of the literature. It was decided that all the data obtained from the pilot study would be used in the development of a three-section of the scale that contained demographic questions, open-ended questions and true/false statements.

Stage 2 (Pilot study for developing the scale)

At the end of the first pilot study in the development of the scale, the DDSS was designed in three sections. The first section covered demographic features; the second section were made up of the two open-ended questions,

What is a disaster? "Explain.
Is a disaster a natural phenomenon? Explain.

The third section was prepared in the form of 25 questions to be answered with the choices of *True/False/I don't Know*. In order to test the validity of the scale that was drawn up, the views of eight experts, namely four faculty members in the fields of meteorology and disaster management, science education, geography education and linguistics, and four experienced teachers working in public schools. After the experts taken their advices, the scale was revised to its final form. The pilot study was carried out with students at a middle school in a district of western Turkey (N=45), 3rd-year students in Science Teaching Department of a public university (N=74), and adults representing different professions in the community (N=11), a total of 130 participants.

In line with the results of the pilot study, some revisions were made. To one of the questions about demographics, *"What is your profession?"* the choice of *academic* was added to the other choices of *teacher, police officer, nurse, lawyer, doctor, and engineer and other*. *The question, "Have you ever experienced a disaster before?"* was removed from the scale because the participants were generally unable to define disaster. To the question, *"Is a disaster a natural phenomenon?"* the word *"only"* was added to the statement to make it

"Is a disaster only a natural phenomenon?" - The final form of the DDSS was reached after the completion of a total of 12 months which included all of the development work and the pilot study.

Stage 3 (Validity and reliability testing of administered scale)

The internal consistency of the scale was calculated using Cronbach's alpha reliability coefficient and on the basis of the responses given to the 25 three-choice items. The α value calculated was .83. The scale's Cronbach Alpha (α) values for the different aspects of the community was .83 for middle school respondents, .85 for high school respondents, .81 for university participants and .82 for adults.

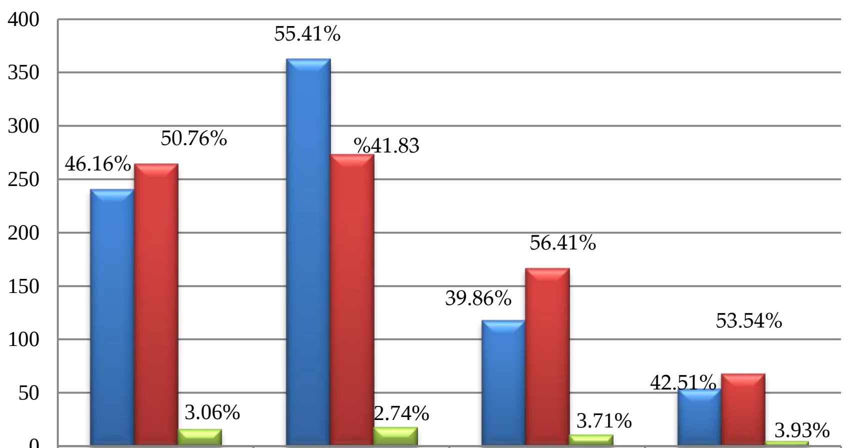
Earth science, geologist, and science education specialists were enlisted to establish content validity for the scale. Following this, test templates were prepared to analyze the construct validity of the scale, or the degree to which the test measured what it purported to be measuring. Lastly, the measuring instrument was revised based on the template that was best suited to provide construct validity.

Results

The research results were analyzed under three headings--demographic characteristics, qualitative and quantitative findings.

Demographic Characteristics of the Participants

The demographic characteristics of the research sample are presented in the tables below. The frequency analysis method of statistical analysis was used to examine the participants' demographic features in Figure 2.



	Middle School	High School	University	Adults
Males	241	363	118	54
Females	265	274	167	68
Blank	16	18	11	5

Figure 2. Distribution of research participants by gender

Table 2 shows the kind of schools the students in the research attended and their grades.

Table 2.Results related to type of school students attended and their grades

Types of Schools and Departments		Grades	Frequency (f)	Percentage (%)
Middle School		7th Year	283	17.68
		8th Year	239	14.93
High School	Vocational H.S.	11th Year	60	3.75
		12th Year	62	3.87
	Anatolian H.S.	11th Year	223	13.93
		12th Year	223	13.93
	Science H.S.	11th Year	87	5.43
University	Science Teaching	4th Year	74	4.62
	Social Studies Teaching	4th Year	77	4.81
	Classroom Teaching	4th Year	98	6.12
	Pre-School Teaching	4th Year	47	2.93

Figure 3 displays the educational level, shown in quantitative data, of the adults who comprised a section of the participants.

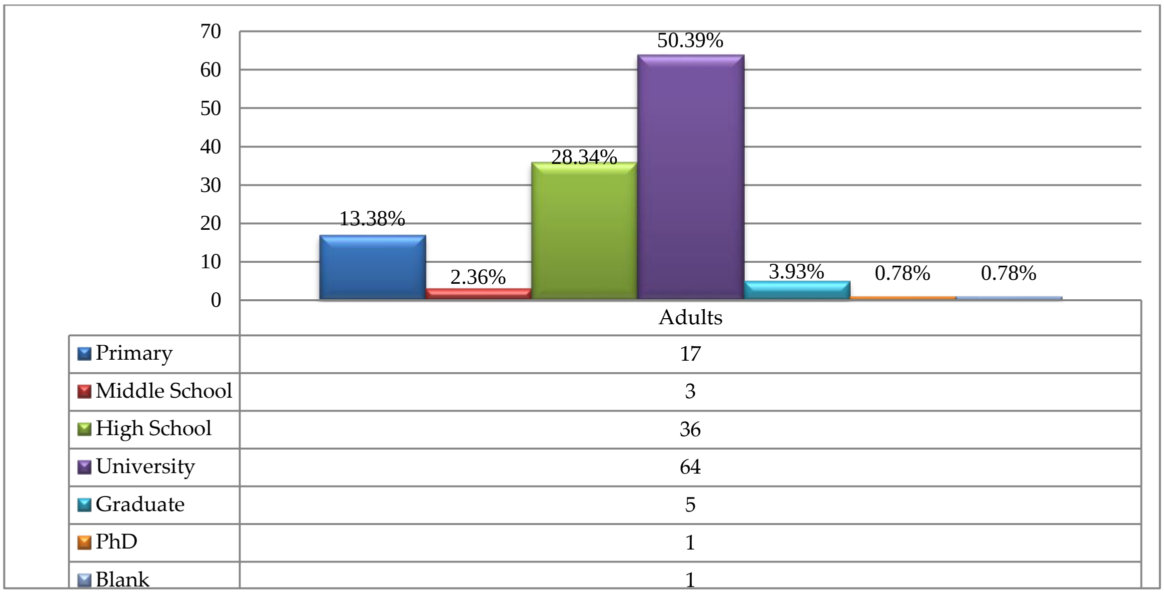
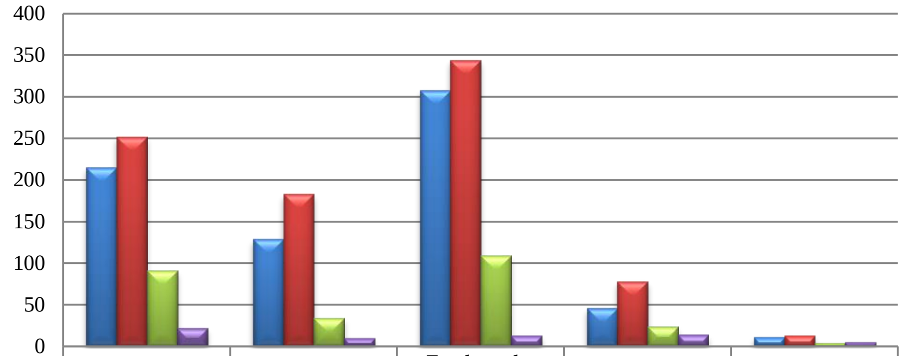


Figure 3. Results related to the educational status of the adults

The adults were asked, *"Do you carry Natural Disaster Insurance (DASK)?"* - Of the adults, 59.05% (N=75) stated that they did not carry DASK even though it was mandatory, and only 39.37% (N=50) revealed that they did. This finding defied the requirement to carry a DASK policy, stipulated by Law No. 4484 dated August 27, 1999. The question asked of the participants about whether they had attended a disaster training course was answered in the affirmative by 1095 people and negatively by 501. The participants who stated that they had received training were asked what the source was of their training. Their answers are summarized in Figure 4.*

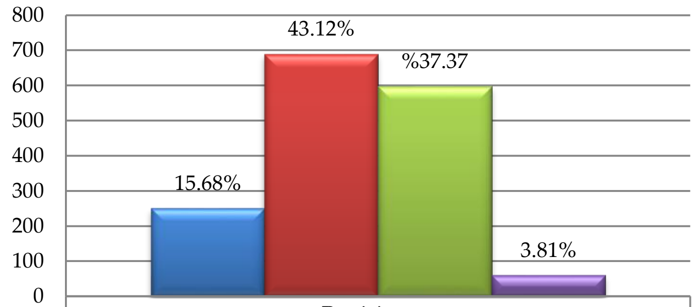


	School lessons	Conferences	Earthquake drills	Civil defense	Other
Middle School	215	129	308	46	11
High School	252	183	344	78	13
University	91	34	109	24	4
Adults	22	10	13	14	5

Figure 4. Quantitative data on the sources from which the participants received training

Note: Since the participants provided more than one answer to this question, the frequency figures corresponding to the responses should not be compared with the total number in the sample.

A review of the results presented in Figure 4 shows that the training the participants received were earthquake drills and whatever was taught in their classes in school. It can be seen from a more in-depth examination of the data that high school and middle school participants had benefited more from basic training compared to the other respondents. The answers the participants gave to the question, *"Are you aware of the work carried out by the Disaster Preparation Unit (AHEB)* that was posed to determine the extent of their knowledge about what was being done in the way of disaster preparation are shown in Figure 5.



	Participants
Yes	251
No	690
This is the first I've heard of such a unit	598
Blank	61

Figure 5. Results related to the awareness of participants about the work of the disaster preparation training unit (DPTU)

It will be seen in Figure 5, that the level of the participants' knowledge about DPTU is very low. The participants were asked the question *"Which sources do you learn from about disasters?"* The responses are presented in Figure 6.* The results showed that participants preferred to depend on the daily media sources to get information about disasters.

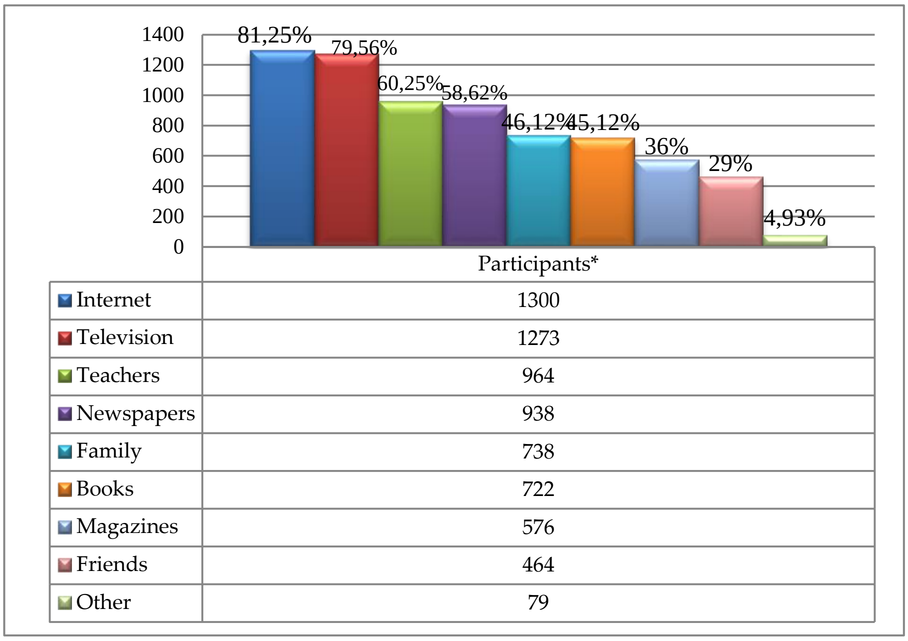


Figure 6. Results related to the sources from which participants obtained information about disasters
(Since the participants provided more than one answer to this question, the frequency figures corresponding to the responses should not be compared with the total number in the sample).

Results related to the Definition of Disaster

In the second section, the question *"How would you define disaster?"* was asked of the participants. Their responses have been grouped under 4 basic themes. These are the following: Nature-based, People-based, Belief-based and Outcome-based Themes. Examples for each theme are given in Table 3.

Table 3. "What is a disaster?" examples of basic themes in the responses to the open-ended question

Themes	Examples
Nature-based	P1474 (adult group): *"A disaster refers to earthquakes, floods, fire, landslides and storms."* P15 (university group): *"Disasters are unexpected natural phenomena."* P819 (high school group): *"Disasters are various natural events."* P304 (middle school): *"A disaster is a natural event that occurs outside man's will."*
People-based	P51 (university group): *"Disasters are temporary and destructive events that occur in the environment because of the imbalance caused by people who are unaware."*
Belief-based	P1482 (adult group): *"A disaster is an act of God."* P835 (high school group): *"Disasters refer to earthquakes, avalanches, landslides, in short, catastrophe. May God save us all from natural disasters."* P679 (middle school group): *"A disaster is dealt out by God..."*
Outcome-based	P1479 (adult group): *"Disasters in their broadest terms are events that cause people loss and damage."* P829 (high school group): *"A disaster refers to the damage sustained by people and the environment."* P298 (middle school group): *"A disaster is an unforeseen, sudden occurrence that results in vast adversities."*

At the same time, six sub-themes were differentiated under these four basic themes: *"Nature and People-based," "Nature and Belief-based," "Nature and Outcome-based," "People and Outcome-based," "Belief and Outcome-based"* and *"Nature, People and Outcome-based*. The responses that were closest to the definition of disaster were those categorized under the sub-theme of *Nature, People and Outcome-based* . Examples for each sub-theme are given in Table 4.

Table 4."What is a disaster?" examples of sub-themes in the responses to the open-ended question

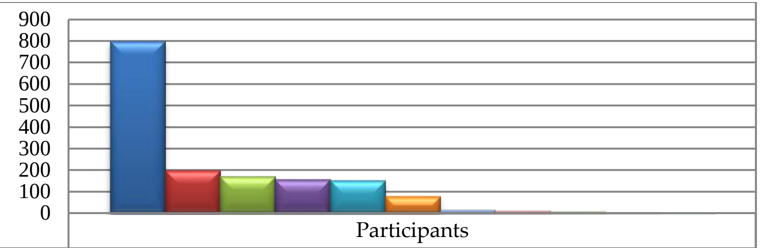
Themes	Examples
Nature and People-based	P1534 (adult group): *"A disaster is a natural phenomenon. It is at the same time an occurrence that stems from people's lack of awareness."* P16 (university group): *"Disasters can be divided into two groups: natural and man-made"* P843 (high school group): *"Disasters are things that are caused by people or natural phenomena."* P358 (middle school group): *"There are two kinds of disasters: "Natural and Man-made."*
Nature and Belief-based	P131 (university group): *"Disasters are occurrences that are caused by extraordinary natural events."* P341 (high school group): *"A disaster is a natural catastrophe. It is brought about by God."*
Nature and Outcome-based	P1483 (adult group): *"Disasters are natural phenomena occurring on the earth such as floods, earthquakes, fires, all of which cause people loss."* P823 (high school group): *"Disasters are natural occurrences that cause losses for man and nature and create material and bodily damage."* P501 (middle school group): *"Disasters are natural occurrences unforeseen by man that cause great loss of life and property."*
Nature and Outcome-based	P1483 (adult group): *"Disasters are natural phenomena occurring on the earth such as floods, earthquakes, fires, all of which cause people loss."* P823 (high school group): *"Disasters are natural occurrences that cause losses for man and nature and create material and bodily damage."* P501 (middle school group): *"Disasters are natural occurrences unforeseen by man that cause great loss of life and property."*
People and Outcome-based	P1442 (high school group): *"A disaster is an event that happens suddenly and causes people bodily and material harm. In general, it happens because of people."*
Belief and Outcome-based	P939 (high school group): *"A disaster is the entirety of events that are brought to people by God to teach them a lesson and test them in their lifetime, a type of examination when they make mistakes."*
Nature, People and Outcome-based	P1544 (adult group): *"A disaster is the general name given to natural or man-made phenomena that lead to physical, economic and social losses for people, an event that may interrupt or put a stop to people's normal lives and activities and for which resources are inadequate."* P825 (high school group): *"Disasters are factors that come about from natural or man-made causes and result in bodily and material loss."* P607 (middle school group): *"Disasters are events that harm people and are caused by either nature or people."*

To ensure the validity and reliability of the analysis, 50 scales were collected from each participating group and analyzed by a second researcher. This was done basically to increase the inter rater reliability of the analysis. To increase consistency, both researchers evaluated each scale individually and made the needed adjustments on the item matrices. After the 50 scales of collected data were encoded, the IRR was calculated on the basis of the matrices rated by each observer.

$$IRR = \left[\frac{E_1 - E_2}{N}\right] \times 100$$

E_1 = Analysis results of first researcher
E_2 = Analysis results of second researcher
N = Total number of participants

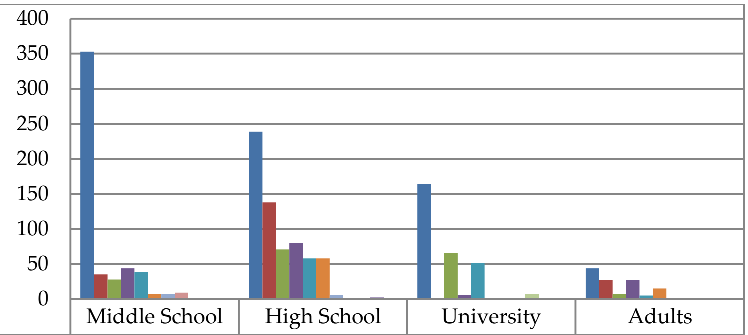
The IRR calculated according to this formula varies between 94%-100% between the items. How the data was collected under the themes described above is shown in Figure 7.



	Participants
Nature-based	800
Nature & Outcome-based	200
Outcome-based	172
I don't know	157
Nature and People-based	153
Nature, People & Outcome-based	80
Belief-based	15
Nature & Belief-based	11
People-based	8
Belief & Outcome-based	3
People & Outcome-based	1

Figure 7. Results related to responses of participants to question "what is a disaster?" by groups

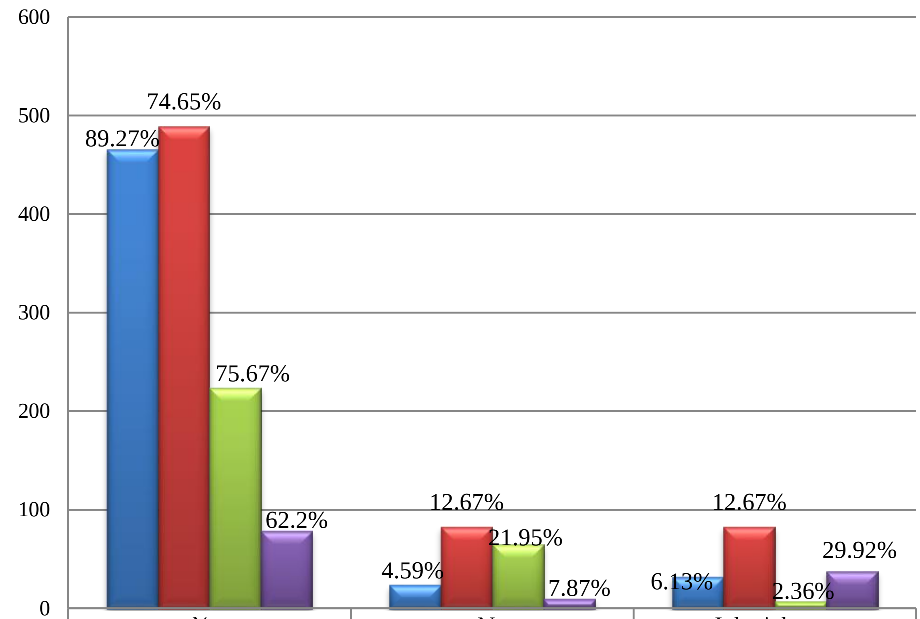
In Figure 7, 49.93% of the participants (N=800) describe a disaster as something natural. Of the participants, 0.5% (N=8) think of disaster as people-based, 10.62% (N=172) as outcome-based. It was observed that only 5% (N=80) of the participants' responses could be collected under the theme "Nature, People and Outcome-based." An analysis of the definition of disaster by different aspects of the populations is presented in Figure 8.



	Middle School	High School	University	Adults
Nature-based	353	239	164	44
Nature & Outcome-based	35	138	0	27
Outcome-based	28	71	66	7
I don't know	44	80	6	27
Nature & People-based	39	58	51	5
Nature, People & Outcome-based	7	58	0	15
Belief-based	7	6	0	2
Nature & Belief-based	9	1	1	0
People-based	0	0	8	0
Belief & Outcome-based	0	3	0	0
People & Outcome-based	0	1	0	0

Figure 8. Results related to responses of participants to question "what is a disaster?" by groups

After the written responses of the participants on the definition of disaster were collected, the second question in this section, "*Is a disaster only a natural phenomenon*?" was asked. The participants were given three choices as answers and were asked to mark "Yes," "No," or "I don't know." The responses were coded as Yes: 1, No: 2 I don't know: 0 and a frequency analysis was performed on the SPSS 20 program. The results showed that of the 1600 participants, 78.62% (*N*=1258) answered *"Yes"* while 11.37% (*N*=182) answered *"No"* and 10% (N=160) responded *"I don't know."* The frequency of the answers by participant categories is shown in Figure 9.



	Yes	No	I don't know
Middle School	466	24	32
High School	489	83	83
University	224	65	7
Adults	79	10	38

Figure 9. Participants' views on whether a disaster is only a natural phenomenon

Results related to the Participants Views on the Scope of Disaster

The third and last sections were aimed to determine the knowledge of the participants about the scope of disaster. Here, the participants were asked, *"Are the events listed in the table each disasters?"* The participants were asked to mark each of the 25 items as *Yes/No/I don't know*. The responses were coded Yes: 1, No: 2, I don't know: 0 and entered into the SPSS 20 Statistics Program. After the entries were made into the SPSS 20 program, conversions were performed for the items that were considered disaster or only a natural phenomenon.

The conversion of the data led to the categorization of the statements according to the "*True*" and "*False*" answers. If in any of the statements, a natural phenomenon was marked by a participant as "*Yes*" or "*I don't know*," the participant was scored as having answered incorrectly with a score of (0). If the response was "*No,*" the participant's answer was counted as right and the score was (1). The total score for the third section of 25 items was thus calculated using this scoring system.

The total scores were then analyzed to determine whether there was a significant difference in the level of knowledge about the concept of disaster between the different aspects of the community (middle school, university students and adults). Because the mean scores of more than two groups were to be compared to determine the significant differences between groups, the researchers used the One-way Analysis of Variance (Pallant 2007: 242). Before starting the analysis however, the hypotheses for the data set were tested for verification. The Scheffé's Test, a more cautious method of determining significant differences between groups, was used for a post-hoc comparison to ascertain the direction of the differences. The level of significance for this analysis was found to be p<0.05. The research process is presented in Table 5.

Table 5. Results related to the scope of disaster as perceived in the various aspects represented by the participant

QUESTIONS	PARTICIPANTS																							
	Middle School						High School						University						Adult					
	Yes		No		N/A		Yes		No		N/A		Yes		No		N/A		Yes		No		N/A	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
1) All the earthquakes occurring in the world	476	91,2	26	5	20	3,80	551	84,1	83	12,7	21	3,2	232	78,4	59	19,9	5	1,7	108	85	17	13,4	2	1,6
2) The 9-11 terrorist attacks on the U.S.	45	8,6	423	81	54	10,3	68	10,4	546	83,4	41	6,3	71	24	204	68,9	21	7,1	22	17,3	100	78,7	5	3,9
3) Traffic accidents with fatalities	59	11,3	438	83,9	25	4,8	57	8,7	573	87,5	25	3,8	64	21,6	218	73,6	14	4,7	21	16,5	97	76,4	9	7,1
4) Man-induced forest fires that do not lead to a loss of life	263	50,4	215	41,2	44	8,40	293	44,7	317	48,4	45	6,9	165	55,7	117	39,5	14	4,7	47	37	72	56,7	8	6,3
5) Force migrations (due to war, political reasons, etc.)	54	10,3	402	77	66	12,6	66	10,1	535	81,7	54	8,2	56	18,9	211	71,3	29	9,8	17	13,4	102	80,3	8	6,3
6) Solar eclipses	188	36	245	46,9	89	17	173	26,4	415	63,4	67	10,2	74	25	198	66,9	24	8,1	33	26	87	68,5	7	5,5
7) The volcanic eruption in 1912 in Katmai, Alaska that was of moderate force and led to material damage	403	77,2	64	12,3	55	10,5	586	89,5	38	5,8	31	4,7	264	89,2	24	8,1	8	2,7	114	89,8	10	7,9	3	2,4
8) The Chernobyl Nuclear Accident of April 26, 1986	94	18	348	66,7	80	15,3	174	26,6	433	66,1	48	7,3	132	44,6	152	51,4	12	4,1	44	34,6	74	58,3	9	7,1
9) The Istanbul İkitelli Radiation Accident of 1998	99	19	345	66,1	78	14,9	149	22,7	441	67,3	65	9,9	110	37,2	159	53,7	27	9,1	37	29,1	77	60,6	13	10,2
10) Acid rain	332	63,6	121	23,2	69	13,2	462	70,5	142	21,7	51	7,8	205	69,3	61	20,6	30	10,1	92	19,7	25	72,4	10	7,9
11) Petroleum leakage into the sea from a petroleum-carrying ship	80	15,3	389	74,5	53	10,2	108	16,5	497	75,9	50	7,6	85	28,7	182	61,5	29	9,8	35	27,6	80	63	12	9,4
12) The Tsunami in Rhodes in 1609 which led to the death of 10,000-12,000 people in southwestern Anatolia	449	86	37	7,1	36	6,9	593	4,6	32	90,5	30	4,9	278	93,9	13	4,4	5	1,7	121	95,3	2	1,6	4	3,1
13) The avalanche in Pakistan that killed 137 soldiers and civilians	446	85,4	43	8,2	33	6,3	616	94	10	1,5	29	4,4	279	94,3	14	4,7	3	1	122	96,1	2	1,6	3	2,4
14) The Typhoon of 1780 in the Atlantic, which killed 22,000 people	399	76,4	49	9,4	74	14,2	589	89,9	29	4,4	37	5,6	283	95,6	11	3,7	2	0,7	121	95,3	2	1,6	4	3,1
15) The death of a soldier when he was hit by lightening while on duty in Gümüşhane	294	56,3	169	32,4	59	11,3	423	64,6	166	25,3	66	10,1	197	66,6	76	25,7	23	7,8	86	67,7	31	24,4	10	7,9
16) Ebbs and tides	297	56,9	145	27,8	80	15,3	283	43,2	317	48,4	55	8,4	114	38,5	157	53	25	8,4	61	48	59	46,5	7	5,5
17) Lunar eclipse	186	35,6	247	47,3	89	17	196	29,9	402	61,4	57	8,7	71	24	201	67,9	24	8,1	24	18,9	97	76,4	6	4,7
18) Drought	272	52,1	180	34,5	70	13,4	399	60,9	202	30,8	54	8,2	220	74,3	60	20,3	16	5,4	98	77,2	19	15	10	7,9
19) The flood in Pakistan that affected about 17 million people	456	87,4	35	6,7	31	5,9	607	92,7	23	3,5	25	3,8	280	94,6	13	4,4	3	1	123	96,9	2	1,6	2	1,6
20) Landslides	480	92	21	4	21	4	601	91,8	31	4,7	23	3,5	261	88,2	29	9,8	6	2	118	92,9	8	6,3	1	0,8
21) Landslip	469	89,8	28	5,4	25	4,8	610	93,1	23	3,5	22	3,4	259	87,5	30	10,1	7	2,4	116	91,3	10	7,9	1	0,8
22) The bird flu epidemic that erupted in December 2003 in South Korea	75	14,4	380	72,8	67	12,8	148	22,6	434	66,3	73	11,1	103	34,8	155	52,4	38	12,8	39	30,7	69	54,3	19	15
23) The thinning of the ozone layer	226	43,3	213	40,8	83	15,9	246	37,6	326	49,8	83	12,7	129	43,6	122	41,2	45	15,2	55	43,3	55	43,3	17	13,4
24) Global climate change	253	48,5	204	39,1	65	12,5	279	42,6	300	45,8	76	11,6	135	45,6	117	39,5	44	14,9	55	43,3	56	44,1	16	12,6
25) Wars	64	12,3	419	80,3	39	7,5	97	14,8	510	77,9	48	7,3	78	26,4	201	67,9	17	5,7	15	11,8	105	82,7	7	5,5

A participant can score a minimum of 0 and a maximum of 25 on the Definition and Scope of Disaster Scale (DSDS) that is used to determine the level of knowledge about the concept of disaster. The number of participants (N), mean scores ($\bar{X}$), and standard deviations (SD) (of the middle school, high school, university students, and other adults) are presented in Table 6.

Table 6. The central tendency and distribution values for the scores of the middle school, high school, university students and adults on the dsds

Participating groups	N	$\bar{X}$	SD
Middle School Students	522	11,44	3,29
High School Students	655	12,80	3,70
University Students	296	14,42	3,94
Adults	127	13,84	3,80

One-way analysis of variance was used to determine whether there was a significant difference in the level of knowledge of the different aspects of the community indicated in Table 6 (middle School, high school and university students and adults) about the concept of disaster. The results of the analysis can be found in Table 7.

Table 7. Results of the one-way analysis of variance (ANOVA) on the knowledge levels of middle school, high school, university students and adults about the concept of disaster

Source of Variance	Sum of Squares	*SD*	Squares Mean	*F*	*p*	Level of Significance
Inter group	1868,50	3	622,83	47,25	.000	Yes
Intragroup	21036,43	1596	13,18			
Total	22904,93	1599				$p \leq .05$

According to Table 7, a statistically significant difference was found between groups ($F_{(3,1529)}$=47,25, p=.00). A post-hoc comparison was performed with Scheffé's Test to account for multiple comparisons between group, While the test results showed significant differences between the university students (M=14.42, Sd=3.94) and the high school students (M=12,80, SD: 3,70) and middle school students (M=11,44, SD=3,29), no statistically significant difference was observed between the university students and the adults (M=13,84, SD=3,80). This shows us that parallel to the increased education that the middle school, high school and university students received, there was also a significant improvement in their knowledge about the concept of disaster, but that the university-level participants and the adults did not demonstrate any improvement in the level of their knowledge about the concept.

Discussion, Conclusion and Recommendations

Every person has his or her own perception of how to define disaster. The most common perception exhibits the confusion between a disaster and a natural phenomenon (78.62%). Just as every natural phenomenon is not a disaster, every disaster does not stem from nature. As long as the knowledge of the general public about what disaster is buried in the murky waters of what has customarily been taught about disasters, everyone will continue to believe that a disaster is an act of nature and that it cannot be prevented. Although there are limited references to this matter in the literature, what little there is supports our argument (Buluş-Kırıkkaya et al., 2011; Cannon, 1994). Indeed, Kadıoğlu (2011) has called attention to disasters within a broad scope of the term, pointing to natural, man-made and technology-based disasters and has discussed the need for separate emergency plans for each type of disaster.

The present study has shown that the participants' knowledge of disasters is largely based on earthquake drills and classroom lessons. Parallel to this, a review of the sources of knowledge that the participants have benefited from with regard to learning about disasters points to the internet and television. We can therefore say that these two channels of communication are effective tools in raising awareness in the public about disasters. Another researcher, Coşkun (2011), has examined in a section of a study the association found between age and the devices owned and used at home and asserted that individuals in the 21-40 age groups are more efficient users of television and the internet compared to users at other ages. The same study also shows that disaster education programs should follow a systematic, regular and renewable process. Öcal (2010) reached the conclusion in a study examining the level of knowledge of primary school pre-service teachers about earthquakes that the participants confused the "size" with the "magnitude" of an earthquake and that this confusion was caused by the explanations of authorized and unauthorized persons over the media channels. Another researcher, Koç (2013), concluded that the most common sources of news about natural disasters were about earthquakes and that these were generally magazine-style human interest stories. Other outcomes of the research were that natural disasters maintained their place in the public interest for as long as they had an impact on social, economic and daily life but when their current relevance faded, they were no longer made the subject of news in the press. Similarly, Barrow & Haskins (1996), in their study with 186 geology students, reported that participants could not define an earthquake and that their knowledge about earthquakes came from TV news stories, newspapers and films.

Our findings about the Disaster Preparation Education Unit (DPEU) showed us that the study subjects were not very informed about the existence of this organization. Varol (2007) also in the study entitled, "Raising Public Awareness about Natural and Technological Disasters and the Role of AFEM" noted that although AFEM (European Natural Disasters Training Center), established as a result of the European and Mediterranean Major Hazards Agreement (EUR-OPA), targeted experts, administrators, educators, decision-makers, primary schools and the general public in its programs of education, most of the aspects of the population were not aware of the existence of AFEM. This finding is true despite the fact that the primary aim of the European Natural Disasters Training Center (AFEM) is to gradually educate the public, and instigate disaster-awareness. A study by Coşkun (2011) queried the impact of the work carried out by the Disaster Preparation and Earthquake Training Association (AHDER), an organization that started to work in various ways in cooperation with different intervention and assistance associations in the provinces and districts after the 1999 Marmara Earthquake. The investigation revealed that the public was not knowledgeable about what to do before or after an earthquake and that although people felt the need for training in the face of the destructive effects that they experienced during the earthquake, the training they in fact received was focused not on pre-earthquake training but on what to do in the aftermath of an earthquake. It is however just as important and necessary to execute interventions before a disaster strikes than it is to execute them afterward.

It was seen in the present study that the middle school participants were more likely to associate the concept of disaster with earthquakes. The focus on the idea of an earthquake perhaps may be due to the extended emphasis of the media in Turkey on the natural phenomenon of earthquakes. Another reason might be that the area in which the study was conducted is geographically and geologically classified as a first degree earthquake hazard area. Besides this, because almost every natural disaster brings out dire consequences, differentiating between the concept of a natural phenomenon and disaster becomes difficult. This might be why people generally refer to an explosion or an accident as a catastrophe but speak about the adverse results of natural phenomena as natural disasters.

When the adage, "Schooling begins at home," is considered, it becomes clear that the findings of this study point to the reality that while children should be educated and their awareness raised about disasters, families also need to be included in the education cycle. In this context, the fact that the percentage of participants receiving disaster education dropped the higher their level of education brings to mind two reasons for this. The first of these is that, related to the great loss the country has suffered due to disasters, the reforms made in education have increased the importance of disaster education and therefore middle school students have started to benefit from these progressive efforts, albeit not adequately. A second reason may stem from the fact that disaster training provided in childhood years may not be easily integrated into practical life in adulthood and that knowledge presented theoretically may be considered to not have been taught at all, remaining only as an abstract classroom concept.

It can be seen that studies on disasters have been conducted in a broad scope of different areas and this might have been because the losses that were sustained have been considered in the context of various categories (e.g., architecture, health, education, management). Deficiencies in any one of these areas that result in disaster may bring out different dimensions. In this, it must not be forgotten that remedying the deficiencies present in any of these areas is a process that must go hand in hand with providing education.

Presenting systematic and regular information to the public about disasters and natural phenomena will increase the confidence individuals have in their own knowledge. As people's confidence about their own knowledge increases, they will be more open to learning and as they learn more, they will become aware that the knowledge they possess is of lifesaving significance. Achieving sustainable disaster education is dependent upon defining the concept of disaster in absolute, simple and clear terms. It can only be after this is done that natural events will cease to be objects of fear and awareness about the preventability of disasters can flourish and be rescued from the bonds of a fatalistic outlook.

The general conclusions the study reached are summarized below.

1) The concept of "disaster" is confused in all aspects of the population with natural phenomena and this results in the use of the term "natural disaster."

2) The different aspects of the population are not aware of the existence of institutions, associations and nongovernmental organizations that work in the area of disaster control.

3) The media occupies an important place in terms of providing the public with information about disasters. The information learned from media sources are more effective sources of knowledge than other sources of information.

4) While the maximum possible score on the DDSS is 25, the average scores received by the different participants ranged between 11.44-14.42. This indicates to us that the concept of disaster is not fully understood and events that lie in the scope of disaster are misinterpreted.

5) The work carried out to create public awareness about the definition and scope of the concept of disaster is quite limited.

Many disasters have taken place around the world during the course of the present study. These disasters were without doubt either preventable or the scope of their destruction could have been reduced. One such disaster that took its toll in Turkey was the recent Soma mining disaster in which 301 miners lost their lives. As with prior disasters, it is clear that this mining disaster too was the product of neglected precautions and inadequate auditing and inspections. As with the 1999 Marmara Earthquake, where 17,480 souls perished, the devastation caused will not by itself be enough to prevent such disasters from happening again and the many lives lost will continue to be the price that humanity will have to pay. If measures had been taken or if the precautions that were put into place had been adequate, this loss of lives and property would not have occurred and the destruction would have been less overwhelming. Indeed, disasters such as these not only result in the loss of lives and property, they also wreak havoc over the psychological state of society as a whole.

Understanding what disaster means will not only create our awareness but will also bring us closer to knowing how to protect ourselves in the face of this adversity. Creating awareness about disaster is therefore only possible by first defining the term. Being aware is to take on responsibility. If awareness can be created in our society, everyone will assume responsibility. Disaster is a phenomenon that has an impact on the whole of society and everyone carries responsibility. This concept must constitute the functional foundation of disaster education. One next research plan is to apply the test we have developed to define the concept of disaster and delineate its scope to different population groups. And in this, we will again be asking, "Is an earthquake an actual disaster?"

References

American College of Emergency Physicians [ACEP]. (2012, July 19). *Disasters.* Retrieved fromhttp://www.acep.org/search.aspx?searchtext=disaster

Akdur, R. (2005). Afetlere karşı kurumsal hazırlık afet sürecinde yapılacak işler. In M. Eryılmaz & U. Dizer (Eds.), . *Afet Tıbbı* (pp. 205-212). Ankara: Ünsal Yayınları.

Alkan, N., Elmas, İ., Karakuş, M. & Akkay, E. (2001). Doğal afetler sırasında karşılaşılan sorunlar: Bir anket çalışması. *Ulusal Travma Dergisi, 7*(3), 195-200.

Altıntaş, K. H. (2005). Afet tıbbında eğitim ve öğretim. *Hacettepe Tıp Dergisi, 36*(3), 139-146.

Arslan, A. (2003). *Türkiye'de tabii afetler (1923-1950)* (Unpublished master's thesis). Fırat Üniversitesi, Elazığ.

Ault, C. R. (1982). Time in geological explanations as perceived by elementary-school students. *Journal of Geological Education, 30*(5), 304-309.

Aycan, S., Toprak, İ., Yüksel, B., Özer, H. & Çakır, B. (2002, December 10). *Afet durumlarında beslenme hizmetleri.* Retrieved from http://ashgm.saglik.gov.tr/dosya/1-78705/h/a

Aydın, F. (2010). İlköğretim sekizinci sınıf öğrencilerinin "deprem" kavramını algılamaları: Fenomenografik bir analiz. *Turkish Studies-International Periodical For the Languages, Literature and History of Turkish or Turkic, 5* (2), 801-817.

Aydın, M. (2012, April 10). *Afetlere hazırlık ve afet sonrası müdahale süreçleri.* Retrieved from http://www.tid.web.tr/ortak_icerik/tid.web/152/4-%20Mustafa%20AYDIN.pdf

Barrow, L. & Haskins, S. (1996). Earthquake knowledge and experiences of introductory geology students. *Journal of College Science Teaching, 26*(2), 143-146.

Başbuğ-Erkan, B. B., Özmen, B. & Güler, H. (2011). Türkiye'de afet zarar azaltımını sürdürülebilir eğitimle sağlamak. Proceedings from *1. Türkiye Deprem Mühendisliği ve Sismoloji Konferansı, 2011, October 11-14,* Ankara.

Başıbüyük, A. (2004). Yetişkinlerde deprem bilgisi ve etkili faktörlerin incelenmesi. *Milli Eğitim Dergisi, 161*(1), 215-218.

Battal, F. (2007). *Doğal afetlerin yapısal risk yönetimi* (Unpublished master's thesis).Çankaya Üniversitesi, Ankara.

Bengtsson, L., Lu, X., Thorson, A., Garfield, R. & Schreeb, J. (2011). Improved response to disasters and outbreaks by tracking population movements with mobile phone network data: a post-earthquake geospatial study in Haiti. *PLoSMed, 8*(8), 1-9.

Blake, A. (2005). Do young children's ideas about the Earth's Structure and processes reveal underlying patterns of descriptive and causal understanding in Earth Science. *Research in Science and Technological Education, 23*(1), 59-74.

Buluş Kırıkkaya, E., Çakın, O., İmalı, B. & Bozkurt, E. (2011). Earthquake training is gaining importance: the views of 4th and 5th year students on earthquake. Proceedings from: *3rd World Conference on Educational Sciences, 2011, February 3-7*, İstanbul.

Buluş Kırıkkaya, E. Oğuz-Ünver, A. & Çakin, O. (2011). Teachers views on the topic of disaster education at the field on elementary science and technology curriculum. *Necatibey Eğitim Fakültesi Elektronik Fen veMatematik Eğitimi Dergisi, 5*(1), 24-42.

Buluş Kırıkkaya, E. & İmalı, B. (2013). What are teachers' opinions about including topics of natural events and their risks in primary curriculum in Kocaeli (Turkey)?.*Asia-Pacific forum on Science Learning and Teaching, 14*(1).

Cannon, T. (1994). Vulnerability analysis and the explanation of 'natural' disasters. In A. Varley (Ed.). *Disasters, Development and Environment.*New York: John Wiley&Sons.

Capelle, W. (2006). *Sokrates'ten önce felsefe (*O. Özügül, Trans.). İstanbul: Pencere Yayınları.

CassiusDio. (1914). *Dio's Roman History (Cassius Dio Cocceianus)*.. (E., Cary, H. B. Foster, & W. Heinemann Trans.) . London, New York: Harvard UniversityPress.

Coşkun, Ş. (2011). Afet *eğitimi algılaması: İlköğretim öğrencilerine verilen afet eğitimlerinin algılanmasını ölçmek üzere bir araştırma* (Unpublished master's thesis).Sakarya Üniversitesi, Sakarya.

Dal, B. (2009). Öğretmen adaylarının yer bilimleri kavramları hakkındaki düşüncelerinin incelenmesi.*Educational Sciences: Theory & Practice, 9*(2), 575-606.

EM-DAT. (2012, May 12). *Disasterlist.* Retrieved from http://www.emdat.be/disaster-list

Ersoy, Ş. (2013, December 12). *2013 Afet raporu "Dünya ve Türkiye"*. Retrieved fromhttp://www.yildiz.edu.tr/images/images/2013%20AFET%20RA PORU_v2.pdf

Fetihi, L. & Gülay, H. (2011). The effect of earthquake awareness development program (EADP) on 6 years old children. *International Online Journal of Educational Sciences, 3*(2), 663-678.

Fuse, A., Igarashi, Y., Tanaka, T., Kim, S., Tsujii, A., Kawai, M. & Yokota, H. (2011). Onsite medical rounds and fact-finding activities conducted by Nippon Medical School in Miyagi prefecture after the Great East Japan Earthquake 2011. *Journal of NipponMedical School, 78*(6), 401-404.

Güler, Ç. & Çobanoğlu, Z. (1994). *Afetler.* Ankara: Aydoğdu Ofset.

Herodotos. (2006). *Tarih* (M. Ökmen, Trans.). İstanbul: Türkiye İş Bankası Kültür Yayınları.

Hesiodos. (2000). *İşler ve günler tanrıların doğuşu* (F.Akderin, Trans.). İstanbul: Say Yayınları.

Higgins, C. M. (2009). *Popular and imperial response to earthquakes in The Roman Empire*(Unpublished master's thesis). Ohio University, Ohio.

Işık, Ö., Aydınoğlu, H. M., Koç, S., Gündoğdu, O., Korkmaz, G. & Ay, A. (2012). Afet yönetimi ve afet odaklı sağlık hizmetleri. *Okmeydanı Tıp Dergisi*, *28*(2), 82-123.

Kadıoğlu, M. (2007). *Havadan Sudan.* İstanbul: Hayy kitap.

Kadıoğlu, M. (2011). *Afet yönetimi: Beklenilmeyeni beklemek, en kötüsünü yönetmek.* İstanbul: T.C. Marmara Belediyeler Birliği yayınları.

Kayrancıoğlu, Y. (2007). *Türkiye'nin afet yönetim yapısı ve uygulamalar* (Unpublished master's thesis). Ankara Üniversitesi, Ankara.

King, C. (2000). The Earth's mantle is solid; Teacher's misconceptions about the Earth and plate tectonics. *The School Science Review, 82*(3), 57-65.

King, T. A. & Tarrant, R. A. C. (2013). Children's knowledge, cognitions and emotions surrounding natural disasters: An investigation of year 5 students, Wellington, New Zealand. *Australasian Journal of Disaster and Trauma Studies, 2013*(1), 17-26.

Koç, H. (2013). Türk basınının doğal afetlere ilişkin bakış açısını belirlemeye yönelik bir inceleme. *Journal of World of Turks, 5*(2), 121-136.

Leather, A. D. (1987). Views of the natüre and origin of earthquakes and oil held by eleven to seventeen year olds. *Geology Teaching, 12*(3), 102-108.

Nakajima, Ş. (2012). Deprem ve sonrası psikoloji. *Okmeydanı Tıp Dergisi*, *28*(2), 150-155.

Nakamura, T. (2007, July 15). *Disaster risk education at school in Japan*. Retrieved fromhttp://drh.edm.bosai.go.jp/Project/Phase2/2Events/ 9_MiniWS/9_DRH_MiniWS_Nakamura.pdf

Oğuz, A. (2005). *Surveying American and Turkish middle school students' existing knowledge of earthquakes by using a systemic network* (Unpublished doctoral dissertation). Ohio State University, Ohio.

Oğuz Ünver, A. ve Öztürk, F. (2012). Definition and Scope of Disaster. Proceedings from *9th International Conference on Hands-on Science,* Akdeniz Üniversitesi, Antalya.

Öcal, A. (2005). İlköğretim Sosyal Bilgiler dersinde deprem eğitiminin değerlendirilmesi. *Gazi Eğitim Fakültesi Dergisi*, *25*(1), 169-184.

Öcal, A. (2010). İlköğretim aday öğretmenlerinin deprem bilgi düzeyleri üzerine bir araştırma. *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi*, *8*(12), 104-110.

Özgüven, B. (2006). *İlköğretim öğrencilerine verilen temel afet bilinci eğitiminin bilgi düzeyine etkisi* (Unpublished master's thesis). Dokuz Eylül Üniversitesi, İzmir.

Pan American Health Organization [PAHO]. (2012, July 19). Retrieved fromhttp://www.paho.org/hq/index.php?option=com_content&view=category&layout=blog&id=2394&Itemid=2395&lang=en

Pallant, J. (2007). *SPSS Survival manual, a step by step guide to data analysis using SPSS for Windows.* (1st ed.). New York: McGraw-Hill.

Patton, M. Q. (1987). *How to use qualitative methods in evaluation.* Newbury Park: Sage.

Plinius, *Nat. Hist.* (Ed. Mayhoff, C. 1892-1909) C. PliniusSecundus. *Naturalis Historia* (C. Plini Secundi Naturalis Historiae Libri XXXVII. Vols. 1-5, ed.

Ross, K. E. K. & Dargush, A. (1992). Investigating teacher knowledge of earthquakes. Proceedings from: *Tenth World Conference on Earthquake Engineering, 1992, June 19-24,* Madrid.

Sever, M. Ş. & Kazancıoğlu, R. (2012). Van Depremi'nin Ardından: Yine Yeniden Deprem Once More-Still Another Disaster: The Van Earthquake, *Türk Nefroloji Diyaliz ve Transplantasyon Dergisi*, *21*(1), 7-9.

Strabon. (2000). *Antik Anadolu Coğrafyası* (A. Pekman, Trans.). İstanbul: Arkeoloji ve Sanat Yayınları.

Şahin, S. (2012). Kragos Oros, Titanis Petra ve Patara Apollon Tapınağı Lykia'nın Tarihi Coğrafyası'na İlişkin Bir Lokalizasyon Denemesi. In A.V. Çelgin & N. E. Akyürek Şahin (Eds.). *Eskiçağ yazılar 3* (1-28). İstanbul: Arkeoloji ve Sanat Yayınları.

Şimşek, C. L. (2007). Children's ideas about earthquakes. *Journal of Environmental and Science Education, 2*(1), 14-19.

Tacitus, *annales* (1942) *Complete Works of Tacitus*, (A. J. Church, W. J. Brodribb, & S. Bryant, Trans.), New York: Random House, Inc. Random House, (Inc. reprinted 1942)

TDK. (2013). *Türkçe sözlük.* Ankara: Türk Dil Kurumu Yayınları.

Uğurlu, M., Bakım, B., Güveli, M., Karamustafaoğlu, K.O., Soydal, T. & Ergüder, T. (2003). Afet Yaşantıları, Afet Psikiyatrisi ve Bingöl Depremi Sonrası Ruhsal Müdahale Programı. *Düşünen Adam*, *16*(4), 203-210.

Uzunçıbuk, L. (2005). *Yerleşim yerlerinde afet ve risk yönetimi* (Unpublished master's thesis). Ankara Üniversitesi, Ankara.

Ünalan, Z. (2010). Uyduların gözünden değişen dünya ve doğal afetler. *TÜBİTAK Bilim Teknik Dergisi, 514*(1), 24-29.

Ünver, G. (2012). *Yazıtlar ışığında Karia kentlerinde yurttaşların kent imarına katılımları (MÖ 1. – MS 3. yüzyıl)* (Unpublished doctoral dissertation). Akdeniz Üniversitesi, Antalya.

Varol, N. (2007). Doğal ve teknolojik afetler konusunda toplumun bilinçlendirilmesi ve "AFEM"in rolü. Proceedings from: TMMOB Afet Sempozyumu, Ankara, 127-131.

World Health Organization [WHO]. (2012, April 9). Retrieved from http://search.who.int/search?q=disaster&ie=utf8&site=who&client=_en_r&proxystylesheet=_en_r&output=xml_no_dtd&oe=utf8&getfields=doctype

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Promoting Physics Literacy through Enquiry-based Learning Online

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Abstract

In Australia, as in a number of other countries, studies have consistently shown a low enrolment trend towards Physics by students in post-secondary years, due partly to the subject being perceived as conceptually difficult and abstract to grasp. In order to promote Physics literacy, continued opportunities such as online courses for students to engage in Physics education are necessary. For courses that are aimed at reaching out to students with little Physics background, the pedagogy needs to be considered carefully, especially when it is taught entirely in an online learning environment. This research investigated a fully online, inquiry-based course design aimed at motivating students to learn Physics and its impact on students' learning experiences at an Australian university. The research compared the learning experiences of students whose career trajectories are science-related and those who are not in order to assess its effectiveness in promoting Physics literacy. An online survey containing Likert-scale items as well as open questions elicited students' perceptions of the impact of the online course on their learning. The volunteer research participants were 59 undergraduates, where about two thirds of the participants were science students and one-third non-science students. The results showed that students were positive about the pedagogical structure and content in the online Physics course. Except for one item, there were no other statistically significant differences between science and non-science students' responses in the study, suggesting that the pedagogical design catered to the needs of both groups of students, an important element in promoting Physics literacy across a broad range of students.

Introduction

In most countries around the world, an essential outcome of school science education is the development of students who are scientifically literate. Scientifically literate individuals are able to use science knowledge and skills to understand articles pertaining to socioscientific issues in the media and engage in social conversations about ethical and moral issues in order to make informed choices of the way of life that are best suited to them (American Association for the Advancement of Science, 2000; Millar & Osborne, 1998; Office of the Chief Scientist, 2012; Shen, 1975). Developing scientifically literate students is also about preparing the next generation of scientists and engineers to study more advanced and specialised areas of science. Across the disciplines of science, it has been argued that it is impossible to achieve multidimensional scientific literacy in all scientific domains (Bybee, 1997; Hazen, 2002) and that it is possible to be highly literate and develop expertise in one area, even without being career-oriented. In school science however, most primary and junior secondary school curricula aim to develop students' general literacy across the principal science domains of biology, chemistry, Physics and earth and space science. In Australia, as in other countries, studies have consistently shown an enrolment trend away from Physics by students in pre-tertiary years (Lyons, 2006; Rodd, Reiss & Mujtaba, 2013; Victorian Auditor-General, 2012) which implies that the attainment of literacy in Physics is relatively low in post-secondary students. A reason for the low uptake of Physics is the perception of irrelevance and that the discipline is conceptually abstract and a difficult subject to learn (Chief Scientist, 2012; Williams, Stanisstreet, Spall, Boyes & Dickson, 2003). In higher (post-secondary) education, opportunities for students to learn more Physics should to be provided, such as in undergraduate introductory courses where the pedagogy aimed at reaching out to students with little Physics background has to be considered carefully to provide rigour at the same time motivation that will sustain the interest of the students. This research aims to investigate the pedagogical design of a fully online introductory Physics course and its impact on the learning experiences of students at an Australian university. In particular, the learning experiences of science and non-science students are compared to examine the extent of the impact of the course on these two groups of students in developing Physics literacy.

Theoretical Framework Underpinning the Research

Design of the Online Introductory Physics course *Everyday Physics*

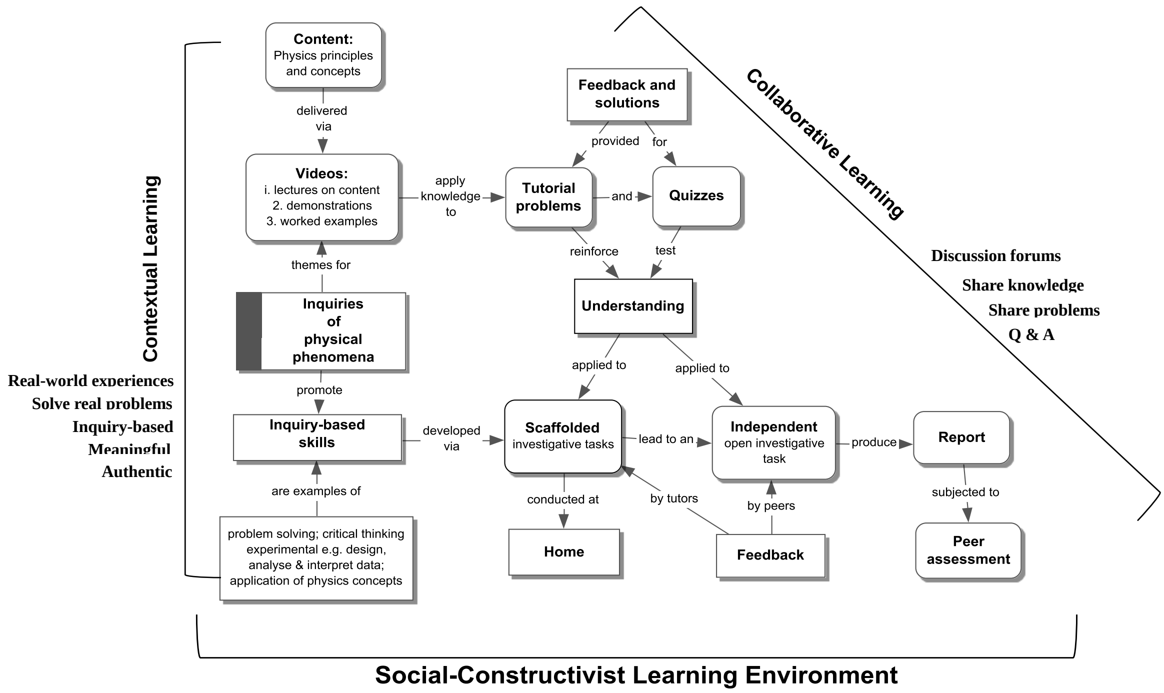

Figure 1. Theoretical framework for the online physics course *everyday physics*

Everyday Physics is a 12-week online introductory Physics course aimed at students who have not studied Physics in high school. Figure 1 shows the main components of the pedagogical design for the course and the theoretical underpinnings for its design, implementation and the research study.

Online learning is the access to learning experiences through the use of a technological platform, e.g. *Moodle* that allows for connectivity and flexibility to support varied interactions that promote learning (Moore, Dickson-Deane & Galyen, 2011). A major benefit of fully online courses is the increased access to courses and learning materials that enable students to learn at times that are suitably integrated into their daily routine and other responsibilities. This advantage was paramount in the decision on constructing the *Everyday Physics* course, which was designed in response to a demand among first and higher year students wanting to study an introductory Physics course but finding it hard to timetable and attend the face-to-face introductory course. The online course was also offered as an elective to students from other faculties, providing the opportunity for non-science students to develop their science literacy, particularly in Physics.

Communication within the course is primarily asynchronous with course materials uploaded onto the course site on *Moodle* and the relaying of messages through the announcement board and/or discussion forums. The social aspect of learning as one of the positive attributes of online learning has been widely emphasised in the literature (e.g. Anderson, 2004; Erdogan, 2016; Author 1 & Author, 2010; Swan, 2003; Zhan, Xu & Ye, 2011). For example, Swan (2003) found that asynchronous discussions were a significant factor in online learning success and that the social presence in an online environment correlated significantly with students' perceptions of satisfaction with and learning from online courses. The benefits as perceived by students in such an environment include a more equal and democratic atmosphere for learning than in traditional classroom discussions, particularly for shy students (Westbrooke, 2006). In addition, asynchronous collaborative learning environments are more conducive to deep learning than synchronously delivered courses as students have the time to self-reflect and think critically about the different perspectives offered by their peers to make judgements that value, support or oppose the different views (Fung, 2004; Stacey, 1999).

Supporters of online learning argue that this type of learning can lead to better learning outcomes. For instance, meta-analysis studies by Means, Toyama, Murphy, Bakia and Jones (2009) of 50 study effects found that students in online learning performed modestly better, on average, than those learning the same material in a face-to-face mode. The researchers found that the average effect size is small (about +.20; medium effect is usually +.40) but significant, in favour of online study conditions.

The pedagogical design of *Everyday Physics* is based on contextual and enquiry-based theories of learning. The course is aimed at providing students with meaningful learning experiences of Physics by situating learning within contexts that are familiar to them. This is done through the everyday applications of Physics in phenomena that the students observe around them. Using an inquiry approach to each phenomenon studied, each week a question that was the focus of the Physics concepts to be studied was asked. Inquiry-based learning is student-centred pedagogy, focusing on questioning, critical thinking and problem solving (Savery, 2006; Marshall, Horton, Igo & Switzer, 2009). Inquiry-based learning uses questions and problems to provide context but does not fit into a more restrictive inductive learning approach. An inquiry-based approach is learner-centred where students adopt more responsibility for their own learning as compared to a traditional transmissive, deductive approach, which has been widely criticized as a key reason for students' declining interest and enrolment in science (Davis, Petish & Smithey, 2006).

In general, inquiry learning is any pedagogical approach that begins with a challenge for which the required knowledge has not been previously provided. The variants of inquiry-based learning differ in the nature of the learner challenge and the type and degree of support provided by the teacher. At the heart of science inquiry-based learning is the idea that students engage in science using the methods and approaches similar to those that scientists use to carry out scientific investigations (Office of Chief Scientist, 2014; Minner, Levy & Century, 2010; Furtak, Seidel, Iverson & Briggs, 2012). In *Everyday Physics*, students are presented each week with a question within contexts that they are familiar with, for example: How does a streetlight work? What decides how fast a river flows? and How does a speed camera work?

A highly contextualised inquiry-based pedagogy motivates and engages students to learn as the learning activities and the problems to be the solved are authentic, relevant and situated within the students' everyday lives (Brown, Collins & Duguid, 1989; Lave & Wenger, 1991). The intended learning outcomes of the course are that students are able to (a) apply Physics principles to everyday phenomena (including solving problems mathematically) (b) develop investigative and analytical skills in experimentations (c) develop as an independent investigator of the physical principles behind phenomena of interest and (d) be aware of ethical and social issues in science, for example the issues surrounding nuclear power and the role Physics plays in the safety of everyday experiences such as the use of transportation and storage of nuclear materials. These are essential elements of being scientifically literate in Physics-related content and issues.

The Use of Instructional Videos

Everyday Physics makes extensive use of video instructions. Technology tools are sufficiently sophisticated for educators to construct instructional e-learning materials that resemble real-time teaching, for example the use of screencast software to capture screen display and annotations of subject matter while simultaneously recording voice-over explanations of concepts. Alternatively, as in the case of this study, live video recordings of the lecturer explaining Physics concepts and showing demonstrations are embedded into *Moodle* as instructional materials for the students to view. An advantage of video recordings is that teaching can be contextual and not confined to the lecture theatre. Video-based online learning is student-centred, allowing for greater access by students at a time and place of their own choosing. Choi and Johnson's (2005) study showed that there was a significant difference in students' motivation with respect to attention, between the video-based and traditional text-based instruction. They found that students' retention and motivation were enhanced using context-based videos in the online courses. Similarly, Chen's (2012) study on the use of video-based instructions showed that the interactive thematic videos fostered more engagement and motivation, enabling the students to acquire and remember more information. The students as a treatment group also obtained higher learning motivation and post-test scores than their peers in the control group.

The video lectures of *Everyday Physics* consist of three components. The first of these is a lecture style section where concepts and equations are presented to students. These videos show the lecturer and important points and equations are edited into the background of the frame. The second component is demonstrations. During these demonstrations concepts are put into practice. The third component is worked quantitative examples. These are recorded with a screen capture program. The solutions are handwritten with an accompanying voice over, showing students how to make use of equations to answer a variety of problems. The course enables students to take control of their own learning. For novice learners, they could view and re-view the videos as often as is required. The detailed solutions to the Physics problems in the tutorial tasks and quizzes scaffold their learning in an explicit manner to reduce cognitive load in the learning (Kalyuga, Renkl & Pass 2010; Sweller 1988). For students who have better prior knowledge and are able to attain understanding quickly, they could move on to the next problems without viewing all the solutions.

Practical Component

As Physics is an experimental science it is very important that investigative type experiments are included as part of the course. This is achieved by setting investigations that the students complete at home. During the course there are six at-home investigations to complete as well as a final report. For the final report, students choose their own topic to investigate that involves an experimental design. Each student's final report is assessed by five of their peers using criteria that are supplied to them. Hence each student receives feedback from five other students. The final mark for the independent report, which has to be submitted via *Turnitin* (software that reports on originality), is decided by the tutor.

Assessment

Each topic has approximately 10 tutorial problems. These are presented to the students as a pdf document. Accompanying these problems are solution videos. Students are encouraged to try the questions before watching these videos which show the step by step method on how to solve a problem. The students' understanding of the course material presented in the lectures and tutorial problems is assessed by online quizzes. There are four online quizzes through the course, one every third week. Students may attempt the questions in the quiz multiple times. There is a 50% penalty for the first two attempts at each part of a question and after that no penalty (and no marks). The parts within a question build on each other. Having the quiz set up this way allows students to continue attempting the earlier parts until they get it correct before moving onto subsequent parts. Once the quiz has closed, worked (videoed) solutions to the quiz problems are released. As most of the quiz questions involve calculations, the students are given randomly generated numbers to try and minimise the risk of students plagiarising each other's work. Students can view the answer to their specific problem by reviewing the quiz after it has closed.

Social-constructivist Learning Environment: Active and Interactive Learning

In the Physics online learning environment, social-constructivist learning theory underpins students' construction of knowledge, individually and socially. Social-constructivism draws on the cognitive (Piaget 1955; Bruner 1960) and social (Vygotsky 1962) theories of learning. It posits that the learner is an active participant in the construction of his/her own knowledge and that prior knowledge and a socially interactive environment influence this learning. In a technologically mediated environment where the interaction is potentially open and non-linear, learners self-direct his/her learning by actively analysing, evaluating and making decisions while manipulating the information (such as the Physics videos, tutorial problems) at hand in order to internalise and construct new knowledge or solve a problem. They seek assistance socially through the asynchronous communication medium of *Moodle* where they interact with the course lecturer, tutors and peers. In the social-constructivist learning environment of *Everyday Physics*, learning is scaffolded through the use of videos and additional resources (e.g. links to simulations), discussions in virtual forums and a peer-assessment task.

The course has a specific online peer-assessment activity where the students' final reports on their investigative tasks are read and provided with feedback by their peers. The value of learning from peers is well documented in the literature (e.g. Blumenfeld, Marx, Soloway & Krajcik, 1996; Havnes, 2008; Kear, 2004). Wen and Tsai (2008) who investigated an online peer-assessment activity found that the quality of group projects and participants' feedback improved, although a decrease in attitudes toward peer assessment was also found. Peer-learning is defined by Topping (2005) as the acquisition of knowledge and skills through the active help and support of people who are equal in status and of similar social grouping but who are not professional teachers. By helping each other to learn, those who help are learning themselves.

The online pedagogical approach to learning has its basis on Vygotsky's (1962) concept of the Zone of Proximal Development (ZPD). ZPD is described as the level of potential development and is the intermediary state between the things that the student is able to do and the things (s)he will be able to do with further development. ZPD is the point where learning takes place and where the learner is able to develop more advanced skills and further knowledge in a topic under the guidance of the educator/tutor and/or in collaboration with peers. Hence the ZPD encompasses cognitive structures that are still in the process of 'maturing' and which become fully developed through the mediating role of 'others' and activities that assist with the development of the individual's learning. Through careful design that considers students' prior knowledge, the educator can create learning activities that fall into the ZPD. For example, the scaffolded investigative tasks in *Everyday Physics* that the students undertake actively are aimed at developing their understanding of design and investigation in scientific experimental work in their ZPD, so that they can independently design an investigative task of a physical phenomenon of choice at the end of the course.

In the scaffolded tasks, appropriate questions are built into the activities to enable the students to engage in metacognition that draws on their existing knowledge to learn the new content. Throughout the course the level of scaffolding for the investigations is slowly reduced. For example in the first investigation students are told explicitly what to plot on each axis of their graphs and stepped through the process of calculating the gradient. By the fifth investigation students are expected to be able to work out what quantities need to go on each axis to produce a graph with the desired gradient. Similarly the tutorial problems and online quizzes that the students undertake on a weekly- and three-weekly basis respectively provide the opportunity to test their understanding and identify their ZPD needs. They seek further assistance to overcome these needs by interacting with the course lecturer, tutors and peers or view the video solutions to the tutorial and quiz problems.

Research Aim and Questions

The aim of the research was to investigate the impact of the pedagogical design of a fully online Physics course on students' learning experiences. The first research question for the study is: What impact does a fully online introductory Physics course that is based on contextual and inquiry-based pedagogy, has on students' learning experiences? The second research question is: What are the differences in the perceptions of science and non-science students of the course? For the first research question, in alignment with the theoretical framework outlined above, we investigated students' post-course perceptions on (i) the online learning materials in helping them learn (ii) peer-peer online collaboration (iii) tutor support (iv) active learning in the online course and (v) their beliefs and attitudes towards the online Physics course. For the second research question, the differences in learning experiences between science and non-science students were examined.

Method

Participants

The online introductory Physics course, based in a large, elite university in Australia, is opened to undergraduate students of science as well as students undertaking a general education elective course from other faculties. In the semester that this research was conducted, 214 students enrolled in the course but 190 completed the course.

Data Collection and Analysis

The research instrument was a questionnaire hosted on *SurveyMonkey* administered to the students at the end of the online course. University ethics approval was obtained prior to inviting students to participate in the questionnaire. The questionnaire consisted of close and open questions where both quantitative and qualitative data were gathered. A breakdown of the questionnaire according to the categories in the first research question is shown in Table 1. Quantitative questions made use of a 7-point Likert scale (1=strongly disagree, 7=strongly agree). On this scale, 4 is neutral and means of 5 and above were considered positive responses while means of 3 and below were considered negative. The items in the questionnaire were adapted from the learning surveys of Clayton (2011) and Author and Author 1 (2009) and validated by the course lecturer and tutors. To avoid conflict of interest and biasedness, the survey was administered by a researcher who did not teach in the course.

The quantitative data was analysed on SPSS. Means and standard deviations were obtained for the items. Each category of items was checked for the reliability of the responses by obtaining the Cronbach alpha value, with values greater than .7 considered as indicating good reliability of the scales. For easier viewing, the means and standard deviations (SD) in the result tables are arranged in descending order of mean value from the most positive to least positive responses for the items in each category. To answer research question two, independent sample t-tests were conducted to elicit differences in responses between science and non-science students. Qualitative data from the open responses were coded and categorised as themes that emerge and the percentage of the responses for each theme were calculated where appropriate.

Table 1. Breakdown of the questionnaire according to the research sub-questions

Research sub-question (topic)	**Quantitative (close questions)**	**Qualitative (open questions)**
(i) Presentation (ii) Online collaboration (iii) Tutor support (iv) Active learning (v) Attitudes and beliefs	5 items 7 items 5 items 7 items 9 items	• Why have you chosen this fully online Physics course to study for this semester? • Any other comments on display and formatting of online learning materials that helped with your learning? • Peer-assessment: Please elaborate on the type of assignment, what you had to do and how beneficial it was for you? • Any other comments about tutor assistance and interactions? • Any other comments about the online course?

Results and Discussion

Demographics

The 190 students who completed the course were invited to participate in the online questionnaire. While 76 students participated in the questionnaire, only 59 responses were considered valid. This represents about 31% return of the total cohort. As shown in Table 2, the number of males and females who participated was 52% and 48% respectively. Ninety-five percent of these students were 25 or below in age.

Table 2. Demographics of research participants (N=59)

Gender		**Age**			**Year of study**				
Male	Female	17-21	22-25	26+	1st	2nd	3rd	4th	Others
52 %	48 %	73 %	22 %	5 %	24 %	15 %	41 %	17 %	3 %

There was a spread in the students' year level of study with first (24%) and third year (41%) students making up about two-thirds of the student cohort. About two-thirds (68%, 40 students) of the participants were in science-based programs while 32% (19 students) were in non-science based degree programs (see Table 3). .

Table 3. Science and non-science degree programs of participants

Types of degree	**Examples of degrees**	**# of Students**	**%**
Science-based degrees	B/Science; MBBS/MD; B/Advanced Maths; B/Medical Science; B/Engineering; B/Computer science;	40	68
Non-science-based degrees	B/Arts; B/Commerce; B/Music; BCom/Law;	19	32
	Total	59	100

Reasons for Undertaking the Online Physics Course

Qualitative analysis of responses indicated four main reasons with respect to why the participants chose to do the fully online Physics course (see Table 4). About two thirds indicated 'convenience and flexibility' (33%) and 'interest and curiosity' (30%) as reasons for undertaking the course. The other two main reasons were to fulfil the general education course requirement (20%) and to prepare for GAMSAT* (12%) exam. Of the 19 non-science degree students, 38% indicated interest and relevance of the course as reasons for studying this course. Examples of quotes are:

> I chose this Physics course as a general education course. When I read the course outline, I found the content to be highly interesting because it is relevant to our everyday lives, as the course name suggests. I also thought the investigations would be interesting and fun to do, coming from a non-science background.

> Because i thought it would be a good course that not only taught us about the concept of Physics but also showed its significance in explaining real life events.

Table 4. Reasons for doing the online physics course

Category	Examples of responses	% of total responses
Convenience and flexibility	- More convenient for me, as I have to balance work and study - Less time spent travelling - Easier to fit in with my busy lifestyle work and uni- especially since I live so far away	33%
Interest and curiosity	- Never studied Physics and the course seems interesting and flexible - I have always been interested in how the things around us work and was motivated to taking an online course to learn it.	30%
To fulfil degree requirement	- To fullfil commerce degree requirement - General education requirements	20%
Prepare for GAMSAT	- To prepare for gamsat and to gain some Physics knowledge - As a way of learning Physics for GAMSAT	12%
Others	- No final exam	5%

Helpfulness of the Online Learning Materials to Students' Learning

As shown in Table 5, the participants were positive about the manner and format of presentation of the online learning materials in helping them learn, in particular they thought that the videos/podcasts were informative and concepts were clearly explained. Issues with navigation were indicated by seven students in the open responses, for example:

> The top right arrows to navigate through sections are really hard to find. It took me a couple of weeks to notice the tutorial solution videos. There are also too many layers of navigation in the left hand side, about 5 different menus. I think this could be designed better.

Independent sample t-test showed no significant differences in the responses between science and non-science students in this category of items.

Table 5. Means and SD for responses to 'online learning materials' items (Cronbach alpha = .798)

Statement	Mean	SD
Videos and podcasts were informative and concepts clearly explained	5.61	1.29
The graphics (photos, graphs, images) were appropriately used to help me understand the topic	5.43	1.29
The text front, colours and style used in the online learning materials fostered easy reading and listening, assisting with my understanding of concepts easily	5.30	1.41
The materials presented on Moodle for this course were motivating	5.18	1.24
The navigation of the site for information and resources was well designed and easy to use	5.16	1.55

* Graduate Admission Medical School Admission Tests

Peer Online Collaboration

Table 6. Means and SD for responses to ‘online collaboration’ items (Cronbach alpha = .895)

Statement	Mean	SD
I found that my online opinions were respected by other members in the course	5.16	1.08
The interactions among students on Moodle in the course were beneficial for my learning	5.00	1.75
Students participated actively in discussion forums	4.92	1.86
Students often provided feedback to each other on questions or activities undertaken	4.82	1.51
Students often asked each other for help with activities they were doing	4.59	1.67
Students communicated regularly with each other	4.32	1.92
Students often shared resources and information with each other	4.00	1.77

Table 6 shows that the students were positive about their online postings being respected by their peers (mean=5.16) and that the postings had been useful for their learning (mean=5.00). The students participated actively in the discussion forums (mean=4.92) and that students often provided feedback to each other on questions or activities undertaken (mean=4.82). They were more neutral on other aspects of online collaboration with peers such as the regularity of communication with each other (mean= 4.32), asking each other for help (mean=4.59) and sharing resources (mean=4.00). Analysis of the postings on the discussion forums indicated that most of the discussions were centred around asking the lecturer or their tutor about things they were unsure of in the required tasks or to further clarify something in the content videos. While the Moodle logs show that majority of the students read the forum postings, a smaller number of students (less than 50%) contributed to these discussions. The number of postings appears to increase during weeks where there were investigative tasks due or quizzes to be completed. Independent samples t-test showed no significant differences in the responses between science and non-science students in their perceptions of peer online collaboration.

The final report was a collaborative task that involved independent investigation of a problem. Each student’s work was assessed online by and provided with feedback from five peers. Examples of topics that the students chose to investigate were: Calculating the speed of light from microwaves; Effect of Temperature on Bounce Height of Ball; Elastic Constant of a Thera Band; Investigation of Physical Density and Refractive Index; Pendulum Motion in Time Keeping and The Influence of Club Face Angle in Determining the Distance Range of a Golf Ball.

The open question on the peer-assessment task and its benefits was answered by 45 students (76% of the participants). The majority of the responses (58%) were positive and the students valued the experience. For example:

> It was useful in that it gave feedback from multiple sources - not just one tutor.
>
> This was extremely beneficial as it allowed the reports to be reviewed from other people's perspectives. Peers were able to notice things that were missed by individuals looking at their own reports, which allowed each student report to be improved.
>
> I found the comments given by my peers very helpful, allowing me to further improve my report as they picked up errors that I did not realised. It was good to get feedback before actual assessment.

Six of the open responses (13%) indicated negative experiences with the peer-assessment task. For example:

> Read over the feedback my peers gave me, was pretty useless, did not give me feedback via the rubric, just some abstract ideas and thoughts.
>
> I felt like the effort I put in to my draft was wasted on the poor quality feedback I received.

Eleven of the non-science students responded to this open question, of which 55% (6 responses) were very positive about the usefulness of the peer-assessment activities. The other responses were neutral, merely stating what they had to do for the task.

Tutor Support

There were six tutors in the online course. As shown in Table 7, the students were generally positive about their tutors' support, with the majority indicating that the tutors' feedback was useful to identify the things that they did not understand (mean = 5.67), their tutors participated regularly in discussion forums (mean = 5.61) as well as responding promptly to their queries (mean = 5.46). The independent samples t-test showed no significant differences in the responses between science and non-science students in their perceptions of tutor support.

Table 7. Means and SD for responses to 'tutor support' items (Cronbach alpha = .888)

Statement	Mean	SD
The online feedback I received from my tutor helped me to identify the things I did not understand	5.67	1.42
My tutor participated regularly in discussion forums	5.61	1.62
My tutor responded promptly to my online queries	5.46	1.82
My tutor regularly sent me online feedback about my progress	4.61	1.73

A third of the participants (19 students) responded to the open question about tutor assistance. The vast majority were happy with their tutors' assistance and feedback. Some of the students were somewhat confused with whom they should be directing their questions to – the lecturer or their tutor. This is an area that could be clarified in future classes. There were only three somewhat negative responses, for example:

> I didn't find the feedback to the investigations too helpful. The feedback was very short and seemed to presume understanding by the student on the feedback…. but if I needed feedback because I got it wrong, if I don't understand in the first place, a 1-liner will not generally be that helpful.

Analysis of *Turnitin* data, however, showed that many students did not look at the feedback from their tutors, who provided on the *Turnitin* rubric detailed comments on their investigations and why they had lost marks. Less than half the students accessed this feedback, hence continued making the same mistakes in further investigations. This could explain the perceptions of students who thought that they were not given feedback.

Active Learning

Active learning is a crucial component of constructivist learning. The results (see Table 8) show that the students' perceptions of this were overall positive. The responses for the 'active learning' items explored have mean values of about 5 and above, indicating that there is reasonably strong agreement amongst the students that they were learning actively in the course. The students were learning actively by interacting with instructional materials, undertaking quizzes and posting messages where these online resources and activities are located within their ZPD to assist them to develop more advanced skills (e.g. critical thinking, reflective) and further knowledge related to everyday Physics. The students felt that they were in control of their learning (mean=5.47). In comparison with the other items, there appears to be a slightly smaller mean (4.98), for motivation to learn from the feedback responses from the online quizzes. This is because students do not get the feedback until after the quiz has closed (to reduce plagiarism). It would be more motivating if they received feedback while the quiz was still open.

Table 8. Means and SD for responses to 'active learning' items. Cronbach alpha = .935.

Statement	Mean	SD
I felt that I was in control of my learning as I reviewed the online material provided	5.47	1.74
Online quizzes helped me to reflect on concepts taught to better understand the topic	5.39	1.95
I had no problems accessing and going through the online materials on my own	5.29	1.85
Moodle enabled me to learn actively	5.29	1.63
Discussion by posting messages on discussion boards is effective for learning	5.22	1.59
I was motivated by the responses I received from the online quizzes	4.98	2.01

The perceptions of science and non-science students did not show any significant differences in the independent samples t-test in this category of items on 'active learning'.

Attitudes and Beliefs about Online Learning

The attitudes and beliefs of the students about online learning are mostly positive, as shown in Table 9. They were mildly agreeable in their beliefs about being able to learn more with online learning and that they were sufficiently challenged to learn in this online course (mean = 4.85 and 4.68 respectively). The students were, however, satisfied with and enjoyed the learning experience (mean = 5.41 and 5.37 respectively) and that they learnt a lot of Physics in the course (mean=5.58). They agreed quite strongly that online learning approaches can be an effective substitute for normal classroom approaches (mean=5.56) and that online learning is a better way of learning due to the flexibility in learning anywhere and anytime (mean=4.98). In comparing the attitudes and beliefs between science and non-science students, an independent samples t-test indicated that only one item (the slow responses to messages on discussion boards is disruptive to learning and students do not learn well) showed significant differences in the scores for science students (M=3.78, SD=1.97) and non-science students (M=5.05, SD=1.35); t(57)=2.55, p=.013. It is unclear why the non-science students indicated more strongly that asynchronous discussion was more disruptive to their learning. A possible explanation is that with a non-science background, they were more eager to receive feedback or see solutions to problem on the forums.

Table 9. Means and SD for responses to ‘attitudes and beliefs’ items (Cronbach alpha = .756)

Statement	Mean	SD
I was motivated and sufficiently independent to learn well in this online Physics course	5.68	1.12
I learned a lot about Physics from this online course	5.58	1.66
Online learning approaches can effectively substitute for normal classroom approaches	5.56	1.35
The inquiry-based (i.e. topic based on a question) style of presenting Physics online is a good way to learn about concepts of Physics	5.44	1.66
I am satisfied with my experiences of using Moodle and the online aspect of learning for this course	5.41	1.70
I enjoyed the online learning experiences in this course	5.37	1.71
Online learning is a better way of learning as one can learn from anywhere and anytime	4.98	1.53
I can learn more in online environments	4.85	1.66
I was challenged to learn in this completely online Physics course	4.68	1.61
The slow responses to messages on discussion boards is disruptive to learning and students do not learn well	4.19	1.88

The majority of the student participants agreed that the inquiry-based style of presenting the Physics course was a good way to learn about concepts of Physics (mean=5.44). The endorsement of an inquiry-based approach to introductory Physics education was shown in the responses to the final open question that asked for general comments of the course. Nearly 80% (11 students) of the 14 students who responded to this question commented positively on the structure and content e.g. “better than most hands-on courses” and “I loved this course, at first was overwhelmed by the Physics, but later was invigorated as I found the content interesting and challenging”. Further quotes from a science and non-science student are shown below:

> Overall, I was very satisfied with this course. It provided me with a flexible method to learn the content and an enjoyable first experience with an online course. The information, lecture videos, tutorial questions, etc. was sufficient to grant solid understanding of what was required of the course, and the links provided for 'Additional Info' was useful from time to time as well. Probably some more videos on solving tutorial problems. But it was very well structured and nicely balanced (in terms of assessment variety - Practical Investigations, Weekly Quizzes, Peer Review and Final Report). (science student)

> Being a person from a non-science background, I had fun and enjoyed learning the Physics concepts. I also found the tutors were very helpful as they attended to queries very promptly. However, I did find the quizzes difficult at times as it required a lot of problem solving skills that truly tested your understanding of the taught concepts. I found that the video lectures did not sufficiently cover some of the concepts that were brought forward in the quizzes. Nevertheless, it was a great course. (non-science student)

The largely positive responses of the research participants in the study suggest that the inquiry-based learning pedagogy that is situated within contexts that students see as relevant and relatable to their everyday lives was effective in motivating students from across faculties to learn in this online course. The results concord with those in other studies, for example, Sun and Looi (2013) have shown that carefully designed system that delivered a web-based inquiry learning environment could impact positively on students' conceptual, understanding, collaboration, modelling skills and self-reflective skills in science learning.

Other evidence that indicate that the online Physics course and its pedagogical features were appropriate for a range of students and successful in its implementation include,

- the relatively low dropout rate of 11% in the course (214 enrolled, 190 completed)
- 43% females and 57% males enrolled in the course, representing a relatively high number of females for a Physics course
- the enrolled students were from a range of degree programs and faculties, an important step in encouraging more interest in Physics education and increasing scientific literacy amongst non-science students
- the overall positive responses to the learning experiences of the students and the overall lack of statistically significantly different responses to questionnaire items between science and non-science students, indicating that the online course catered to the needs of both groups of students
- the failure rate was 7% which was relatively lower than a similar face-to-face introductory Physics course and
- in the reiteration of the course in the following two semesters, the enrolment increased substantially to around 250 students.

There were however, issues that arose. One of them was plagiarism in the final report, where five students had to be interviewed about their work. Another issue was with the last investigative task on astronomy which required students to actually look at stars. Bad weather and late sunset meant that there were not many nights they could actually view the stars to gather the data. A compromise was made where extension time for this task was given and the best 5 of the 6 investigations were taken for their final mark. In the next reiteration of the course, this task was replaced with an electromagnetic simulation task.

Conclusion

The research shows that a fully online course provided the flexibility and opportunity for students from different faculties to undertake an introductory Physics course. The framework underpinning the design of the course and the layers of scaffolding within the structure of the course benefitted both science and non-science students, which is important to promote Physics literacy amongst a broad range of students. The results showed that students were positive about the pedagogical structure and content in the online Physics course. Except for one item, there were no other significant differences between science and non-science students' responses in the study, suggesting that the pedagogical design (contextual, relevant and inquiry-based), catered to the needs of both groups of students.

A limitation of the study is that the study sample size was relatively small to allow for generalisation across similarly designed online courses. As the course gets reiterated, more research in its sustainability with a focus on the learning outcomes (e.g. products created), including testing under examination. Another aspect for investigation with respect to the home-based Physics experiments is to integrate virtual Physics laboratory simulations into the pedagogical design as an alternative or a supplement to traditional experimentations. While Darrah, Humbert, Finstein, Simon and Hopkins (2014) have shown that virtual laboratories are as effective as traditional hands-on Physics laboratories, the immersion of virtual laboratories in a fully online Physics course needs to be researched to examine if learning experiences are richer that lead to better learning outcomes. An advantage of virtual experimentation is that difficult to measure or gather data could be alleviated and it does not restrict hands-on investigations to the use of only simple and less sophisticated scientific equipment.

In summary, promoting scientific literacy in undergraduate students is important for their future participation as citizens in debates and decision-making about issues that affect their lives. As indicated in the introductory paragraph of this paper, among the science disciplines, Physics is generally the less popular subject chosen by students at the school and university levels. However, a well-designed introductory Physics course as described in this paper provides the motivation for students from cross-faculties to learn more Physics concepts. The motivating features include *relevance* i.e. inquiry that relates to their everyday lives, *challenging* i.e. there is a need to solve problems, *self-directing* i.e. able to view content videos as frequently as required as well as pace the learning according to the students' capability and availability and *collaborative* i.e. socially construct new knowledge.

References

American Association for the Advancement of Science (2000). *Designs for science literacy.* Washington, DC: AAAS.

Anderson, T. (2004). Towards a theory of online learning. In T. Anderson & F. Elloumi (Eds), *Theory and practice of online learning* (pp. 33-60). Canada: Athabasca University Press.

Author & Author 1. (2009).

Author 1 & Author (2010).

Blumenfeld, P. C., Marx, R. W., Soloway, E., & Krajcik, J. (1996). Learning with peers: From small group cooperation to collaborative communities. *Educational Researcher, 25*(8), 37-40.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Bruner, J. (1960). *The process of education.* Cambridge, MA: Harvard University Press.

Bybee, R. (1997). *Achieving scientific literacy: From purposes to practices*. Portsmouth, NH: Heinemann.

Chen, Y. T. (2012). The effect of thematic video-based instruction on learning and motivation in e-learning. *International Journal of Physical Sciences, 7*(6), 957-965.

Choi, H. J., & Johnson, S. D. (2005). The effect of context-based video instruction on learning and motivation in online courses. *The American Journal of Distance Education, 19*(4), 215-227.

Clayton, J. (2011). Initial findings from the implementation of an online learning environment survey. *International Journal of Cyber Society and Education, 4*(2), 127-138.

Darrah, M., Humbert, R., Finstein, J., Simon, M., & Hopkins, J. (2014). Are virtual labs as effective as hands-on labs for undergraduate Physics? A comparative study at two major universities. *Journal of Science Education and Technology, 23*(6), 803-814.

Davis, E., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research, 76*(4), 607.

Erdogan, N. (2016). Communities of practice in online learning environments: A sociocultural perspective of science education. *International Journal of Education in Mathematics, Science and Technology, 4*(3), 246-257.

Fung, Y.H. (2004). Collaborative online learning: Interaction patterns and limiting factors." *Open Learning, 19*(2), 54-72.

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and Quasi-Experimental Studies of Inquiry-Based Science Teaching: A Meta-Analysis. *Review of Educational Research, 82*(3), 300-329.

Havnes, A. (2008). Peer-mediated learning beyond the curriculum. *Studies in Higher Education, 33*(2), 193-204.

Hazen, R. (2002). *Why Should You Be Scientifically Literate*? Retrieved September 30, 2015 from http://www.actionbioscience.org/education/hazen.html.

Kalyuga, S., Renkl, A., & Pass, F. (2010). Facilitating flexible problem solving: A cognitive load perspective. *Educational Psychology Review, 22*(2), 175-186.

Kear, K. (2004). Peer learning using asynchronous discussion systems in distance education. *Open Learning: The Journal of Open, Distance and e-Learning, 19*(2), 151-164.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Lyons, T. (2006). The puzzle of falling enrolments in Physics and chemistry courses: Putting some pieces together. *Research in Science Education, 36*(3), 285–311.

Marshall, J. C., Horton, R., Igo, B. L., & Switzer, D. M. (2009). K-12 science and mathematics teachers' beliefs about and use of inquiry in the classroom. *International Journal of Science and Mathematics Education, 7*(3), 575-596.

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2009). *Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies*. Washington, D.C.: US Department of Education.

Millar, R., & Osborne, J. (Eds). (1998). *Beyond 2000: Science education for the future.* London: King's College London, School of Education.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teachin, 47*(4), 474-496.

Moore, J. L., Dickson-Deane, C., & Galyen, K. (2011). e-Learning, online learning, and distance learning environments: Are they the same? *The Internet and Higher Education, 14*(2), 129-135.

Office of the Chief Scientist. (2012). *Mathematics, Engineering and Science in the National Interest*. Australian Government: Canberra.

Office of the Chief Scientist. (2014). *Science, technology, engineering and mathematics: Australia's future*. Australian Government: Canberra.

Piaget, J. (1955). *The construction of reality in the child.* London: Routledge Keegan Paul.

Rodd, M., Reiss M. & Mujtaba, T. (2013). Undergraduates talk about their choice to study Physics at university: what was key to their participation? *Research in Science & Technological Education, 31*(2), 153-167.

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-based Learning*, *1*(1), 9-20.

Shen, S.P. (1975). Science literacy and the public understanding of science. In S.B. Day (Ed.), *Communication of Scientific Information,* (pp. 44-52). Karger: Basel.

Stacey, E. (1999). Collaborative learning in an online environment. *Journal of Distance Education, 14*(2), 14-33.

Sun, D., & Looi, C. K. (2013). Designing a web-based science learning environment for model-based collaborative inquiry. *Journal of Science Education and Technology*, *22*(1), 73-89.

Swan, K. (2003). Developing social presence in online course discussions. In S. Naidu (Ed.), *Learning and teaching with technology: Principles and practices* (pp. 147-164). UK: Kogan Page Ltd.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, *12*(2), 257-285.

Topping, K. J. (2005). Trends in peer learning. *Educational Psychology: An International Journal of Experimental Educational Psychology, 25*(6), 631-645.

Victorian Auditor-General. (2012). *Science and Mathematics participation rates and initiatives*. Melbourne, Victoria: Victorian Government.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wen, M. L., & Tsai, C. C. (2008). Online peer assessment in an inservice science and mathematics teacher education course. *Teaching in Higher Education, 13*(1), 55-67.

Westbrook, V. (2006). The Virtual Learning Future. *Teaching in Higher Education, 11*(4), 471-482.

Williams, C., Stanisstreet, M., Spall, K., Boyes, E., & Dickson, D. (2003). Why aren't secondary students interested in Physics?. *Physics Education, 38*(4), 324.

Zhan, Z., Xu, F., & Ye, H. (2011). Effects of an online learning community on active and reflective learners' learning performance and attitudes in a face-to-face undergraduate course. *Computers and Education, 56*(4), 961-968.

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Improving the Pedagogical Content Knowledge (PCK) among Cycle 3 In-Service Chemistry Teachers Attending the Training Program at the Faculty of Education, Lebanese University

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Abstract

The purpose of this study was to explore to what extent the in-service chemistry teachers' improved their PCK after attending the training program at the Faculty of Education. The research questions were: 1. How do in-service teachers' personal perceptions about the teaching/learning process change after attending the training course at the Faculty of Education? 2. How do in-service chemistry teachers' beliefs about the nature of science and scientific literacy change after attending the training course at the Faculty of Education? 3. Do in-service chemistry teachers make use of the newly acquired skills and knowledge about teaching at the end of the training program? Results indicated that teachers' beliefs about teaching and learning have changed away from the behaviorist towards more constructivist beliefs. Their conception of the nature of science has slightly inclined toward more "science as a way of knowing" and the "interaction of science with technology and society". Finally, their teaching practices have developed toward more use of more active teaching strategies. Finally recommendations were made to enhance the development and improvement of PCK for both pre-service and in-service teachers.

Introduction

The Lebanese Ministry of Education and Higher Education (MEHE) cooperates with the Faculty of Education at the Lebanese University in training in-service teachers. To become public tenured teachers, in-service contractual teachers should pass the civic service exam and then should attend and pass a training program at the Faculty of Education, Lebanese University. In 2012, a group of more than 1200 in-service cycle 3 contractual teachers from all over Lebanon, of which 116 were chemistry teachers, were admitted to the Faculty of Education to pursue a training program in order to be tenured as public school teachers. A special training program was prepared for those in-service teachers aiming at helping them acquire the knowledge and skills required to deliver high-quality science teaching.

As instructors at the Faculty of Education and engaged in the training of chemistry teachers, we noticed that most of the in-service chemistry teachers focused in their teaching mainly on transmitting the science content in a traditional way. This is not surprising, since all these teachers hold a B.S in Chemistry or Biochemistry from the Faculty of Science and most of them did not enroll in any professional training course before. They have no idea about diverse teaching strategies nor relevant assessment procedures. Kind (2009) noted that the possession of a good Bachelor's degree in a science subject is not a *de facto* guarantee that someone will teach that subject effectively. The Office for Standards in Education (Ofsted) reported that with the extensive subject knowledge of most secondary science teachers much teaching paid scant regard to what and how pupils were learning, teachers simply passed on information without any expectation of pupils' direct engagement in the process (Ofsted, 2008, p. 17). Bucat (2005) also stated that there is a vast difference between knowing about a topic and knowledge about the teaching and learning of that topic.

It has been shown that student achievement has improved when teachers have strong content background and pedagogical knowledge (NSTA, 2004). It is the teacher's ability to transform his or her subject matter knowledge to pedagogical knowledge that is crucial to student achievement. This transformation is generally known as pedagogical content knowledge (PCK). Shulman (1987) defined PCK as "a special amalgam of content and pedagogy that is uniquely the province of teachers". He added: "It represents the blending of content and pedagogy into an understanding of 'how' particular topics, problems, and issues are organized, represented, and adapted to the diverse interests and abilities of learners and presented for instruction"

(Shulman, 1987, p. 8). He argued that teachers need a large spectrum of rather different competencies. In teacher education programs, teachers are usually taught content knowledge and pedagogical knowledge and the link between the two kinds of knowledge is usually missing. Shulman believed that this kind of knowledge, the PCK, is the major key to successful teaching. Linking competencies provided by the content domain and competencies from various other disciplines, especially pedagogy and psychology is at the heart of the conception of science education (Duit, 2007). According to Chiappetta and Koballa (2010), "PCK fuses the 'what' and the 'how' of instruction in a way that facilitates learning" (p.33).

PCK Components

Shulman (1986) proposed a general description of PCK to include three components: (1) knowledge of topics regularly taught in one's subject area, (2) knowledge of forms of representation of those ideas, and (3) knowledge of students' understanding of the topics. Subsequent researchers expanded PCK components. Grossmann (1990), for example, clarified four components: (1) conceptions of purpose for teaching subject matter, (2) knowledge of students understanding, (3) curricular knowledge, and (4) knowledge of instructional strategies. Tamir (1988) extended Shulman's clarification to include knowledge of evaluation. Magnusson, Krajcik, and Borko (1999) conceptualized PCK for science teaching as consisting of five components: (1) orientations toward science teaching, (2) science curriculum knowledge, (3) knowledge of the students, (4) assessment, and (5) instructional strategies.

The traditional separation of content and pedagogy in science preparation programs has lead Veal and Makinster (1999) to develop two PCK taxonomies that can serve as models for secondary science teachers' preparation: General taxonomy of PCK and taxonomy of PCK attributes. The General Taxonomy of PCK was organized hierarchically from the broadest conception 'general PCK' to a more specific 'Domain PCK' to the most specific 'topic specific PCK'. The Taxonomy of PCK attributes has ten attributes that are inter-related. 'Content knowledge' and 'knowledge of students' are two attributes that should be developed before the other eight attributes are integrated into a coherent manner. The eight attributes include: Content, environment, nature of science, assessment, pedagogy, curriculum, socioculturalism and classroom management (Veal & Makinster, 1999).

Van Driel et al. (1998) defined craft knowledge as an "integrated knowledge which represents teachers' accumulated wisdom with respect to their teaching practice" (p. 674). This definition is restricted to types of knowledge which actually guide the teachers' behavior during classroom practice, thus PCK is a specific form and an essential component of craft knowledge. They indicated that pre-service teachers had inadequate content knowledge and PCK and could not use teaching methods effectively and concluded that without a strong PCK, science teachers are said to have little knowledge of potential student's problems and specific preconceptions and have difficulties selecting appropriate representation of subject matter (van Driel et al., 1998). Van Driel et al. (2002) also investigated the development of pedagogical content knowledge (PCK) within a group of 12 pre-service chemistry teachers. They found that classroom experience had the strongest impact on PCK development. These experiences include activities and events in classroom teaching which also positively affected the knowledge of representation and teaching strategies among the pre-service teachers.

Teaching and Learning Conceptions

Generally there are two major conceptions of teaching: The traditional approach and the constructivist approach. The traditional approach is a teacher-centered approach characterized by the direct transmission of knowledge from the teacher to the passive, receivers of knowledge students. This teacher-centered method of teaching assumes that all students have the same level of background knowledge in the subject matter and are able to absorb the material at the same pace (Lord, 1999). On the other hand, in the constructivist approach, students are actively involved in the learning process and the teacher guides them in constructing their own knowledge. Learner-centered methods allow students the opportunity to take responsibility for their learning by being actively involved in the learning process rather than simply passively receiving information from a lecture (Slunt & Giancario, 2004).

The teaching and learning processes are affected by many variables like epistemological beliefs, and teaching and learning conceptions. Epistemological beliefs express the beliefs on the nature of knowledge and gaining knowledge (Aypay, 2010). Chan (2004) reported there exists a relationship between epistemological beliefs held by teacher education students and their conceptions about teaching and learning. Aypay (2010) investigated the relationship among the teaching-learning conceptions and epistemological beliefs of student teachers. He concluded that: “Student teachers’ epistemological beliefs and conceptions of teaching and learning are viewed as important since they will influence their behavior in classroom and determine their teaching strategies” (p. 2600). Teachers’ teaching/learning conceptions were found to have an impact on students’ conceptions and learning strategies (Igwebuike et al, 2013). Donche et al (2007) indicated clear relationships between teachers’ conceptions of learning and teaching and students’ learning strategies. They found that how teachers think about learning and teaching is associated with how their students learn and consequently have a differential impact on different learning strategies.

Nature of Science and Scientific Literacy

The phrase “nature of science” typically refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). Philosophers of science, historians of science, sociologists of science, scientists, and science educators disagree on a specific definition for NOS. The NOS has been defined in many ways throughout the decades. The 1907 report of the Central Association of Science and Mathematics Teachers emphasized in the definition of NOS on the scientific method and the processes of science (Lederman, 1992). However, Lederman and Zeidler (1987) referred to the values and beliefs inherent in scientific knowledge and its development. This lack of consensus is not surprising given the multifaceted and complex nature of the scientific endeavor.

Like scientific knowledge, conceptions of NOS are dynamic and have changed throughout the development of science and systematic thinking about science (Abd-El-Khalick & Lederman, 2000a). More importantly, for purposes of teaching and learning about NOS at the precollege level, they stressed that for science teachers to be able to convey adequate NOS conceptions to their students, they should themselves possess informed conceptions of the scientific enterprise. Abd-El-Khalick and Lederman (2000b) advocated that science teachers need to have more than a rudimentary or superficial knowledge and understanding of various NOS aspects in order to be able to effectively teach NOS to K-12 students. Teachers need to know a wide range of related examples, explanations, demonstrations, and historical episodes. They should be able to comfortably discourse about various NOS aspects, contextualize their NOS teaching with some examples or ‘stories’ from HOS, and design science-based activities to render the target NOS aspects accessible and understandable to K-12 students.

Traditionally, science content primarily denotes science concepts and principles. However, recent views of scientific literacy claim that also science processes, views of the nature of science, and views of the relevance of science in daily life and society should be given substantial attention in science instruction (Bybee, 1997 as cited in Duit, 2007). Assessing beliefs on various dimensions of science education has become an important research topic in the field of science education. Amongst these dimensions, the assessment of teachers’ beliefs regarding the nature of science (NOS) has been the focus of attention in the last two decades with the assumption that teachers’ beliefs about the subject matter they teach exert a powerful influence on their instructional practice (Shulman, 1986).

Researchers argue that NOS can be seen as a part of subject matter knowledge (SMK). Mihladiz and Dogan (2011) conducted a research to determine the status of pre-service teachers’ subject matter knowledge of the nature of science by investigating in which contents they were inadequate and/or they have naïve view about the NOS. They concluded that improvement is needed and teachers should be educated about philosophy, history, sociology and psychology of science.

Project 2061 (AAAS 1989) defined a scientifically literate person as one who is: “Aware that science, math, and technology are independent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes” (AAAS, 1989, p.4). Holbrook and Rannikmae (2009), recognized two points of view regarding the meaning of scientific literacy: a) those that advocate a central role for the knowledge of science; and b) those who see scientific literacy referring to a society usefulness.

Recently, Duschl, Schweingruber, and Shouse (2007) argued that a long-standing demand for a better scientifically trained workforce persist, while evidence mounts that scientific literacy is far from what it could or should be. They proposed a working model consisting of four interrelated strands of scientific proficiency that lay out broad learning goals for students. They address the knowledge and reasoning skills that students must eventually acquire to be considered fully proficient in science. They claimed that students who are proficient in science (p. 36):

1. know, use, and interpret scientific explanations of the natural world;
2. generate and evaluate scientific evidence and explanations;
3. understand the nature and development of scientific knowledge; and
4. participate productively in scientific practices and discourse.

Chiapetta *et al.* (1991) proposed a scientific literacy framework and identified the four aspects that seem to permeate all definitions of scientific literacy: 1) the knowledge of science, 2) the investigative nature of science, 3) science as a way of thinking, and 4) the interaction of science, technology and society (STS). BouJaoude (2002) adopted these four aspects to investigate the balance of scientific literacy themes in the Lebanese science curriculum. Results showed that the Lebanese curriculum emphasizes the knowledge of science, the investigative nature of science, and the interactions of science technology and society, but neglects 'science as a way of knowing'. These four aspects of science were used in this study to investigate the teachers' understanding of the nature of science and scientific literacy. The components of the four aspects appear in Table 1.

Table 1. Aspects of scientific literacy

Aspect	Components
The knowledge of science (Aspect 1)	• Facts, concepts, principles, laws, hypotheses, theories, and models of science
The investigative nature of science (Aspect 2)	• Using methods and process of science such as observation, measuring, classifying, inferring, recording and analyzing data, communicating using a variety of means such as, writing, speaking, using graphs, tables, and charts, making calculations, and experimenting • Emphasis on hands-on minds-on science
Science as a way of knowing (Aspect 3)	• Emphasis on thinking, reasoning, and reflection in the construction of scientific knowledge and the work of scientists • Empirical nature in science • Ensuring objectivity of science • Use of assumptions in science • Inductive and deductive reasoning • Cause and effect relationships • Relationship between evidence and proof • Role of self-examination in science • Description of how scientists experiment
Interaction of science, technology, and society (Aspect 4)	• Impact of science on society • Inter-relationships between science, society, and technology • Careers • Science-related social issues • Personal use of science to make everyday decisions, solve everyday problems, and improve one's life • Science related moral and ethical issues

PCK components related to the present research

In this research, and because of constraints to measure some of the aforementioned PCK components, we assumed that if teachers develop their understanding of the nature of science (NOS) and scientific literacy and if they can relate the topic they are teaching to everyday life, then they have improved their content knowledge. It was also assumed that if teachers improve their beliefs regarding the teaching/learning process and if they can use a variety of strategies in their teaching, then they have improved their pedagogical knowledge. The integration of improvements in both content knowledge and pedagogical knowledge is assumed as improvement in PCK. The suggested PCK components for this research appears in figure 1.

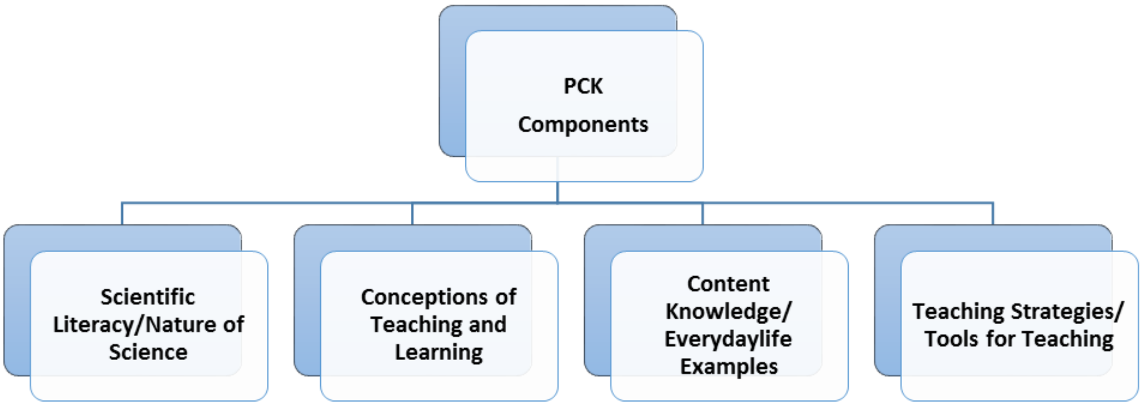


Figure 1. PCK components used in this research

Purpose of the Study

It is agreed that if teachers' PCK expands, both in pedagogy and content, their ability to impact students' learning increases. Accordingly, the teachers' training programs should emphasize developing teachers' PCK. In their review of studies related to PCK in the context of science teacher education, Aydin and Boz (2012) found that among the twenty eight studies, only three studies focused on determining in-service teachers' PCK. Since studies mainly focused on pre-service teachers' PCK, the purpose of this study is to explore to what extent the in-service chemistry teachers' improved their PCK after attending the training program at the Faculty of Education. The main research questions investigated were:

1. How do in-service teachers' personal perceptions about the teaching/learning process change after attending the training course at the Faculty of Education?
2. How do in-service chemistry teachers' beliefs about the nature of science and scientific literacy change after attending the training course at the Faculty of Education?
3. Do in-service chemistry teachers make use of the newly acquired skills and knowledge about teaching at the end of the training program?

Methodology

This study is a descriptive one and of an exploratory nature. As the aim of this study was to explore in-service teachers' PCK improvement after attending the training program, and not to emphasize causality or generalize results, a qualitative approach is preferable (Johnson & Christensen, 2008). For the purposes of this study a mixed design with more qualitative data than quantitative ones was used.

Participants

A total of 116 in-service chemistry teachers, who attended the training program at the Faculty of Education, participated in this research. Thirty were males (26%) and 86 were females (74%), the English teachers were 42 (36%) and the French teachers were 74 (64%). Participants were: Forty two (36%) from the North and Akkar, 6 (5%) from Beirut, 28 (24%) from Bekaa, 16 (14%) from Mount Lebanon, and 24 (21%) from The South and Nabatiyeh. All the French in-service teachers were graduates from the Lebanese University while only almost half of the English in-service teachers graduated from the Lebanese University. The number of years of teaching experience ranged from 2 to 22 years with an average of 9.33 years.

Data Collection Tools

In order to answer the research questions stated above, qualitative and quantitative data were collected using different data tools: pre- and post-questionnaires, classroom observations, and achievement test scores.

The pre- questionnaire questions aimed to collect trainees' personal and professional profile. Part of the questions were used to collect personal data such as: Name, phone number, e-mail address, and education. Other questions aimed to collect data related to the trainees previous experiences such that if they have participated in a training program before and if they have access to the Internet. The rest of the questions were intended to collect data regarding their pre- PCK knowledge such as: their knowledge of the newest trends in science teaching, teaching strategies they consider most effective for teaching science, and their beliefs related to the teaching/learning process and the nature of science.

The Post-questionnaire questions aimed to collect data related to teachers' ideas and beliefs regarding the teaching/learning process and the nature of science.

Drawings were used in the pre- and post- questionnaires to collect data related to the teachers' beliefs regarding teaching and learning by asking them to draw their mental image of what they think of the teaching/learning process and to write an explanation of their drawings to aid in the analysis of the drawings.

Classroom observations were another data collection tools. Participant observers observed trainee teachers twice, one time during the training program and the second at its end. They filled an observation log for every teacher composed of eight criteria and wrote a brief report concerning the strong points, points that need improvement and suggestions for the future (Figure 2).

Classroom observation log

	Criteria	Highest score
1	Lesson plan	15
2	Content knowledge	20
3	Everyday life examples	10
4	Teaching strategies	15
5	Teaching tools	5
6	Teacher personality	10
7	Language of instruction	5
8	Student-teacher interaction	20
Total		100

General assessment
Points to be improved
Suggestions

Figure 2. Classroom observation log

Scores on four criteria of the observation log and the participant observers' field notes and comments were used as data in this research. Scores on 'content knowledge' and 'examples from everyday life' were used as a measure of teachers' subject knowledge. The 'content knowledge' score was related to the teacher's knowledge of the specific content of the lesson taught at the time of observation and the score on 'examples from everyday life' reflected teachers' chemistry knowledge as it is assumed that good teachers can relate everyday life examples to the chemistry content taught. The sum of the scores on 'teaching strategies' and 'teaching tools' was assumed to measure improvement in the use of the teaching strategies.

Achievement test scores of the two courses: 'Methodology of teaching chemistry' and 'practicum' were also used as quantitative data to measure improvement in PCK.

Description of the Training Program

The goals of the training program held at the Faculty of Education, Lebanese University for the 1200 in-service teachers, were mainly to update their pedagogical and teaching skills. Their attendance and completion of the program were the two conditions to become tenured public teachers. The training spanned over 24 weeks, where in-service teachers attended courses two days per week, six hours per day. The training program, as appear in figure 3, is organized around six modules: General Education; Educational Psychology; Chemistry Teaching Methodology; Practicum; Educational Technology; and Language of Instruction (French/English).

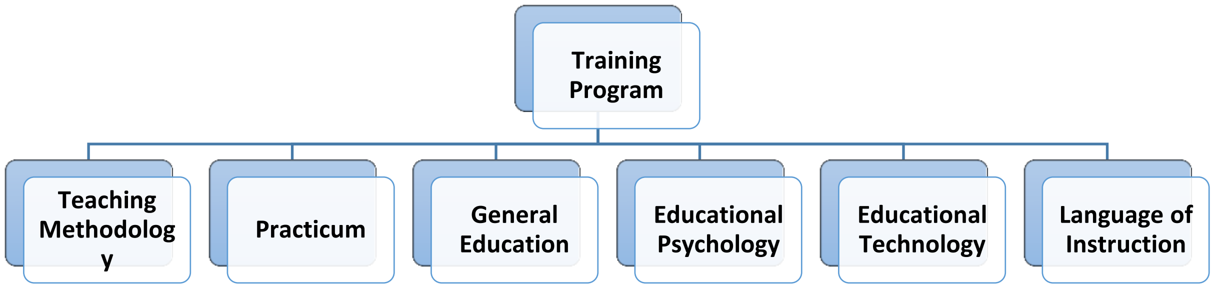


Figure 3. The training program

The two core courses are "Teaching Methodology" and "Practicum", the first deals with the theoretical knowledge needed for the teaching of chemistry and it includes the following themes: Learning theories, lesson planning, science literacy, conceptual change and common students' alternative conceptions, teaching strategies, the chemistry curriculum and students' evaluation and assessment. The second course deals with the practical knowledge of teaching chemistry at the intermediate level (cycle 3).

It is composed of two components, one is done in the Faculty where issues related to teaching from lesson planning to actual teaching are discussed and the other is practice teaching in the schools where they are supervised by participant observers who observed every teacher twice and filled the observation log at the end of the second observation. The other four courses were: General Education, where teachers were introduced to the fundamentals of education stressing classroom management, curriculum and evaluation, Educational Psychology, stressing topics related to child development and learning theories, Educational Technology, stressing computer skills and use of the active board and ActiveInspire software to prepare lessons, and Language of Instruction to upgrade teachers' English or French language as it is the language of science instruction in the schools.

Results

Results related to Research Question 1 (RQ1)

RQ1 stated: How do trainee teachers' personal perceptions about the teaching/learning process change after attending the training course at the Faculty of Education?

To answer this question teachers' pre- and post- drawings of their mental images of the learning-teaching process and their comments on the drawings, were analyzed and compared based on the following criteria:

1. Teaching practices (e.g. frontal teaching, group work…)
2. Teacher face expression (e.g. no expression, happy face, smiling…)
3. Class management (e.g. how students are seated)
4. Use of technology in instruction (e.g. computer, LCD projector, screen…)
5. Indoor/outdoor instruction (e.g. classroom, laboratory, outdoor activity…)
6. Captions (e.g. teacher's talk, students' talk)
7. Use of philosophical metaphors displaying the role of a teacher (e.g. burning candle, watering plants…)

In the pre-questionnaire, many teachers left blank the box addressed to the drawing of the mental image of the learning-teaching process. Teachers who drew pictures of their mental image, their drawings were very simple and represented the teacher in the classical cliché as standing in the middle of the class with the chalk and the board as the only teaching tools, while students are small in size sitting in rows with no facial expressions. This shows that these teachers held a traditional behavioristic view about teaching and learning where the teacher is in charge of the teaching/learning process and that knowledge is transmitted from the teacher to his passive students through the only chalk-and-talk instruction. Teachers also drew learning as happening in an isolated place where students gain knowledge irrelevant to the outside world.

In the post-questionnaire, more teachers drew their mental image of the teaching/learning process. Although few drawings representing the traditional teaching remained, most teachers presented richer drawings. These drawings reflected an emphasis on the learning environment, by showing a smiling teacher whose role is to create an engaging and a comfortable environment to students. Drawings also represented the teacher guiding the students while they are working in the laboratory, working in groups, or learning outside the classroom in a field trip. In addition, they emphasized the use of more active teaching methods mainly the use of group work and technology. Examples of pre and post drawings appear in figures 4, 5, and 6.

Comparing the teachers' written explanations showed that in the post-questionnaire they used richer vocabulary to explain their drawings as one can read now about developing creativity, critical thinking and imagination, terms that were missing in the pre-questionnaire. They started to think that one of the objectives in science education is to prepare scientifically literate future citizens as some teachers admitted the role of the teacher as the bridge between the learners and their needs to know about the society. They also started to think of the teaching-learning as an active process where students work together and the teacher guides them and facilitates their learning. These results revealed that most of the teachers' beliefs about the teaching and learning of science has changed from a traditional behavioristic conception to a more constructivist facilitator conception. Excerpts from the teachers' comments in the pre-questionnaire:

> The learning –teaching process is an exchange of information between the learner and the teacher.

In the post-questionnaire, another teacher wrote:

> After this course, I found that a learner can learn through discovery-based with the help of his teacher and he becomes autonomous layperson.

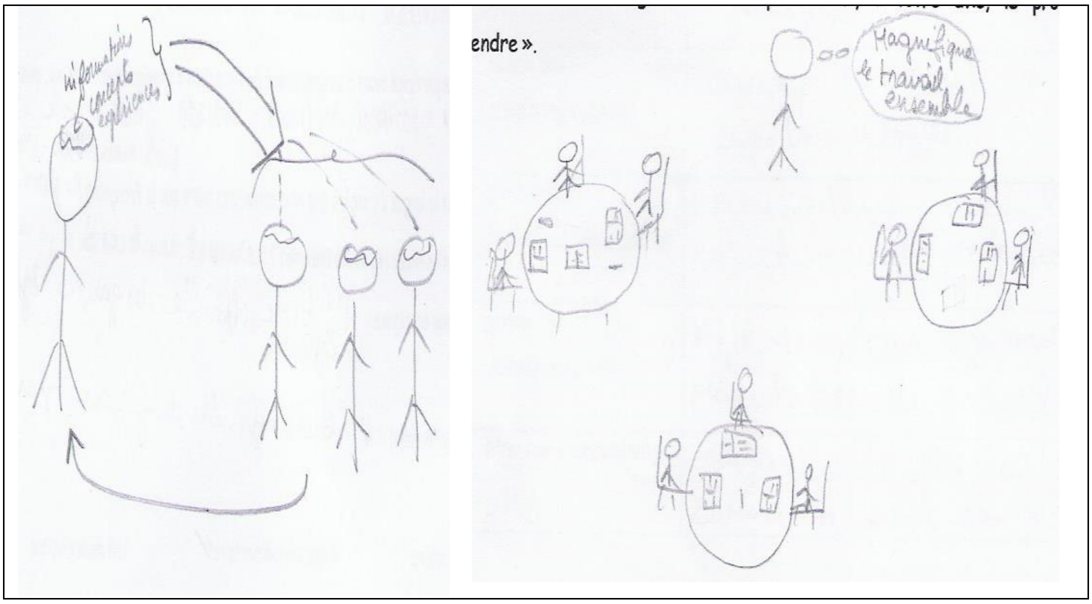


Figure 4. Pre- and post- drawings by one teacher

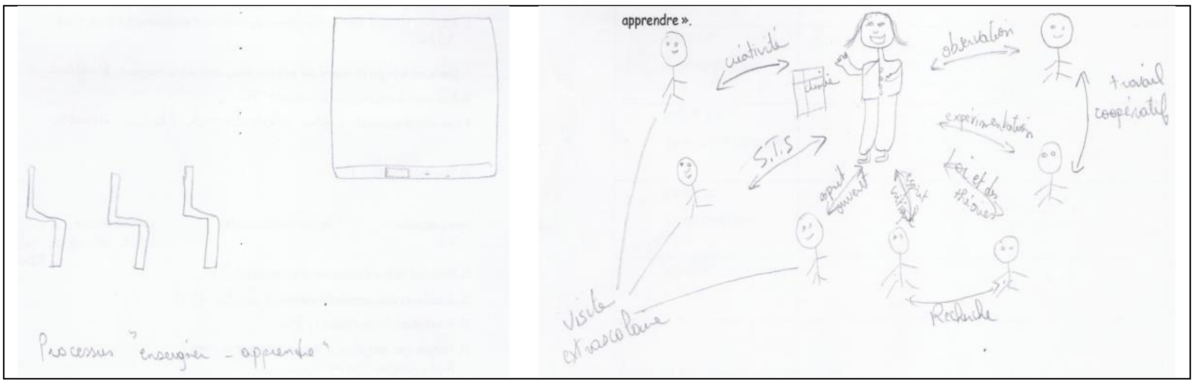
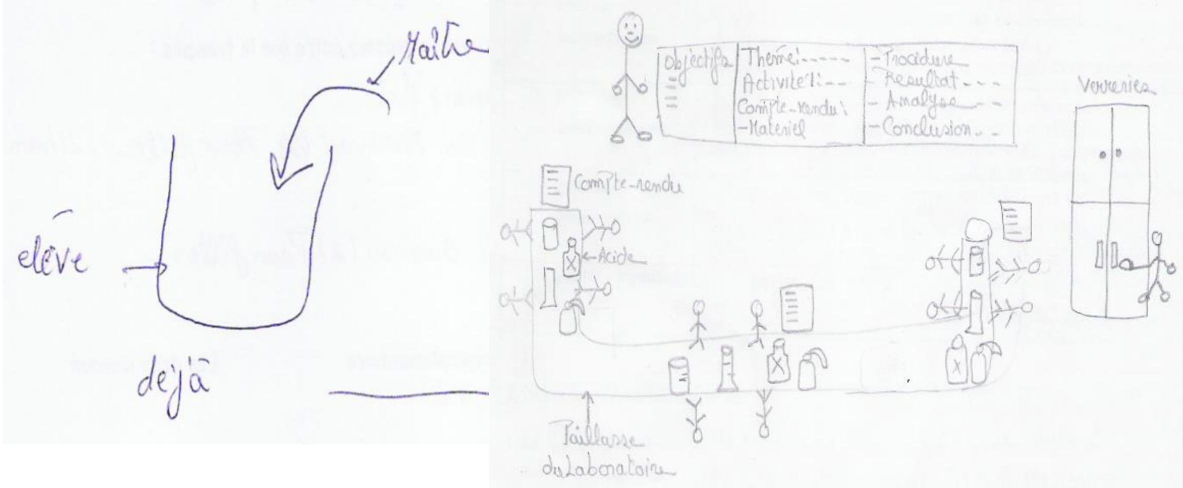


Figure 5. Pre- and post- drawings by another teacher



A recipient to be filled	*Teaching as discovery. Students use inductive/deductive reasoning in order to find a conclusion by cooperative work. Teacher guides them and makes a sum-up at the end-of-lesson.*

Figure 6. Pre- and post- drawings and the explanations written by one of the teachers

Results Related To Research Question 2 (RQ2)

RQ2 stated: How do in-service chemistry teachers' beliefs about the nature of science and scientific literacy change after attending the training course at the Faculty of Education?

To answer this question, chemistry in-service teachers' responses to the question: *What does science mean to you?* from the pre- and post-questionnaires were coded, analyzed, and categorized according to the four aspects of 'Scientific Literacy' presented by Chiappetta and Koballa (2010, p.105): 1. Science as a body of knowledge, 2. Science as a way of investigating, 3. Science as a way of knowing and 4. Interaction of Science with Society and Technology (STS).

Table 2 shows the percentages of teachers' responses aligned with the four aspects before and after the training program. It shows that almost half of the teachers at the beginning of the training program thought of science as 'body of knowledge' and more than one third of them said that science is related to investigation while only 2.9% thought of it as a 'way of knowing' and only 8.1% considered 'STS' in their responses, reflecting that almost 90% of the teachers considered science as the knowledge produced by doing experiments. After training, the percentages of the 'body of knowledge' aspect decreased to 27.9% and the 'way of knowing' aspect increased to 10.9%, of the 'STS' aspect increased dramatically to 26.3% with that of the 'way of investigating' aspect slightly decreasing to 34.9%. These results indicate a slight shift from understanding science as a 'body of knowledge' more towards the 'STS' and to a lesser degree towards science as a 'way of knowing'.

Table 2. Percentages of teachers' responses aligned with the four aspects of scientific literacy before and after the training program

Aspects of Scientific Literacy	Body of Knowledge	Way of Investigating	Way of Knowing	STS
Before training	51.5%	37.5%	2.9%	8.1%
After training	27.9%	34.9%	10.9%	26.3%

Further analysis revealed that at the beginning of the training program all teachers mentioned, in their definition of science, only the first two aspects while at the end of the training program almost 10% of them mentioned three or all the four aspects (Table 3), indicating a trend towards more comprehensive understanding of the nature of science and scientific literacy.

Table 3. Percentages of teachers' different combinations of the four aspects of scientific literacy before and after the training program

	One aspect	Two aspects	Three aspects	Four aspects
Before	62.6%	37.4%	0%	0%
After	55.2%	34.9%	7.6%	2.3%

Excerpts of same teachers' responses to the question what science means to you, before and after the training program appear in Table 4.

Table 4. Excerpts of definitions of science before and after the training

Before training	After training
It is life science, it is the study of living species	*Science is a way of thinking, it is interaction between science and technology, it is investigating.*
It is understanding the world	*Science means to continue learning, to be creative, to be organized and disciplined, to do research and to continue to learn and to develop new skills*
Science is to explain everything around us	*Science is to learn lots of knowledge and to relate them to daily life, to try to solve societal problems, such as related to our environment. In this way we become good citizens*
Science means everything you need to know about. It is the knowledge of life	*S stands for science, C stands for create, I stands for identify, E stands for explore, N stands for note, C stands for cooperate and E stands for evaluate*

Results Related To Research Question 3 (RQ3)

RQ3 stated: Do in-service chemistry teachers make use of the newly acquired skills and knowledge about teaching at the end of the training program? To answer RQ3, teachers' responses to the questions in the pre-questionnaire related to what is considered a pre-PCK knowledge were analyzed and compared to the quantitative and qualitative data gathered from achievement scores and classroom observations respectively.

Teachers' experiences before attending the training program appear in Table 5. It shows that only 46.5% of the teachers did participate in short-duration fragmented training programs while 41.4% did not participate in any training course. Table 5 also indicates that almost half of those who have access to the internet do not use technology in their teaching and that almost two thirds (67.2%) of the teachers admitted that they were not well informed about the newest trends in science education and referred this lack of information to heavy work load, lack of time, lack of technological skills and lack of continuous professional development courses.

Analysis of the responses to the question related to teachers' perceived needs at the beginning of the training course revealed that although they were not novice teachers, their needs revolved around basics in teaching chemistry. Almost half of the teachers' responses were related to the need to learn about teaching strategies, 16.1% need to improve general pedagogical skills (lesson planning, assessment, classroom management) and 18.1% need to learn how to improve students' lab skills. The need to learn more about chemistry including content knowledge, nature of science and science literacy, constituted only 4.4% of the responses, the same percentage for the need to improve their technology skills.

Responses to the question about the materials and resources teachers use in their teaching revealed that almost 40% of the teachers use experiments and lab activities while only 9% use visual aids and only 1.1% use fieldtrips. Surprisingly 15.6% use internet and 10.6% use computer technology compared to 14.5% who use printed materials and 9.5% who use no resources or chalk and talk. To the question: how do you teach chemistry for students, who learn chemistry for the first time? Only 40 teachers (34.5%) of the sample answered this question. Of those who answered 30% said that lecturing is the way to teach chemistry, other 22.5% said they use experiments and almost half of them (47.5%) reported using the application of chemistry to everyday life.

Table 5. Percentages of teachers' responses to questions related to their experience

Question	Yes	No	No Answer	Total
Did you participate to any training program before?	41.4%	46.5%	12.1%	100%
Do you have a regular access to the internet?	52.6%	28.4%	19%	100%
Do you use technology in teaching	26.7%	55.2%	18.1%	100%
Do you feel informed with the newest trends in teaching?	16.4 %	67.2%	16.4%	100%

Excerpts of the teachers' responses to the question about how to teach chemistry for students for the first time are: One teacher wrote

> Yes, I start a small class discussion, then I name some concepts and I ask them to name some chemical products from their daily life, then I start the explanation". Another one wrote: "I give examples from their everyday life and classify them into physical and chemical.

The quantitative post data concerning teaching strategies came from teachers' achievement scores in the 'methodology of teaching chemistry' and the 'practicum' courses and from scores on the components of the practicum evaluation considered important in revealing improvement in PCK criteria scores: 'content knowledge', 'use of everyday life examples', and 'use of teaching strategies and tools'. Descriptive statistics of these scores appear in Table 6.

Table 6. Descriptive statistics of teachers' achievement scores

Scores	Minimum	Maximum	Mean	SD
Teaching Chemistry	54	87	68.91	6.693
Practicum	60	92	78.28	5.976
Content Knowledge	60	95	81.25	8.794
Everyday life examples	40	90	70.17	12.299
Teaching Strategies and Tools	50	95	77.93	8.749

Spearman correlation coefficients among the above mentioned scores were obtained (Table 7). They revealed that strong significant correlations were obtained between 'Practicum' and two of its criteria: 'Content Knowledge' and 'Teaching Strategies' and moderate significant correlation with 'Everyday Life Examples', indicating that even when teachers know their subject matter they do not, during their teaching, often relate chemistry to everyday life. This can also be concluded from the weak significant correlation between 'Teaching Strategies' and 'Everyday Life Examples'. Surprisingly, weak significant correlations existed between 'Teaching Chemistry', on one hand, and 'Practicum' and 'Teaching Strategies' on the other, and no correlations existed between 'Teaching Chemistry' and 'Content knowledge' and 'Everyday life examples'

Table 7. Correlations among the different achievement measures

Measures		Teaching Chemistry	Practicum	Content Knowledge	Everyday life example	Teaching Strategies
Teaching Chemistry	Pearson Correlation	1				
	Sig. (2-tailed)					
Practicum	Pearson Correlation	.219*	1			
	Sig. (2-tailed)	.019				
Content Knowledge	Pearson Correlation	.093	.768**	1		
	Sig. (2-tailed)	.325	.000			
Everyday life Examples	Pearson Correlation	.151	.540**	.348**	1	
	Sig. (2-tailed)	.107	.000	.000		
Teaching Strategies	Pearson Correlation	.188*	.703**	.446**	.318**	1
	Sig. (2-tailed)	.044	.000	.000	.000	

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Qualitative analysis of the participant observers' field notes and written comments revealed that, even though not all teachers at the end of the training program have acquired the necessary skills to be qualified teachers, most of them have improved their pedagogical knowledge and skills. Observers' comments revealed that many chemistry teachers started to use technology in their daily routine, e.g., using the internet to back up their lessons with science examples and writing exams for their students. Also, most of them were using a variety of teaching strategies and tools such as group work, classroom demonstrations, and PowerPoint presentations.

Detailed analysis of the observers' comments regarding the teachers' strong points, weak points and suggestions for improvement revealed that although most of the teachers had a good command of the content they are teaching but not all of them were able to relate the chemistry lesson they are teaching to everyday life. Results also revealed that more teachers started to use more student-centered approaches and a variety of teaching strategies such as group work, lab work, technology, and questioning and wait time. They became more aware of the importance of involving students and capturing their attention by relating topic taught to previous knowledge and putting students in problem situations to motivate their thinking and participation. Observers' comments also included teachers' needs to improve their understanding of the chemistry content in its minute details, to use chemistry language correctly and to relate content they are teaching to everyday life. Still some teachers need to work on varying the teaching strategies and using more teaching aids and others need to align activities with the lesson objectives and to use more active teaching methods.

Although the strong points exceeded the points that need improvement, participant observers suggested that almost one third of the teachers still need to master the middle school chemistry curriculum, to vary the teaching strategies to actively involve the students, to use laboratory experiments and technology more effectively and to relate chemistry content with everyday life. Excerpts from the observers' reports regarding teachers' strong points, weak points and suggestions follow:

Strong points

- *Invests tools from everyday life in learning, uses purposeful questioning and wait time, positive environment for learning, varies activities, respect and love relationship with students*
- *Uses lots of examples from everyday life which increased interaction with students, active classroom environment*
- *Ability to attract students' attention all the time by using LCD and putting students in problem situations to motivate their thinking*
- *Confident in her abilities, active, captures her students' attention, varies in teaching methods, can work with whole class and with individuals, achieve the objectives*
- *Encourages students to induce and analyze by using variety of teaching strategies, good class manager, good questioning techniques to deepen understanding, good language of instruction and good use of chemistry language*
- *The teacher is self-confident, she is a happy and enthusiastic teacher and she uses various science activities. She is flexible, she is able to address to the whole class as well as to small groups and she can help students who have difficulties in understanding.*

Weak points

- *Some activities do not align with objectives, sometimes no connection with students*
- *No good investment of activities in improving higher level thinking skills*
- *She did not relate lesson with everyday life, lesson planning is limited to textbook*
- *Lacks precision in chemistry content details*
- *Lacks the use of lab wares, limiting her planning with the textbook*
- *Weak involvement of students in learning and difficulty in managing group work*
- *Some activities do not align with objectives, no variety of activities, no good management of objectives and time*
- *No use of misconceptions to build learning, does not involve all students while using questioning leading to less interaction with all students.*

Suggestions

- *Look up in internet for everyday life examples and applications of chemistry*
- *Concentration on higher level thinking skills*

- *Focus on learning outcomes while preparing activities and align activities with learning objectives*
- *Focus on the students as the center of the teaching/learning process*
- *Learn more about the chemistry curriculum for cycle 3 and lab work*
- *Use group work and students' misconceptions in the learning process*
- *Involve students in constructing their knowledge by using a variety of teaching strategies and activities and linking the content to everyday life*
- *Improve group work and involve students in problem solving and high level thinking activities*

Discussion

The PCK used in this study is described as composed of two major components: Content knowledge and pedagogical knowledge. In this research, teachers' understanding of the nature of science and scientific literacy in addition to their ability to relate the chemistry content to everyday life were considered as measuring the chemistry content knowledge. Pedagogical knowledge was aligned with both teachers' conceptions of the teaching/learning process and the teaching strategies, tools, and activities they use while practicing teaching. Discussion of the findings from the three research questions in connection with the PCK components used in this research follows.

First, it was found that teachers at the beginning of the training program held a traditional behavioristic conception about teaching and learning as revealed by the drawings of their mental images of the teaching/learning process. At the end of the training program, teachers presented a wide variety of drawings revealing a change in their conceptions towards more active teaching and learning. Most of the teachers' beliefs about the teaching and learning of science has changed from a traditional behavioristic conception to a more constructivist conception. In-service teachers became more aware of their role as facilitators of learning where they guide students' work and support the development of their higher order skills.

The fact that, teachers' conceptions of teaching and learning have shifted from traditional behavioristic conception to a more constructivist conception and that they became more aware of their role as facilitators of learning rather than transmitters of knowledge is in accordance with findings from previous research. BouJaoude (2000) investigated pre-service biology, chemistry, and physics teachers' conceptions of science teaching by analyzing the metaphors they used to describe their teaching during a one-year science education program. He found that pre-service teachers' who subscribed to a "Transmitter"/ "Transfer" conception decreased while the percentage of those who subscribed to a Constructivist"/"Facilitator" conception increased. Usaka, Ozdenb, and Eilksc (2011) found that most of the Turkish teachers had beliefs about teaching chemical reactions that can be characterized as traditional. They were strongly oriented towards teacher-centered methods, science facts and test scoring, a transmission-oriented view of knowledge in science teaching, which is in contrast to the modern view of education that emphasizes student-centered methods and focuses on the constructivist learning. Varnava-Marouchou (2012) analyzed the students' conceptions of learning and concluded that if educators are to place learners at the heart of the learning process, then they should be able to provide them with the educational experiences that promote the realization of high quality outcomes. Hence it is imperative to develop new teacher training programs that would help teachers to adopt the 'learning oriented' strategies instead of the 'teacher oriented' strategies that could positively impact students' learning and attainment of high quality learning outcomes. Many researchers argue that the teaching practices adopted by teachers are based on their beliefs and conceptions. There has been much research evidence concluding that improvement in teaching practices depends on the existence of student-centered conceptions of teaching. Trigwell, Prosser and Waterhouse (1997) highlighted the importance to improve the quality of student learning by discouraging teacher-focused transmission teaching and encouraging higher quality, conceptual change student-focused approaches to teaching that are more likely lead to high quality student learning outcomes.

Second, it was found that more than half of the teachers at the beginning of the training program viewed science as a 'body of knowledge' and almost 90% of them considered science as the knowledge produced by doing experiments. This view has slightly shifted, at the end of the training program, from viewing science as 'content knowledge' to viewing science as a 'way of knowing' and 'STS' while science as a 'way of investigation' remained unchanged. Teachers' views about the NOS also slightly shifted from thinking of only one or two aspects of scientific literacy, mostly 'science as content knowledge' and 'science as a way of investigation', to considering three or the four aspects, indicating a trend towards more comprehensive understanding of the NOS and scientific literacy.

The finding that teachers at the beginning of the training program viewed science as a 'body of knowledge' produced by doing experiments, is in accordance with findings from Abd-El-Khalick and Boujaoude (2003) who found that science teachers defined science as an academic subject whose purpose is to give information about the world, and most of them saw themselves and others using science in academic rather than everyday life settings. Ayoubi and Boujaoude (2006) found that chemistry teachers focused heavily, in their teaching, on academic objectives, with some apparent attention to STS objectives, and almost total negligence of history of chemistry. These findings might explain the lack of the attainment of currently advocated goals for science education, which mainly aim to help students internalize more informed views of NOS as a process and a way of generating valid knowledge about the natural world that is relevant to students' everyday personal and social, as well as, academic lives.

The fact that after training there was a slight shift in teachers views from science as 'content knowledge' to science as a 'way of knowing' and 'STS' while the view of science as a 'way of investigation' remained unchanged, may be explained as a consequence of the training program which emphasized the nature of science and scientific literacy. Integrating explicit, reflective discussions about nature of science into an inquiry curriculum showed some success in shifting students' conceptions of the nature of science (Kenyon & Reiser, 2005). Similar findings were obtained from other studies concluding that if we want to improve students' understandings about NOS, then we should teach it explicitly through investigative activities and reflective discussions (Abd-El- Khalick & Lederman, 2000b; Bartholomew, Osborne, & Ratcliffe, 2004; and Schwartz, Lederman, & Crawford, 2004). Bartholomew, Osborne and Ratcliffe (2004) added that as pre-service teachers will be teaching about science and not "doing" science, they must have knowledge of the concepts and effective approaches to teaching science. As such, to teach NOS, teachers need knowledge and pedagogical knowledge of NOS. Schwartz, Lederman, and Crawford (2004) suggested that, as the purpose of teaching about NOS and scientific inquiry is to enhance scientific literacy and not necessarily to train students to be scientists, the development of NOS views in an inquiry context can be achieved through explicit attention to NOS issues and guided reflection.

The lack in teachers' perceptions about NOS, although most of them hold a diploma in Chemistry or Biochemistry from the Faculty of Science, implies that the regular chemistry preparation programs do not emphasize the understanding of the nature of science or the structure of chemistry. This requires that teachers should be compensated for this lack by providing them with opportunities to participate in meaningful professional development activities aiming at improving their understanding of the NOS and teaching about the NOS. Teachers should be able to use teaching approaches that focus on the use of the history of science or the history of chemistry (e.g., scientist biography, the history of inventions) to enhance students' understanding of all aspects of scientific literacy especially science as a 'way of knowing' or a 'way of thinking'.

Finally, at the beginning of the training program, it was found that most teachers could be identified as traditional teachers. The pre-PCK knowledge, related to teachers' experiences before attending the training program, indicated that they were not well informed about the newest trends in science education and most of them admitted the need to learn about the new teaching strategies especially about conducting laboratory experiments and relating chemistry to everyday life. Observations revealed that, at the end of the training program, most teachers started to use more active teaching strategies, linked content knowledge to everyday life and used technology in meaningful ways but only in schools that are equipped with computers. Moreover observers' comments indicated that most of the teachers have improved the second time they were observed but still some of them need to master the middle school chemistry curriculum, to vary the teaching strategies, to actively involve the students, to use laboratory experiments and technology more effectively, and to relate chemistry content with everyday life. Even though teachers were found to know their subject matter well, they did not often relate the chemistry content they are teaching to everyday life.

The fact that most chemistry teachers at the beginning of the training program relied mostly on traditional frontal teacher-centered instruction, might be because they were not well prepared and trained to teach. In order to change the way teachers teach science, they must be given new experiences that enable them to learn to teach encompassing a range of pedagogical approaches and methods such as inquiry, constructivism, conceptual organizers, questioning, nature of science, cooperative learning, and authentic science laboratory investigations, in order to develop students higher level skills such as imagination and creativity – pillars of 21st century skills. There is an increase evidence indicating that providing teachers with prescribed skills and teaching recipes will not necessarily improve their teaching practices and thus improve student learning. The improved quality of education often requires teachers to radically change their classroom practices. As teacher learning is a necessary condition for student learning, Dani (2009) recommended that science teacher preparation become a mandated prerequisite for teaching and that mandated in-service professional development be provided.

Recommendations

Based on the results of this research we recommend that in-service teachers' should be involved in continuous training and professional development programs to keep them informed and up-to-date in both content and pedagogy. Improving the content PCK comprise understanding the structure of chemistry knowledge, nature of chemistry, how it is produced and its relation to everyday life and society. To improve pedagogy, professional development programs should pay special attention to developing teachers' understanding of the constructivist conceptions of teaching and learning and consequently should focus on planning and implementing the active and student-centered teaching strategies, and not forgetting the integration of technology in their teaching. In addition, special attention should be paid to the understanding of the chemistry curriculum and the assessment of student learning procedures. The organization of workshops, seminars and any other forms of in-service training should be targeted toward exposing chemistry teachers to the various components of PCK to support their PCK which in turn will enhance the effectiveness of teaching chemistry in the classroom. The same is true for pre-service teaching, the teachers of methodology of chemistry teaching in the teacher education programs should expose the student-teachers PCK and its various components.

We recommend that more research should be conducted focusing on the effect of the teachers' acquired PCK on students' learning outcomes especially on higher order outcomes. Improving the quality of student learning requires working with future teachers and encouraging them to adopt higher quality approaches to teaching as they are the critical factors in students' learning. In the same manner, future research should be conducted on improving PCK for university educators and science educators since they are the ones who are in direct contact with the future teachers and responsible for their preparation for teaching. If teachers are to be well qualified to teach in the schools, their teachers should be well qualified to teach them. There is an ample research on teachers' PCK and it is time to explore how the university professors' construct and implement their PCK. Finally, as technology is becoming more and more an important factor in teaching, and as it is becoming an important part of teachers' PCK, Mishra and Koehler (2006) proposed a TPCK framework that they believe can guide further research and curriculum development work in the area of teacher education and teacher professional development around technology. The TPCK framework allows viewing the entire process of technology integration in teaching. It is vital to explore how teachers are integrating technology in their teaching practices and to focus on studying how the integration of technology into teaching affects students' learning.

Limitations

At the end we have to report some limitations that could be avoided in future research. First, we measured content knowledge of the chemistry teachers by their views about the nature of science and scientific literacy, as it was assumed that in-service teachers have acquired the chemistry content knowledge they have bachelor degrees in chemistry or biochemistry. This might not be the case since the chemistry knowledge acquired at the university might not be the knowledge needed to teach at the school level. Future research should focus on this area. Also, the focus of this research was mainly on general PCK (teaching/learning process and teaching strategies) and on domain PCK (NOS, scientific literacy), future research should focus on topic PCK where PCK related to specific topics in chemistry is investigated. Another limitation emanates from the fact that not all teachers drew their conceptions of the teaching/learning process or answered all the open ended questions which might have affected the results. Future research should compensate for this validity issue by adding closed questions as well as conducting structured and/or focus group interviews.

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References

AAAS. (1989). American Association for Advancement of Science. *Science for all Americans*, Washington, D.C, American Association for the Advancement of Science.

AAAS. (1990). American Association for Advancement of Science. *Chapter One: The nature of science*. Retrieved from: www.aaas.org.

Abd-El-Khalick, F., & Boujaoude, S. (2003). Lebanese students' views of the nature of science. *Mediterranean Journal of Educational Studies, 8*(1), 61-79.

Abd-El-Khalick, F., & Lederman, N.G. (2000a). Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Science Education, 22*(7), 665-701.

Abd-El-Khalick, F., & Lederman, N.G. (2000b). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching*, 37(10), 1057-1095.

Aydin, S., & Boz, Y. (2012). Review of studies related to pedagogical content knowledge in the Context of science teacher education: *Turkish case. Educational Sciences: Theory and practice*, 12(1), 497-505.

Ayoubi, Z., & BouJaoude, S. (2006). A profile of pre-college chemistry teaching in Beirut. *Eurasia Journal of Mathematics, Science and Technology Education, 2*(3), 2006.

Aypay, A. (2010). Teacher education student's epistemological beliefs and their conceptions about teaching and learning. *Procedia Social and Behavioral Science, 2*, 2599-2604.

Bartholomew, H., Osborne, J. & Ratcliffe, M. (2004). Teaching students "ideas-about-science": Five dimensions of effective practice. *Science Education, 88*(5), 655–682.

BouJaoude, S. (2000). Conceptions of science teaching revealed by metaphors and by answers to open-ended questions. *The Journal of Science Teacher Education, 11*, 173-186.

BouJaoude, S. (2002). Balance of scientific literacy themes in science curricula: the case of Lebanon. *International Journal of Science Education, 24*(2), 139-156.

Bucat, R. (2005). Implications of chemistry education research for teaching practice: Pedagogical content knowledge as a way forward. *Chemistry Education International* 6 (1), 1 -2.

Chan, K.W. (2004). Pre-service teachers' epistemological beliefs and conceptions about teaching and learning: Cultural implications for research in teacher education. *Australian Journal of Teacher Education, 29*, 2-13.

Chiapetta, E., Fillman, D. & Sethna, G. (1991). *Procedures for conducting content analysis of science textbooks*. University of Houston, Department of Curriculum and Instruction, Houston.

Chiapetta, E. L., & Koballa, T.R. Jr. (2010). *Science instruction in the middle and secondary schools. Developing fundamental knowledge and skills for teaching*. Upper Saddle River: Prentice Hall.

Dani, Danielle (2009). Scientific literacy and purposes for teaching science: A case study of Lebanese private school teachers. *International Journal of Environmental & Science Education, 4*(3), 289-299.

Donche, V., De Maeyer, S., & Van Petegem, P. (2007). *Teachers' conceptions of learning and teaching and their effect on student learning.* Paper presented at the British Educational Research Association Annual Conference, Institute of Education, University of London.

Duit, R. (2007). Science Education Research Internationally: Conceptions, Research Methods, Domains of Research. *Eurasia Journal of Mathematics, Science & Technology Education, 3*(1), 3-15.

Duschl,R. A., Schweingruber, H. A., & Shouse, A. W. (Eds.). (2007). Taking science to school: Learning and teaching science in grades K-8. Washington, DC: The National Academies Press.

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*. New York, NY: Teachers College Press.

Holbrook, J., & Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Environmental & Science Education, 4*(3), 275-288.

Igwebuike, T.B., Okandeji, C.O., & Ekwevugbe, A.O, (2013). Teacher educators' conception of teaching and learning in teacher education institutions. *International Journal of Research Studies in Education, 2*(2), 43-52.

Johnson, B. & Christensen, L. (2008). *Educational research: Quantitative, qualitative and mixed approaches*. Boston: Pearson Education, Inc.

Kenyon, L.O. & Reiser, B.J. (2005). *Students' epistemologies of science and their influence on inquiry practices*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Dallas, TX.

Kind, V. (2009). Pedagogical content knowledge in science education: Potential and perspectives for progress. *Studies in Science Education*, 45 (2), 169-204. http://dx.doi.org/10.1080/03057260903142285Lederman, N.G. (1992). Students' and teachers' conceptions about the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*, 331-359.

Lederman, N.G. (1992). Students' and teachers' conceptions about the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*, 331-359.

Lederman, N. G., & Zeidler, D. L. (1987). Science teachers' conceptions of the nature of science: Do they really influence teaching behavior? *Science Education, 71*(5), 721-734.

Lord, T. R. (1999). A comparison between traditional and constructivist teaching in environmental science. *Journal of Environmental Education, 30 (3)*, 22-28.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical* *content knowledge: The construct and its implications for science education.* Dordrecht, the Netherlands: Kluwer Academic.

Mihladiz, G. & Dogan, A. (2011). Pre-service science teachers' subject matter knowledge of nature of science. *Western Anatolia Journal of Educational Scienc*es *(WAJES),* Special Issue: Selected papers presented at *WCNTSE (World Conference on New Trends in Science Education)*, 311- 316.

Mishra, P. & Koehler, M.J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017-1054.

NSTA. (2004). *The highly qualified teacher and pedagogical content knowledge*. Retrieved from: http://www.nsta.org/docs/2004CongressPedContentKnowledge.pdf

Ofsted (2008). *Success in Science.* London: Office for Standards in Education.

Schwartz, R.S., Lederman, N.G. & Crawford, B.A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education*, *88* (4), 610–645.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 1-32.

Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1-22.

Slunt, K. M., & Giancarlo, L. C. (2004). Student centered learning: A comparison of two different methods of instruction. *Journal of Chemical Education*, *81*(7), 985-988.

Tamir, P. (1988). Subject matter and related pedagogical knowledge in teacher education. *Teaching and Teacher Education*, *4*(2), 99-110.

Trigwell, K., Prosser, M. &Waterhouse, F. (1997). Relations between Teachers' approaches to teaching and students' approaches to learning. *Higher Education, 37*(1), 57-70.

Usaka, M., Ozdenb, M., & Eilksc, I (2011). A case study of beginning science teachers' subject matter (SMK) and pedagogical content knowledge (PCK) of teaching chemical reaction in Turkey. *European Journal of Teacher Education*, *34*(4), 407–429.

Veal, W. R. & MaKinster, J. G. (1999). Pedagogical content knowledge taxonomies. *Electronic Journal of Science Education*, *3*(4). Retrieved from: http://wolfweb.unr.edu/homepage/crowther/ejse/vealmak.html

Van Driel, J.H., Verloop, N., & De Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching, 35*, 673-695.

Van Driel, J.H., De Jong, O., & Verloop, N. (2002). The development of preservice chemistry teachers' pedagogical knowledge. *Science Education*, *86*, 572–590.

Varnava-Marouchou, D. (2012). The impact students' conceptions of learning may have on students' learning outcomes. *Higher Learning Research Communications, 2* (*2*), 18-36.

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The Babushka Concept – An Instructional Sequence to Enhance Laboratory Learning in Science Education

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Abstract

This paper deals with a novel method for improving the traditional "verification" laboratory in science education. Drawing on the idea of integrated instructional units, we describe an instructional sequence which we call the Babushka concept. This concept consists of three integrated instructional units: a start-up lecture, a laboratory session and a wrap-up lecture. Like the Russian nested doll, the sequence has a nested conceptual structure, moving from "bigger" questions to "smaller" ones. The students are actively involved during the lectures by answering reflective questions. This careful sequencing of ideas and activities aims to help the students to relate new ideas to prior knowledge, and to understand the purpose of the laboratory activity. The Babushka concept was implemented in a master's course in pharmaceutical technology and its impact was evaluated using both qualitative and quantitative methods. The evaluation focused on the students' perceptions of the intervention as well as their learning gains. A majority of the students found the Babushka concept helpful for their learning and agreed that this concept should be used in other courses. Moreover, the number of correct answers on the final written exam increased by 10%. We briefly discuss one way to enhance the Babushka concept.

Introduction

Laboratory teaching is ubiquitous in science education and used as an important complement to classroom teaching. The laboratory setting offers unique opportunities for learning and the intended learning outcomes of laboratory teaching have been widely discussed (Feisel & Rosa, 2005; Kirschner & Meester, 1988; Wieman, 2015). Ernst (1983), for example, argued that laboratory teaching should support three central learning outcomes: "First, the student should learn how to be an experimenter. Second, the laboratory can be a place for the student to learn new and developing subject matter. Third, laboratory courses help the student to gain insight and understanding of the real world." However, the effectiveness of traditional laboratory teaching has been questioned (Kirschner & Meester, 1988).

According to Domin (1999), there are two major problems with the traditional or "verification" laboratory. First, students are not given sufficient time to engage in *meaningful learning* where they "integrate new experiences with prior knowledge, establish a context for the purpose of the laboratory activity, and determine the activity's relevance to themselves". Second, traditional laboratory activities do not engage students in *higher-order thinking skills*, such as analysis, synthesis and evaluation. These problems have been confirmed in empirical studies (Lippmann & Redish, 2002). Redish (2003) reported that students spend most of the time discussing "how to configure, run and get information from the apparatus" and "make little or no attempt to synthesize in order to get an overview of what the point of the lab is". These results are worrisome and clearly demonstrate that the traditional laboratory does not reach its full potential.

A promising approach for improving laboratory learning is encapsulated in the idea of *integrated instructional units* (Singer, Hilton & Schweingruber, 2006). Drawing on recent findings from the learning sciences, the idea is to "interweave laboratory experiences with other types of science learning activities, including lectures, reading, and discussion. […] Diagnostic, formative assessments are embedded into the instructional sequences and can be used to gauge student's developing understanding and to promote their self-reflection on their thinking" (Singer, Hilton & Schweingruber, 2006). Previous research at school level suggests that integrated instructional units are "more effective than typical laboratory research for improving mastery of subject matter, developing scientific reasoning, and cultivating interest in science" (Bybee et al., 2006).

There has, however, been relatively little research on how to improve laboratory teaching in science education (Singer, Nielsen, & Schweingruber, 2012). In this paper, we focus on how to improve the "verification" laboratory, which is by far the most prevalent laboratory teaching style in science education (Domin, 1999; Wieman, 2015). We draw on the idea of integrated instructional units, but we have developed a novel take on this idea, which we call the *Babushka concept*. The Babushka concept consists of three integrated instructional units: a start-up lecture, a laboratory session and a wrap-up lecture. Moreover, like the famous Russian nested doll, the sequence has a *nested conceptual structure*, moving from "bigger" ideas to "smaller" ones. This careful sequencing of ideas and activities aims to help the students to relate new ideas to prior knowledge, and to understand the purpose of the laboratory activity.

The rest of the paper is organized as follows. We first describe the central components of the Babushka concept and its theoretical underpinnings. This is followed by an account of how the instructional sequence was implemented in a master's course in pharmaceutical technology given at Chalmers University of Technology in Gothenburg, Sweden. We then describe how the intervention was evaluated using both qualitative and quantitative methods, and the results of the evaluation. Finally, we discuss our results in relation to previous research on laboratory teaching.

The Babushka Concept and Theoretical Underpinnings

The Babushka concept consists of three integrated instructional units: a start-up lecture, a laboratory session and a wrap-up lecture (see Figure 1). During the *start-up lecture*, key concepts are introduced together with the equipment that will be used in the laboratory activity. The start-up lecture consists of an interactive presentation structured around a set of nested reflective questions, moving from general to specific. While the more general questions focus on the broader relevance of the topic and the laboratory activity to the students' future profession, the more specific questions typically focus on details of the topic and the experiment.

The idea is to start from the students' current understanding of the topic and to help them to relate new ideas to their prior knowledge and experiences. Moreover, by answering the questions during the start-up lecture, the students are encouraged to start to think about the key concepts and the purpose of the laboratory, how the experiments will be carried out, and to come to the laboratory session with their own questions. The students are asked to write down their answers to the reflective questions individually and hand in their answers at the end of the start-up lecture. This kind of formative assessment allows the teacher to probe the students' prior knowledge of the topic and adapt subsequent teaching to the students' needs. During the *laboratory session*, the students link theoretical concepts to the real world, and get practical training using different techniques and equipment. During the *wrap-up lecture*, the results from the experimental work are summarized and the students are asked to reflect on the results. This is done by posing the same questions that were asked during the start-up lecture, but in the opposite order, moving from specific to general. Finally, the teacher collects the students' individual answers again to gauge the impact of the instructional sequence on the students' conceptual understanding. The steps in the Babushka concept are summarized in Table 1.

In our analogy, the nested set of reflective questions corresponds to the set of Babushka dolls (see lower part of Figure 1). Answering the questions, from general to specific, corresponds to opening the dolls, from bigger to smaller. Moreover, each question or doll leads to a new one until the innermost is revealed. The smaller dolls in the Babushka set are studied during the laboratory session, and during the wrap-up lecture the dolls are put back together again, from smaller to bigger.

The overall design of the Babushka concept is strongly rooted in a *constructivist* view on learning (Bodner, 1986). The central tenet of constructivism is that learning is an *active* process, where knowledge is *constructed* by the student through interactions with the environment. In other words, knowledge cannot be transmitted from the teacher to the student. For *meaningful learning* to occur, students must link new ideas to their prior knowledge and experiences, and determine the activity's relevance for themselves (Novak & Gowin., 1984).

In recent years, we have witnessed a strong shift towards constructivist teaching in science education, where students, for example, are more actively involved during lectures (Felder & Brent, 2016). As Shuell (1986) put it: "It is helpful to remember that what the student does is actually more important in determining what is learned than what the teacher does". These interactive engagement methods serve a twin purpose: to let the students test and possibly revise their understanding, and to provide the teacher with feedback on the students' level of understanding. In constructivist teaching, the role of the teacher therefore shifts from being a "sage on the stage" to a "guide on the side" (King, 1993).

Implementing the Babushka Concept

The Babushka concept was implemented in a course which enrolled 30 master students in a composure course at Chalmers University of Technology in the pharmacy program in Gothenburg. The overall aim of the instructional sequence was for the students to learn more about dissolution of an insoluble drug and solid dispersions. The reason for producing solid solutions or dispersions is to increase the dissolution rate of a drug substance that otherwise would have been difficult for the body to adsorb.

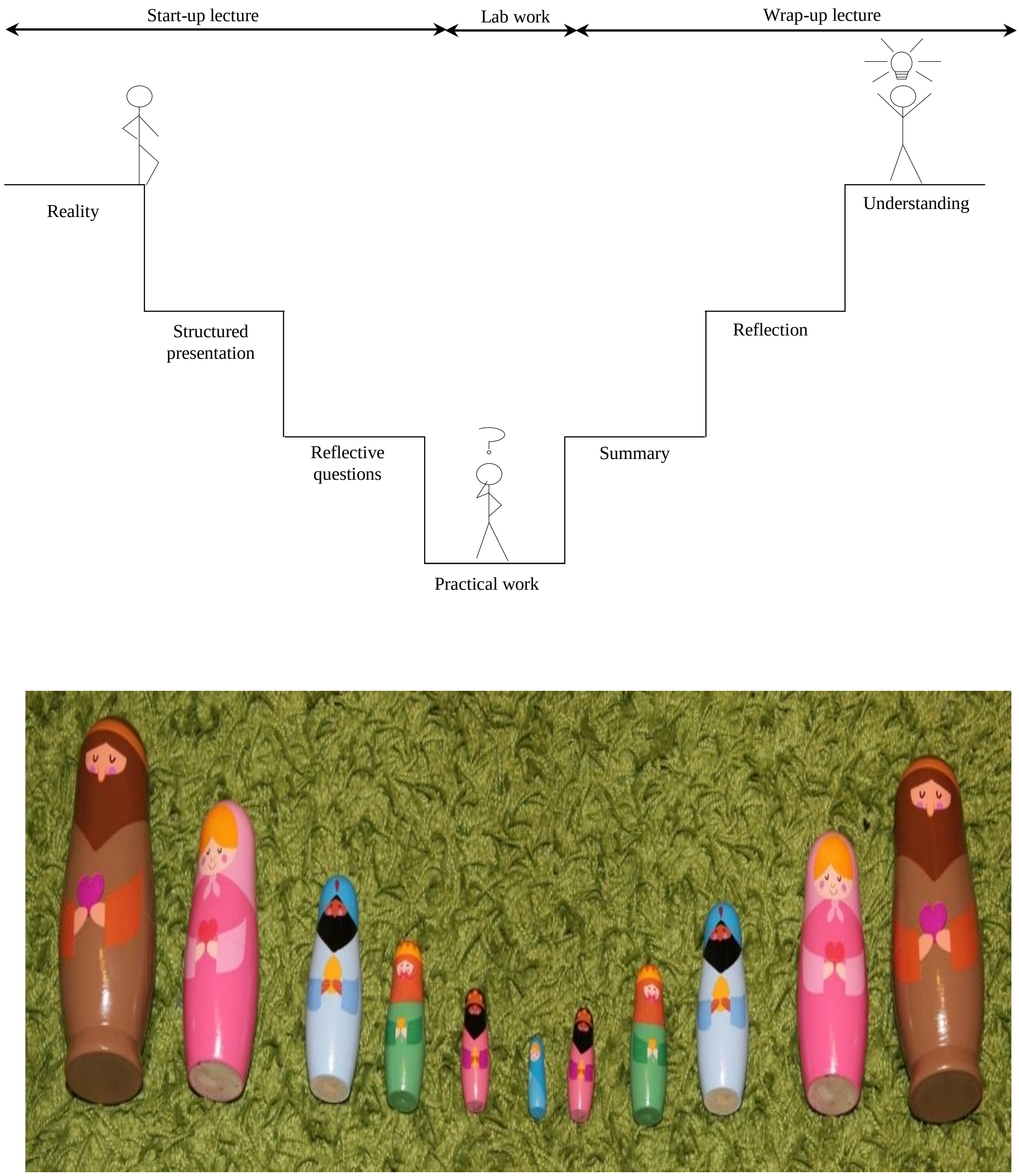

Figure 1. The top part illustrates the teaching and learning activities involved in the Babushka concept

In Figure 1, the lower part is a photograph of Babushka dolls, symbolizing the construction of knowledge.

Table 1. Summary of the steps in the Babushka concept

Start-up lecture

- Prepare a set of questions which moves from general to more specific.
- Prepare a presentation where the questions are located at suitable places. Let the students first answer the questions individually and in writing, before providing the correct answers.
- Collect the students' written answers at the end of the lecture.

Laboratory session

- The students carry out the experiments in smaller groups. Different tasks can be given to different individuals or pairs.
- The students summarize their results in a file prepared by the teacher.
- Present the results and briefly discuss the results together with the students.

Wrap-up lecture

- Go through the results and interpret the data.
- Ask the same questions as in the start-up lecture but in the reverse order. Let the students answer the questions individually and in writing.
- Collect the students' written answers at the end of the lecture.

We start with some background information for readers who are not familiar with the subject. Solid solutions and dispersions can be used to increase the dissolution rate of a hydrophobic drug, which is important for the uptake of the drug in the gastro-intestinal wall. Polyethylene glycol (PEG) is a hydrophilic polymer which is built of the monomer $-CH_2CH_2O-$ and it is commonly used in different pharmaceutical products such as suppository material (Stavchansky, Garabedian, & Newburger, 1977), as plasticizers (Repka & McGinity, 2001) and in solid solutions/dispersions (Chiou & Riegelman, 1971; Corrigan, 1986). At room temperature, PEG is in a liquid state for molecular weights below 800 g/mol, more "Vaseline"-like if the molecular weights are between 800-1500 g/mol, and between 2000 and 6000 g/mol PEG has a consistence that can be described as "waxy". However, PEG is, as many other polymers, a semi-crystalline polymer, which means that the PEG molecules are partly in the crystalline state and partly in the amorphous state (Buckley & Kovacs, 1976) – see Figure 2. The crystalline parts are ordered with the polymer axis perpendicular to the crystalline layers, while the amorphous parts are disordered. The crystalline parts melt at 50-70°C, depending on the molecular weight. Adding a drug substance to this semi-crystalline polymer results in a solid solution or a solid dispersion depending on the amount of drug substance added.

As shown in Figure 2, the drug substance is mainly located in the amorphous parts of the polymer, and in a solid solution the drug substance is located as single molecules (Unga, Tajarobi, Norder, Frenning, & Larsson, 2009). At some point, the available amorphous parts will be full, hence the drug substance will start to aggregate and a solid dispersion will form. In a solid dispersion it is still possible to find some individual molecules of the drug substance, as shown in Figure 2.

The aim of the start-up lecture was to introduce central concepts and equipment, such as solid solutions, solid dispersions, differential scanning calorimetry (DSC), and United States Pharmacopeia (USP) dissolution apparatus. To activate the students during the lecture and help them to link new ideas to prior knowledge and experiences, the students were asked to answer a set of questions individually and in writing. Examples of questions that were asked during the start-up lecture are listed in Table 2, illustrating how the questions moved from general to specific. The students handed in their written answers to the questions at the end of the lecture.

The objective of the laboratory work was to prepare solid dispersions and investigate the dissolution rate and study the thermal properties. Thermal properties were studied using a DSC and dissolution rate was measured in USP-apparatus. For the acquisition of one DSC instrument, the students were divided into groups of six to eight. The laboratory work was divided into three parts, and the students worked in pairs. The students were asked to fill in their results in tables (see Table 3 and 4) that were prepared by the teacher on a computer. The students prepared a plot of the absorbance against the time, and normalized for the weight of model drug (Butyl paraben, BP) in the sample and calculated the dissolution rate for each sample.

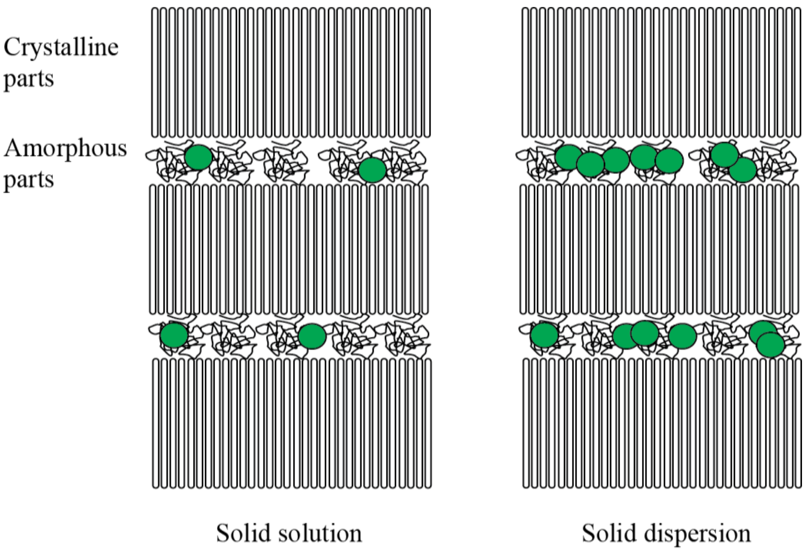

Figure 2. The structure of the semi-crystalline PEG where both amorphous and crystalline parts are present

In Figure 2, the green dots represents a drug substance that will locate in the amorphous parts of the structure. The left picture shows a solid solution, while the right picture shows a solid dispersion.

Figure 3 shows the normalized release against time, where the fastest release was obtained for the mixture of 5:95% BP:PEO. In this case, a solid solution is expected which means that the BP is dissolved as individual molecules in the amorphous parts (as shown in Figure 2a). The release from the combination with 10% BP is lower and in this case, a combination of a solid solution and solid dispersion is most likely the explanation behind the decreased release. The combination with 40% BP resulted in a release comparable to the pure BP. The results were shown during the laboratory session and discussed in more detail during the wrap-up lecture.

Table 2. Questions that were asked during the start-up and wrap-up lecture

1. What is affecting the oral bioavailability?
2. Describe the difference between a “normal” solution and a solid solution.
3. How is the dissolution rate affected when going from a solid solution to a solid dispersion?
4. How the dissolution rate is affected comparing a solid dispersion and pure particles of active pharmaceutical ingredient?
5. How can the drug dissolution rate be determined experimentally?
6. Name three things that are possible to receive from a DSC experiment.
7. How do you determine these units?

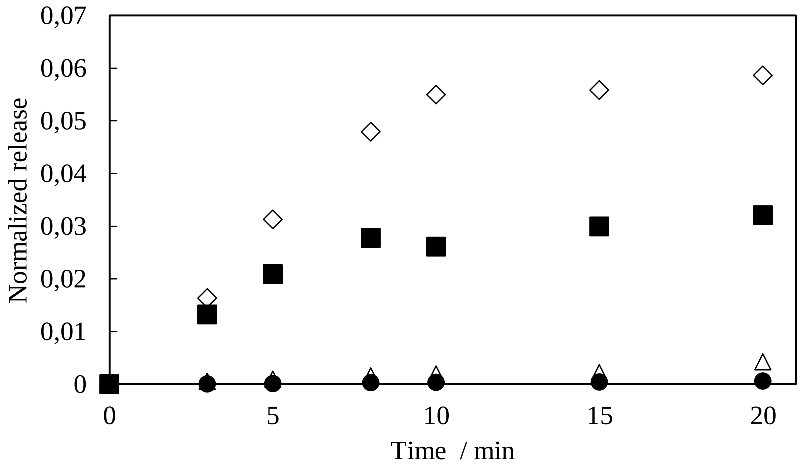

Figure 3. Normalized release of the active pharmaceutical ingridient (BP) againt time, where ◇ represents 5% BP, ■ 10% BP, △ 40% BP and ● 100% BP

Table 3. Example of a table that the students filled in during the laboratory session

Group	Weight fractions BP:PEG	Determined T_m (BP) (°C)	Determined T_m (PEG) (°C)	Enthalpy PEG (J/g)	Enthalpy (BP) J/g
	100:0				
1	0:100				
2	5:95				
3	10:90				
4	25:75				
5	40:60				

During the wrap-up lecture, the teacher summarized all the results from the laboratory session. The reflective questions that were asked during the start-up lecture (see Table 2) were now asked in the opposite order. Again, the students answered the questions individually and in writing, and they handed in their written answers at the end of the wrap-up lecture. The students' answers to the questions, before and after the laboratory session, were used together with three other data sources to evaluate the impact of the Babushka concept.

Table 4. Table used for absorbance at different dissolution times.

Time / min	3	5	8	10	15	20
Group	------	------	------	------	------	------
1						
2						
3						
4						

Methods

The evaluation focused on the students' *perceptions* of the Babushka concept and its impact on the students' *learning*. To probe the students' perceptions of the Babushka concept, we collected data from the *course evaluation* and through *semi-structured interviews*. However, since positive perceptions of an intervention do not necessarily translate into improved learning, the impact of the Babushka concept on the students' learning was also investigated. Two different evaluation designs were used to gauge the impact of the Babushka concept on the students' learning.

The first was a classical *pre-test and post-test design* (Creswell, 2012), where we compared the students' answers to the *reflective questions* (see Table 2) that they provided individually during the start-up lecture and the wrap-up lecture. The impact of the Babushka concept on the students' learning was also investigated using a *quasi-experimental design* (Creswell, 2012). This means that we compared the results on the *final exam*, before and after the Babushka concept was implemented. The Babushka concept was introduced in 2014 and this part of the course was taught by the same teacher before and after the reform.

Results

The results from the *course evaluation* revealed that most students were positive to the Babushka concept. A large majority of the students (71%) agreed that the Babushka concept should be used in the next iteration of the course, while 13% disagreed and the rest were neutral. A large majority of the students (83%) were also positive to the in-class reflective questions, while only 4% were negative. The following are some representative comments from the course evaluation:

> The new pedagogical sequence works really well, and the start-up lecture and the wrap-up lecture were valuable for my understanding.
> The laboratory work was fun and provided us with the overall picture.
> The lab was very good, I understood more than I use to do.
> The Babushka part was good, instructive and structured in a way which made it easier to understand.

Three students also took part in *semi-structured interviews* (Kvale, 1996) approximately six months after the reformed course had ended. The interviews focused on what the students perceived to be the main benefits of the Babushka concept and how it could be improved. All three students emphasized the importance of being prepared in advance of the laboratory session, which made it easier to remember and understand the purpose of the laboratory activity. However, one of the students pointed out a problem with handing out the lecture slides in the start-up lecture, since the answers to the in-class reflective questions could be found in the slides. This may have resulted in overestimated scores for the questions in the start-up lecture.

The percentage of correct answers to the *reflective questions* asked during the start-up lecture and the wrap-up lecture is shown in Figure 4. As expected, the percentage of correct answers decreased from question 1 (a more general question) to question 7 (a more detailed question) for the start-up lecture. For the wrap-up lecture, there was a significant increase in the percentage of correct answers compared to the start-up lecture. This shows that the Babushka concept had a significant impact on the students' conceptual understanding. A more detailed analysis of the students' answers to the questions revealed some common misconceptions or knowledge gaps, and how the intervention mitigated these. For example, the correct answer to question 1 is "solubility and permeability".

In the start-up lecture, the students often answered with a long list of different chemical and physical factors (such as pH, charge, molecular weight, temperature, stability, and size), while they were more sure about the correct answer in the wrap-up lecture. In question 3, we asked about the changes in the dissolution rate when the amount of drug is increased, i.e. going from a solid solution to a solid dispersion. In the start-up lecture, 44% of the students gave the correct answer. However, half of the students that knew the correct answer did not explain why, while the rest could provide an explanation. In the wrap-up lecture, 88% of the students gave the correct answer and 80% could now give an explanation to why a solid solution has a faster dissolution rate compared to a solid dispersion.

The percentage of correct answers on the *final exam* which were covered in the Babushka concept is shown as white bars in Figure 5. The black bars represent another part of the course. The number of correct answers on the final exam was more or less constant for the 2012 and 2013 iterations of the course, and for both parts of the course. In 2014, the number of correct answers for the part covered by the intervention increased, from 74% in 2013 to 85%. This result demonstrates that the Babushka concept is superior to the traditional verification laboratory when it comes to enhancing the students' conceptual understanding of the subject.

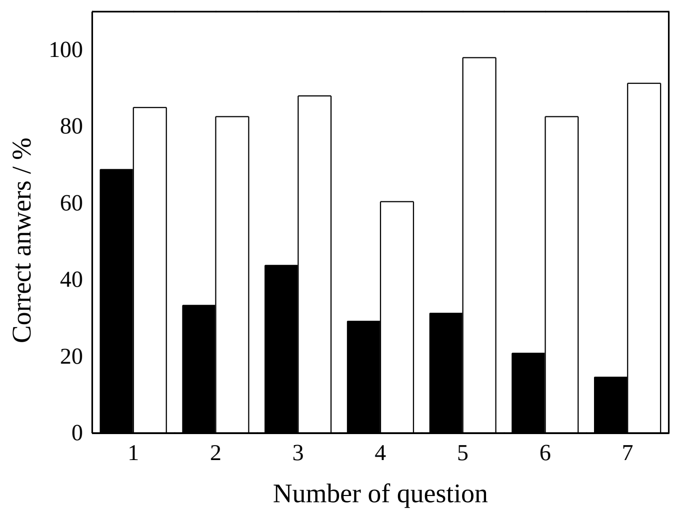

Figure 4. The percentage of correct answers to the reflective questions asked during the start-up lecture (black columns) and the wrap-up lecture (white columns)

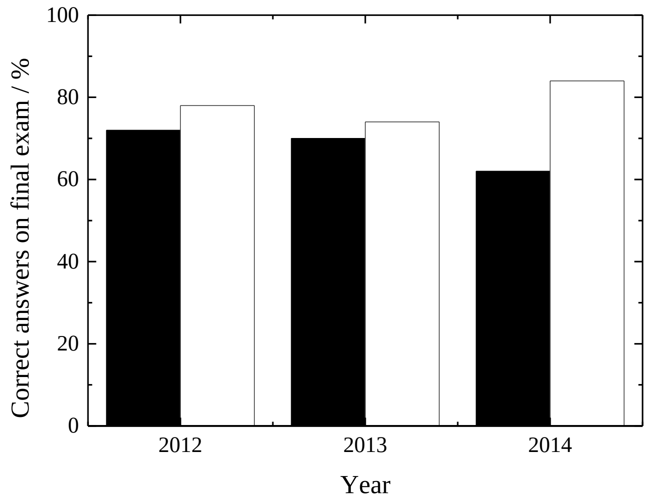

Figure 5. The percentage of correct answers on the final exam before and after implementing the Babushka concept in 2014

In Figure 5, the white columns represent the part of the course for which the Babushka concept was implemented, while black columns represent another part of the course.

Discussion and Conclusion

In this paper, we have described the design and evaluation of a novel instructional sequence – the Babushka concept – to improve the traditional verification laboratory in science education. Drawing on the notion of *integrated instructional units* (Singer, Hilton & Schweingruber, 2006), the Babushka concept consists of three integrated units: a start-up lecture, a laboratory session and a wrap-up lecture. The backbone of this instructional sequence is a nested set of reflective questions, moving from general to specific. The results from the evaluation showed that a large majority of the students were positive to the Babushka concept. Moreover, the Babushka concept had a significant impact on the students' conceptual understanding and it was shown to be superior to the verification laboratory when it comes to enhancing the students' conceptual understanding.

One dominant reason for the positive comments from the students is that they could see the "big picture" of the laboratory work. A dismaying finding from previous research on laboratory instruction in science education is that students often do not understand the purpose of the laboratory work (Kirschner & Meester, 1988). Redish (2003) described the problem in the following way: "One might hope that [students] get the numbers in the lab and then think about them outside of class. This may be the case, but I suspect it is a pious hope. Students rarely have the skills to think deeply about experiments". White (1996) described traditional laboratory work as a "mindless exercise: students following directions without thinking about the purpose of how the experiment relates to other information they have learned". By complementing the laboratory session with a start-up lecture and a wrap-up lecture, providing students with both time and structure to reflect on the laboratory work, the Babushka concept mitigates this central problem.

The significant increase in learning can be attributed to the active involvement of the students throughout the Babushka concept. By answering the nested set of reflective questions during the start-up lecture, the students are encouraged to link new knowledge to their prior knowledge, and to test and revise their understanding of key concepts. The students are also encouraged to start to think about the laboratory work and to come to the laboratory session with their own questions, which is a hallmark of a *deep approach to learning* (Biggs, 2011). The discussions at the end of the laboratory session help the students to see the link between the theory presented in the start-up lecture and the observations made during the laboratory session. The students' conceptual understanding is further strengthened when the results are revisited and discussed from different perspectives with peers and the teacher during the wrap-up lecture. In this way, the students get to test, get feedback on and potentially revise their understanding of key concepts several times during the instructional sequence. Bruner (1960) argues that this kind of "spiraling back", or revisiting of key ideas in different contexts, is central to effective learning.

One interesting way to enhance the Babushka concept is to ask the students to formulate a hypothesis during the start-up lecture. This would encourage the students to start to think about how they could test the hypothesis based on what they learn during the start-up lecture. It would also open up for letting the students work more independently during the laboratory session and engage in the different stages of the *inquiry cycle* (Pedaste et al., 2015). This extension of the Babushka concept is in line with recent calls to move away from the traditional verification laboratory and replace it with *inquiry-based* laboratory activities (Buck, Bretz & Towns, 2008; Hofstein & Lunetta, 2004). Future research could compare the effectiveness of the Babushka concept when it is grounded in the verification laboratory and the inquiry-based laboratory.

We conclude that it is possible to improve the traditional verification laboratory and that the Babushka concept offers a promising and potent way to do so. By aligning the nested set of reflective questions with the objectives of the specific laboratory work, the Babushka concept can be used across subjects in higher science education. We hope that the work presented in this paper will inspire our fellow educators to adopt or adapt the Babushka concept to enhance their students' laboratory experience.

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References

The sequence of learning cycle activities in high school chemistry. *Journal of Research in Science Teaching, 23*(2), 121-143. doi: 10.1002/tea.3660230205

Biggs, J. B. (2011). *Teaching for quality learning at university: What the student does*. McGraw-Hill Education (UK).

Bodner, G. M. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education, 63*(10), 873. doi: 10.1021/ed063p873

Bruner, J. (1960) *The Process of Education*. Cambridge, Mass.: Harvard University Press.

Buck, L. B., Bretz, S. L., & Towns, M. H. (2008). Characterizing the level of inquiry in the undergraduate laboratory. *Journal of College Science Teaching*, *38*(1), 52-58.

Buckley, C. P., & Kovacs, A. J. (1976). Melting behaviour of low molecular weight poly (ethylene-oxide) fractions. *Colloid and Polymer Science, 254*(8), 695-715. doi: 10.1007/BF01643767

Chang, H. P., & Lederman, N. G. (1994). The effect of levels of cooperation with physical science laboratory groups on physical science achievement. *Journal of Research in Science Teaching, 32*, 167-181.

Chiou, W. L., & Riegelman, S. (1971). Increased dissolution rates of water-insoluble cardiac glycosides and steroids via solid dispersions in polyethylene glycol 6000. *Journal of Pharmaceutical Sciences, 60*(10), 1569-1571. doi: 10.1002/jps.2600601031

Corrigan, O. I. (1986). Retardation of Polymeric Carrier Dissolution by Dispersed Drugs: Factors Influencing the Dissolution of Solid Dispersions Containing Polyethlene Glycols. *Drug Development and Industrial Pharmacy, 12*(11-13), 1777-1793. doi: doi:10.3109/03639048609042609

Creswell, J. W. (2012). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. United States of America: SAGE.

Domin, D. S. (1999). A Review of Laboratory Instruction Styles. *Journal of Chemical Education, 76*(4), 543. doi: 10.1021/ed076p543

Ernst, E. W. (1983). A New Role for the Undergraduate Engineering Laboratory. *IEEE Transactions on Education, 26*(2), 49-51. doi: 10.1109/TE.1983.4321598

Feisel, L. D., & Rosa, A. J. (2005). The Role of the Laboratory in Undergraduate Engineering Education. *Journal of Engineering Education, 94*(1), 121-130. doi: 10.1002/j.2168-9830.2005.tb00833.x

Felder, R. M., & Brent, R. (2016). *Teaching and Learning STEM: A Practical Guide*. John Wiley & Sons.

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science education, 88*(1), 28-54.

King, A. (1993). From Sage on the Stage to Guide on the Side. *College Teaching, 41*(1), 30-35. doi: 10.1080/87567555.1993.9926781

Kirschner, P. A., & Meester, M. A. M. (1988). The laboratory in higher science education: Problems, premises and objectives. *Higher Education, 17*(1), 81-98.

Kvale, S. (1996). *Interviews: An Introduction to Qualitative Research Interviewing*. London: SAGE.

Lippmann, R. F., & Redish, E. F. (2002). Analyzing student's use of metacognition during laboratory activities. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Novak, J. D., & Gowin., D. B. (1984). *Learning How to Learn*: Cambridge University Press.

Pedaste, M., Mäeots, M., Siiman, L. A., De Jong, T., Van Riesen, S. A., Kamp, E. T., ... & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational research review*, *14*, 47-61.

Redish, E. (2003). *Teaching Physics With the Physics Suite*. United States of America: John Wiley & Sons.

Repka, M. A., & McGinity, J. W. (2001). Bioadhesive properties of hydroxypropylcellulose topical films produced by hot-melt extrusion. *Journal of Controlled Release, 70*(3), 341-351. doi: http://dx.doi.org/10.1016/S0168-3659(00)00365-5

Shuell, T. J. (1986). Cognitive Conceptions of Learning. *Review of Educational Research, 56*(4), 411-436. doi: 10.3102/00346543056004411

Singer, S. R., Hilton, M. L., & Schweingruber, H. A. (Eds.). (2006). *America's lab report: Investigations in high school science*. National Academies Press.

Singer, S. R., Nielsen, N. R., & Schweingruber, H. A. (2012). *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Sciecne and Engineering*. Washington DC: National Research Council.

Spencer, J. N. (1999). New Directions in Teaching Chemistry: A Philosophical and Pedagogical Basis. *Journal of Chemical Education, 76*(4), 566. doi: 10.1021/ed076p566

Stavchansky, S., Garabedian, M., & Newburger, J. (1977). In vivo Retention Time Evaluation of Polyethylene Glycol Suppository Bases. *Drug Development and Industrial Pharmacy, 3*(2), 111-119. doi: doi:10.3109/03639047709051918

Unga, J., Tajarobi, F., Norder, O., Frenning, G., & Larsson, A. (2009). Relating solubility data of parabens in liquid PEG 400 to the behaviour of PEG 4000-parabens solid dispersions. *European Journal of Pharmaceutics and Biopharmaceutics*, *73*(2), 260-268. doi: http://dx.doi.org/10.1016/j.ejpb.2009.06.003

White, R. T. (1996). The link between the laboratory and learning. *International Journal of Science Education*, *18*(7), 761-774.

Wieman, C. (2015). Comparative cognitive task analyses of experimental science and instructional laboratory courses. *The Physics Teacher*, *53*(6), 349-351.

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