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# THE EFFECTS OF INQUIRY SUPPORTED BY ARGUMENT MAPS ON SCIENCE PROCESS SKILLS AND EPISTEMOLOGICAL VIEWS OF PROSPECTIVE SCIENCE TEACHERS

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## Introduction

In many of the countries all over the world, the national science education curricula cite competence in scientific inquiry (Erduran, 2006; Turkish Ministry of National Education Board of Education and Discipline Primary Science and Technology Curriculum [MEB], 2005; Abd-el-Khalick et al., 2004; Boujaoude, 2002; American Association for the Advancement of Science [AAAS], 1993). It may be because the most effective form of learning is likely to be inquiry-oriented which is personalized and collaborative, and conducted in accordance with the norms and values of community of the scientists, under the guidance of a skilled practitioner (Trowbridge & Bybee, 1996). Therefore, it may be claimed that inquiry is central to science learning as it is the active process of learning to reflect the nature of scientific inquiry in the scientific context (Anderson, 2007).

Although the curricular emphasis on inquiry is necessary, it is not sufficient for the fruitful implementation (Boujaoude, 2002). There are many factors affecting this situation such as the students' assessments based on standardized testing which result in teaching practices those are in contradiction with the aim of the curriculum creating a pressure for teachers to prepare students for tests covering a large amount of content and emphasizing factual knowledge (Blanchard, Annetta & Southerland, 2008). Anderson (2002) summarizes these obstacles which must be overcome for teachers to acquire inquiry approach to teaching science under three headings as *technical* (related to the ability to teach constructively and the role of the teacher), *political* (related to limited in-service education, parental resistance, lack of resources and etc.), and *cultural* (related to system of beliefs and values, preparation ethics and etc.). He also claims that preparing teachers for inquiry

**Abstract.** *Situating arguments as a central element in the design of inquiry learning environments is important for engaging learners in the coordination of conceptual and epistemological goals. The purpose of this study was to find out the effects of inquiry based laboratory activities which are supported by argument maps on the prospective science teachers' science process skills and epistemological views. A quasi experimental research was conducted with sixty 3<sup>rd</sup> grade prospective science teachers of a faculty of education in Turkey for over 3 months. The results displayed that although the inquiry supported by argument maps had significantly affected the science process skills of prospective science teachers; it did not affect their epistemological views. It is thought that it may take some time and special efforts to see the effects of inquiry supported by argument maps on the epistemological views of prospective science teachers.*

**Key words:** *argument mapping, inquiry, prospective science teachers.*

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teaching is much bigger than technical matters. Therefore, it seems teaching science through inquiry needs to accomplish much more than simply detailing what we know about scientific inquiry (Simon, Erduran & Osborne 2002). This situation may depend on that although inquiry learning has a sound definition as an active process of learning by having relationship to scientific inquiry; inquiry teaching has no clear definition or boundaries (Anderson, 2007).

On the other hand, less than 10% of science teachers are able to provide one of two crucial pieces of evidence that demonstrate the Earth spins (Osborne, 2005). This reveals that although the science teachers seem to be well equipped to teach science, there are missing key points in their professional life such as engaging in the process of scientific argumentation. In other words, they fail to give students critical thinking, thinking with evidence and as a result of doing the essence of science. Moreover, the science teachers encounter problem of relating evidence from practices and experiments to the knowledge claims in texts and statements of scientific theory (Duschl & Erduran, 1996). According to this view, one part of the problem concerns the cognitive and manipulative procedures of scientific exploration and investigation that generate data and evidence. The other part of the problem concerns learning the skills of argumentation and of theory development and evaluation that forge evidence into scientific explanation

Understanding science has conceptual and procedural patterns (Gott & Murphy, 1987, as cited in Millar, 1991, p44). While conceptual side addresses the core subjects of science such as natural events and facts; procedural side involves the fundamental skills to do science. This procedural side addresses the science process skills. Harlen (1999) emphasized that the development of science process skills has to be a major goal of science education besides being general descriptions of logical and rational thinking:

Learning with understanding in science involves testing the usefulness of possible explanatory ideas by using them to make predictions or to pose questions, collecting evidence to test the prediction or answer the question and interpreting the results; in other words, using the science process skills (p. 130).

In this context, it gets highly important for students to gain understanding about the science as a way of knowing (Driver, 1995). Furthermore, the aim of science and scientific works are idea testing, and as a result scientific knowledge is constructed through justification (Smith, 2000; Carey, Evans, Honda, Jay & Unger, 1989). The justification addresses how the knowledge in science is developed, how it is understood to be true and how is the quality of the data that build up the knowledge is determined and evaluated (Ryder & Leach, 2006; Saunders, Cavallo & Abraham, 2001). Consequently, the scientific knowledge or the epistemology of science basically concerns with the questions of "what do we know?", "how do we know?" and "how do we come to believe in our knowledge to be true?" (Duschl & Osborne, 2002). These issues all address the importance of scientific knowledge and in particular the need in science to justify our claims with evidence or argument (Erduran, 2006).

Some of the researchers define *argument* as the justification of claims with evidence and *argumentation* as the coordination of theory and knowledge (Erduran, 2006; Patronis, Potari & Spiliotopoulou, 1999; Kuhn & Pearsall, 2000). According to Nussbaum, Sinatra & Poliquin (2008, p. 1978) *scientific argument* refers to the application of scientific standards (e.g., provision of evidence, consideration of counterarguments and rival hypotheses) to arguments for the purpose of understanding scientific phenomena. Moreover, an argument is not a mathematical proof but the discussions that present and provide support for claims with evidence and premises (Belland, Glazewski & Richardson, 2008). The evidence only has meaning in the context of the ideas we use to interrogate. In other words, "ideas and evidence" is always an implicit part of the context for practical work in a school context (Taber and et al., 2006). Argumentation can also be used to help students develop rigorous standards for what counts as warranted knowledge in science (Driver, Newton & Osborne 2000).

In this study, arguments are composed in form of maps as they are easy to construct, document and to keep for groups of students when comparing and discussing. Argument or reasoning mapping is a thought mapping technique such as concept mapping and mind mapping (Austhink, 2010; Stolpe & Strömdahl, 2007; Novak & Gowin, 1984). However, in argument maps the focus is on exclusively reason-



ing or argument structure and this time instead of putting just one concept word in each box, a whole statement is used. Different statements are connected by lines or arrows which indicate the chronology of statements or support of evidence for a claim and thereby give a graphical picture of reasoning process (Stolpe & Strömdahl, 2007). It may be also defined as the graphical display of evidential relationship (evidence for or against others) by making a picture of reasoning (Austhink, 2010). Reasoning can be defined as the process of constructing and evaluating arguments (Shaw, 1996). Therefore, the basic unit of all reasoning is composed of simple arguments. A single argument contains one contention and one piece of evidence related to it. Therefore, argument maps can be used to characterize idea testing behavior of individuals (White, 2004).

On the base of above literature, it is clear that inquiry and arguments have essential roles in science teaching and learning. As it is stated in the next chapter, they both also have potential of affecting prospective science teachers' science process skills and epistemological views. Therefore, this study aims to answer the following research questions:

1. Is the Inquiry Supported by Argument Maps effective on prospective science teachers' science process skills?
2. Is the Inquiry Supported by Argument Maps effective on prospective science teachers' epistemological views?

### Science Education and Prospective Science Teachers

There are many studies examining inquiry and use of arguments in science education. For example, Yerrick (2000) examined the effects of open inquiry instruction with low achieving, marginalized high school students in general course instruction that was included generation, experimental design, and argument construction. She reported that students' arguments were observed to improve toward those more consistent with the nature of the scientific arguments including students' tentativeness of knowledge claims, students' use of evidence, and students' views regarding the source of scientific authority.

Besides, Hogan & Maglienti (2001) studied on the reasoning abilities of scientists, non-scientists and students and found out that the performance of non-scientists and students were lower than that of scientists. They also added that students are able to perform well if they are given opportunity to participate into discussions through the criteria of scientific work.

Moreover, in her study with children and adults, Kuhn (1993) put forward that both groups she studied on showed a low level of coordination of evidence and theory (or use of arguments). Additionally, she also reported that students with more constructivist epistemic perspectives were more likely to consider alternative theories and disconfirming evidence. Additionally, Bell & Linn (2000) showed that students who viewed science as dynamic and constantly changing tended to create more complex and integrated arguments.

Kelly & Takao (2001) studied with university students about inquiring by writing of arguments through accessing the geological data bases through the use of an interactive CD-ROM. They found that, student generation of scientific argument derived from real earth data improved their scientific inquiry skills.

Gott & Duggon (2003, p. 191) examined the concepts of evidence through 5 layers on how various practical work relates to the underlying ideas. They structured layers of evidences in circles where a single datum lies at the centre (region A). This core layer is outwardly followed by a data set (region B). In region C, there lie the relationships between the variables -patterns in data and 'truth tables'- in the private claim. This layer is outwardly followed by the comparison with other sources of data (region D). After then, there come the wider societal issues about defining the way the task is conducted such as costs, values and bias (prejudice, preconception, fear, authority and etc.) in region E. In their structure while the regions addressed by A, B and C represent the design determining the selection of ideas to be used in the task, all of the regions from A to E address a public claim based on all the evidence.

In the same manner Osborne (2005) claimed that scientific literacy depends on the ability to reject and recognize poor scientific arguments as well as on the ability to reproduce the correct scientific view



based on evidences. It means there is relation between understanding and using arguments and being scientifically literate.

Lederman, Lederman & Wickman (2008) also conducted an experimental study with science teachers of three groups in order to see the effects of direct instruction, guided inquiry and hybrid of two on the subject matter knowledge, knowledge of inquiry and attitudes towards science. He reported that the most successful group was the one having the instruction of hybrid approach.

Besides being skilled on inquiry teaching and learning, Morowitz (1990) also claim that, in order to avoid the appeals to authoritarianism, the science teacher must be equipped with a deeper understanding of the acquisition and validation of knowledge. As explained above, argument in science education is the core subject in order to understand the role of evidence for justification of the scientific knowledge as a process. Through taking part in activities that require them to argue the basis on which knowledge claims are made, students also begin to gain an insight into the epistemological foundations of science itself (Newton and et al., 1999). Therefore, teaching how to argue with evidence is essential for students to understand how scientific knowledge is constructed and validated (Okada, 2008).

Lawson (2002) in his study with prospective biology teachers where they submitted written arguments as lab reports found out that when students were able to manipulate observable hypothesis they argued well. However, he pointed out that when the hypothesized causes were unobservable and indirectly tested, their performance of argument dropped. He concluded that in order for prospective teachers understand and develop adequate hypothesis-testing skills and nature of science is closely related to their argumentation skills.

However, it is cited in many of the studies that getting individuals to adopt argumentation either as discourse or as written task is a long and difficult term (Osborne, 2005; Erduran, 2006, Prain & Hand, 1996) and difficult process due to the individual differences. These individual differences may range from willingness and preparedness to learn; from engaging in argumentation and epistemological beliefs to having mistaken views about argument as a disagreement and resulting in not appreciating the role of argumentation as a normal part of the working of science (Nussbaum, Sinatra & Poliquin, 2008; Nussbaum & Bendixen, 2003; Duschl & Osborne, 2002; Bell & Linn, 2000).

Nussbaum and Bendixen (2003) found out that epistemic beliefs are directly related to students' willingness to engage in argumentation. Specifically, students who believe that knowledge is simple, certain, and unchanging reported that arguments were anxiety-promoting, and thus they tended to avoid them. Therefore, as a role model for student, the science teachers' prior knowledge, willingness about argumentation extending down their years at faculties gets importance.

As part of their project, IDEAS, Erduran, Ardaç and Yakmaci-Güzel (2006) studied with 17 trainee teachers for 6 weeks in 90 minutes workshops through Toulmin's argument pattern. At the end, they examined the teachers' strategies on how they structured the task, used group discussions, questioned for evidence and justifications, modeled argument, used presentations and established the norms of argumentation. They found out that formative feedback in argumentation might be challenging to beginning teachers although other advanced skills such as modeling and questioning did not present as much difficulty. Therefore, as the researchers offered the developmental stages in the learning to teach argumentation needs to be traced.

On the other hand, Von Aufschnaiter, Erduran, Osborne & Simon (2007) put forward that when engaging in argumentation students draw on their prior experiences and knowledge. Besides, they pointed out that activities based on argumentation enabled students to consolidate and elaborate their existing knowledge but did mainly not result in new (conceptual) understanding.

Nussbaum, Sinatra & Poliquin (2008) in their experimental study with college undergraduates found out that constructivist epistemic beliefs and instruction in the criteria for a sound scientific argument facilitated students' consideration of evidence and alternative points of view, which in turn would create greater opportunities for conceptual development. By proposing that many of science teachers are unsure about how to conduct and support inquiry learning in the classroom, Sampson & Gleim (2009) improved an argument-driven inquiry model where the laboratory task is presented to the students as the problem and they produce arguments based on laboratory experiences in groups.



The researchers claim that the model they developed has the potential of fostering scientific literacy since the students actively involved in science process skills during argument sessions.

In summary, situating arguments as a central element in the design of inquiry learning environments is important for engaging learners in the coordination of conceptual and epistemological goals and making students skilful regarding scientific inquiry (Simon and et al., 2002). Hahn & Gilmer (in Abd-el-Khalick and et al. 2004, p. 403) and Anderson (2002) proposed that most science teachers have never directly experienced scientific inquiry during their education in the science courses and science education programs. A critical component of professional development of science teachers should include direct experiences with science as they need to be well experienced in scientific inquiry as a teaching approach, set of process skills and content area as well as pedagogical skills necessary to teach about inquiry and nature of science (Abd-el-Khalick and et al. 2004, p. 403). Therefore, the best inquiry teaching experience can be obtained by experiencing inquiry learning. Moreover, it is known that, students need to be modeled by their science teachers in making their thinking explicit for scientific argumentation (Okada, 2008; Hogan & Maglienti, 2001; Simon, Erduran, Osborne, 2002). Based on the above arguments, it is thought that experiencing inquiry supported by argument maps may have important outcomes for prospective science teachers. Therefore, by addressing the above issues related to the importance of both inquiry and arguments in science education, this study aimed to see the effects of the inquiry based laboratory activities which are supported by argument maps on the prospective science teachers' science process skills and epistemological views.

## Methodology of Research

### *Research Design*

This study is based on quasi-experimental research design where the researcher studies the effects of the treatment on the intact groups which are not randomly assigned as experimental and control groups (Fraenkel & Wallen, 1996; Mertens, 1998). This research is structured to see the effects of the inquiry supported by argument maps on the prospective science teachers' science process skills and epistemological views in a cause-effect relationship in Science Laboratory Practices II course. Although the participants are not randomly assigned to the groups, the groups were randomly assigned as experimental and control.

### *Participants*

The participants of this research are prospective science teachers of a faculty of education from a state university in one of the cities located on the west of Turkey. A total of sixty 3<sup>rd</sup> grade prospective science teachers (N=29 in experimental and N=31 in control groups with average age of 22.1) took place in the research. Before participating into this research, all of the participants had Science Laboratory Practices I course (for approximately 3 months) about how to conduct activities and practices in the laboratory during the fall term of the same instructional year. In that course, they all had experiences in conducting expository, discovery and problem based laboratory activities as defined by Domin (1999). Therefore, the prospective science teachers had already had the basic skills and knowledge about laboratory activities when they came to The Science Laboratory Applications II course for the spring term.

### *Assumptions and Limitations*

The external validity of this research is limited in that the study was conducted only with sixty prospective science teachers in one faculty. The application is restricted to general science subjects within the scope of subjects requiring basic knowledge of physics, chemistry and biology. It is assumed that the prospective science teachers followed directions in the worksheets, and the teaching was performed by the researcher.



### *Data Collection Tools*

Science Process Skills Test and Epistemological View Questions were used for collecting data in this research. The instruments were given to students at the beginning and at the end of the course.

#### *Science Process Skills Test*

In the literature, there are many paper-pencil tests developed for assessing science process skills of individuals from elementary school to college level (Burns, Okey & Wise, 1985; Germann, Aram & Burke, 1996; Temiz, Taşar & Tan, 2001; Ateş, 2005; Aydoğdu, Yıldız, Akpınar & Ergin, 2006; Temiz & Tan, 2007). Among these tests, namely, Science Process Skills Test (SPST) was developed towards assessing the science process skills of prospective science teachers by Aydoğdu and et al. (2006). SPST has two parts. There are 9 multiple choice items those require explanations for choosing in the first part and there are 4 scenarios ending with open ended questions. The science process skills measured by SBST are doing observation (1 multiple choice item and 1 scenario), classification (1 multiple choice item), inferring (1 multiple choice item), controlling variables (1 multiple choice item, 2 scenarios), interpreting data (1 multiple choice item), measuring (1 multiple choice item), hypothesizing (1 multiple choice item) and fair testing (2 multiple choice items and 1 scenario). The reliability coefficient (KR-20) was found to be 0.70 for SBST.

#### *Epistemological View Questions*

The epistemological views or beliefs have been interest of many resarchers who also developed questionnaires to determine the epistemological views of individuals from different age levels (Ünal & Ergin, 2008; Oksal, Senşekerci & Bilgin, 2006; Saunders and et. al, 2001; Holschuh, 1998; Pomeroy, 1993; Schommer, 1990). These questionnaires, in common, have explicit questions or items directly related to epistemological characteristics. On the other hand, Roth & Roychoudhury (1994) claimed that asking explicit questions leads individuals to give answers inconsistent with the epistemological understanding that is expected from them instead of reflecting their actual thoughts. Therefore, it is important to put forward the implicit or actual epistemological views of individuals through different data collection tools such as dialogues, scenarios and etc. revealing the epistemological views indirectly rather than explicit questions. In this research, the aim of using Epistemological View Questions (EVQ) is to figure out the implicit thoughts of prospective science teachers towards epistemological foundations of scientific knowledge. EVQ has 5 items including 2 dialogues and 3 scenarios which were developed by Ünal Çoban (2009) towards primary school students. These questions were adapted to the prospective science teachers considering their age level and experiences. All questions were examined by one professor of science, two lecturers of science education and one lecturer of philosophy of science and then revised accordingly. In addition, the questions were piloted on another group of 5 prospective science teachers for clarity and comprehensibility. Initially, the pilot participants were asked to read and answer the questions by themselves. Afterwards, the researcher interviewed each of the pilot participants about what they think about the meaning of each question and suggesting ways of rewriting the questions if they are unclear. At the end, final revisions on the questions were done and EVQ turned out to measure about justification (2 items), scientific method (1 item) and theory ladenness (2 items).

#### *Procedure*

During the instruction, while the experimental group received inquiry based laboratory activities supported by argument maps the control group received inquiry based laboratory activities from the same instructor (the researcher) for over 3 months. Since both groups of students had already learnt about basic science process skills before the study was conducted, they were assumed to be ready to take in place in a deeper study which emphasizes the importance of use of arguments as a way of using evidence and justification in scientific inquiry.



The scientific inquiries took place as a part of the Science Laboratory Applications II course which scheduled as two hours of lesson in a week and held by students in groups of three or four who were randomly assigned to work collaboratively in both groups. The tasks for the scientific inquiries were given in form of scenarios each of which include a problem to be defined and solved through scientific inquiry and reflect real life situations and problems. As known, learning by inquiry allows for classroom activities to be teacher-led, negotiated and shared between student or teachers and students with varying amounts of teacher guidance and support (Trowbridge & Bybee, 1996). However, since the participants had experience with guided inquiry before, this study was based on free inquiry. In free inquiry, there is an undetermined outcome, students generate their own procedure and take responsibility. Moreover, free inquiry instruction requires students formulate the problem, state the purpose of investigation, identify the procedure and perform investigation with components of higher order thinking skills (Domin, 1999). Seven free inquiry scenarios were used during the instruction. The scenarios extended from directly experimenting such as determining the O<sub>2</sub> level in an aquarium to designing a tool such as making a submarine or a bridge. The same scenarios were delivered to both experimental and control group students. Each session (90 min.) composed of performance of the inquiry related to the scenario that was given in the previous week and the discussion and the planning of the newly given scenario.

#### *Treatment in Control Group*

In this study, the control group students were given the same scenarios with the experimental group. The procedure is three step including *identification of task* where they were given time to understand, comprehend and discuss the task given by the scenario; *planning* where they formulate the problem and figure out ways for the solution and *performing the plan* by setting the experimental design and conducting the experiment followed by reporting. Teacher only guided students to better understand the issues given in the scenarios and replied the students' relevant questions. She also helped to provide the basic materials or measurement tools (such as AVometer, power supply and etc.) which are required by students to perform investigation if there is any in the laboratory. The time for identification of task and planning took place almost 30-40 minutes in the same session and the students were given a week for preparing the performance for the next lesson. They are advised to conduct trial experiments or construct preliminary drafts towards their performance in the laboratory whenever they wish in that one week interval before the lesson. Finishing the preparations by the next lesson, they conducted the experiments or presented their results or constructs and submitted their reports which took almost 50-60 minutes.

#### *Treatment in Experimental Group*

In this study, although the experimental group received the same free inquiry scenarios with the control group the implementation was different due to use of argument maps. The general structures of the lessons were the same with the control group's lessons apart from use of argument maps and the group discussions before and after their performance. During *the identification of task* after they understood and started to comprehend and discuss about the task they were asked to *map the argument* given in the scenario. The teacher followed the argument maps of each group in order to ensure if they correctly coordinate the knowledge or explanation, evidence and required solution by asking them provoking questions such as "How do you know that happen?"; "What do you need to figure out that?"; "Do you think the data presented is enough?"; "What else do you need?" and etc. After raising their awareness, they were asked to revise their arguments accordingly and leave empty for any unrelated or unexplained issues in the structure of the argument (the structure of the arguments is explained in Construction of Arguments part).

Completing the argument maps based on the scenario they started *planning* in the same way with the control group. After spending a week on investigation and trial performances in the laboratory as in the same way with the control group students, they conducted their experiments in the following lesson. Completing and reporting the results of experiments, the students are asked to *draw the argument*



*maps* for the second time of what they performed through experiments. The aim of constructing this second argument map is to provoke the students about the coordination of theory and evidence and the general steps they had taken during experimentation. This time, the researcher asked each group probing questions about their argument maps such as “How do you know that your data is reliable?”, “How do you reach that conclusion?”, “Do you have enough data to support your ideas?”, “Does your conclusion answer your research question?” and etc. which are about the validity, reliability and theory-evidence coordination of the experimental design. The groups revised their arguments accordingly after discussing the answers of these questions. After completing revisions on the second argument maps, the students are asked to go back to their first argument maps and compare and discuss it with the second one and revise, correct and fill in any issues on the first one accordingly. The aim of this process is to identify similarities and differences as a way of confirming the consistency of both argument maps originated from the same scenario representing a real life situation.

As seen, in this study, mapping the arguments is held as a two step process. The first argument mapping is related to the scenarios showing the real life situations and the second argument map is related to the experiments conducted in the laboratory. The idea of using two argument maps during the scientific inquiry is based on Gott & Duggon (2007, p. 282) who emphasize the importance of understanding the use of evidence in order to become scientifically literate. By referencing their previous study (Gott & Duggon, 2003, p. 191) on concepts of evidence (in layers of circles), they claim about the importance of “looking back” and “looking forward”. When the real life issues are subject and real-life decisions have to be taken the scientifically reader of science should have to delve back through the claim to the data (going from public claim to single datum) by *looking back*. Moreover, the investigator proceeds from data, through design, to a claim by *looking forward* (from single datum to public claim) based on evidence. They explain that, looking back and looking forward are important because they allow us to understand what is behind the public claim (considering the design, data collection and analysis required to support that claim) and students are exposed to the reality of the design and collection of data by using evidences. Therefore, it was thought that it will be appropriate to use of first and second argument maps during the scientific inquiry in the experimental group in order to coordinate theory and evidence and to see the correspondences of real life situations and their experimental trials.

#### *Construction of Argument Maps*

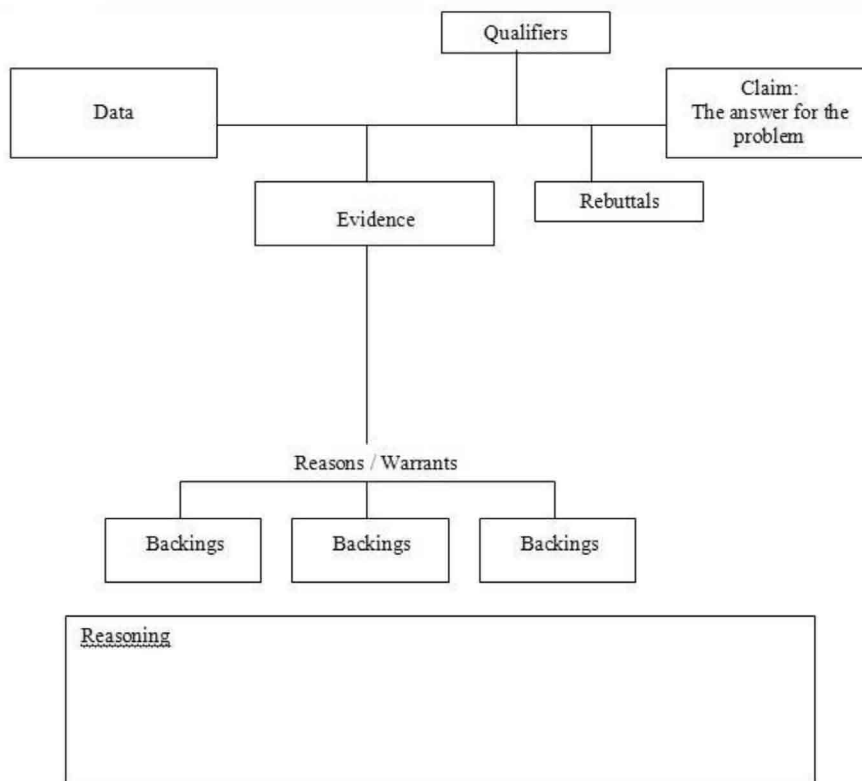
In order to establish the ground on which the argument maps will be constructed, firstly, Toulmin's (1958) argument model was investigated. In this model there are four main types of statements: *claims*, assertions or conclusions whose merits are to be established; *grounds* or data which are the facts that are appealed to in support of the claim; *warrants* which are the reasons justifying the connection between particular data and the knowledge claim; and finally, *backings* which are basic assumptions that provide the justification for particular warrants (Gott & Duggon, 2007; Newton, Driver & Osborne, 1999; Patronis, Potari & Spiliotopoulou, 1999). There are also *qualifiers* which is about the strength of the claim and *rebuttals* which is exception to the claim and / or conditions under which the claim is not true (Gott & Duggon, 2007). This model of argument has been used in many science education studies (Erduran, 2006; Simon and et al., 2002).

However, Kelly & Takao (2002) identified the problem of the ambiguity of the categorical system with Toulmin's layout of arguments regarding the fact that claims may serve as data in broader, more complex chains of reasoning. They claim that Toulmin's argumentation approach does not consider the relative epistemic status of the one's assertions (i.e., degree of abstractness of knowledge claims), nor the position of embedded claims in larger arguments. On the other hand, Sampson & Gleim (2009, p.467) put forward a more simpler argument approach which consists of an explanation, evidence and reasoning. According to this, *the explanation* serves as an answer to the research question that guides the investigation. It may also offer solution to the problem, articulate a descriptive relationship or provide a causal mechanism. Additionally, *the evidence* includes measurements or observations to support the legitimacy of the explanation. This evidence may range from numerical data to observations including either a trend over time or a difference between groups or a relationship between variables. *The reason-*





ing component of the argument includes a rationalization that illustrates how the evidence supports the claim and the evidence provided is justifiable evidence. It was decided to use an approach that was closer to Sampson & Gleim's (2009) approach by considering the above points about arguments. The main structure of arguments and argument maps used in the study is given in Figure 1.



**Figure 1: The structure of arguments and argument maps used in the study.**

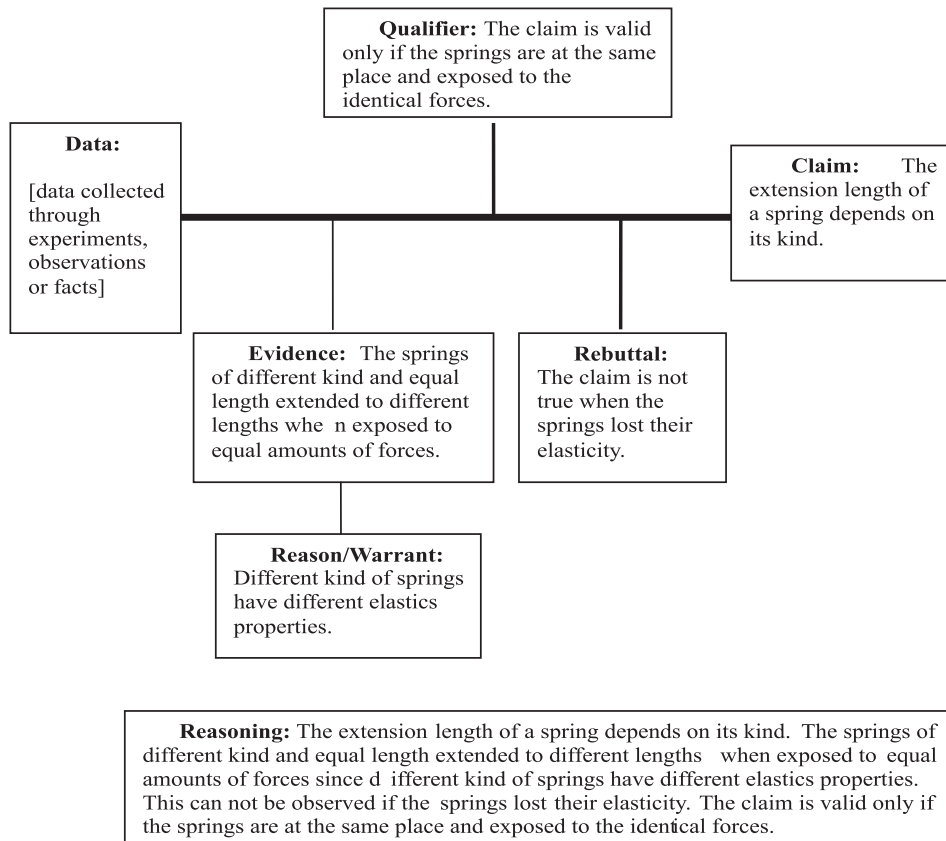
In order to map their arguments in accordance with the above mapping, the prospective science teachers are given the following points:

- Every box should contain a meaningful, exploratory and appropriate full sentences. Avoid using a word or simple phrase in case it may lead problems in understanding.
- No question words should take place in the boxes. Therefore, the propositions in the boxes are neither right nor wrong.
- If the given situation (or data) includes more than one claim, then it should be separated into single claims and then chain of claim-evidence should be established for each single claim.
- If a claim is supported or refuted by more than one evidence (multi-layer arguments), then one reason can provide evidence in support or refute of another.
- If a claim is supported by more than one evidence then the evidence which is more abstract and general should be put hierarchically further as the primary reason then the one which is more concrete and more particular as the secondary reason and so on.
- Arguments are made of claims. Therefore, claims must be supported by the evidences. The reasoning should take place at the end of each map as a summary of the claim-evidence relation.

In order not to exceed the limited number of pages of the paper, an example of a secondary argument map prepared by the prospective science teachers about the Hook's Law related to the experi-



ments they conducted in the laboratory is given in Figure 2 below. The research question drawn from the related free inquiry scenario for the Figure 2 is "What affects the extension length of a spring?"



**Figure 2:** An example of a secondary argument map prepared by the prospective science teachers about the Hook's Law.

#### Preparation for Experimental Group

Since none of the prospective science teachers in the experimental group knew about argument maps before the lesson, they were firstly given a 4 hour preparatory lesson at the beginning. The preparatory lesson started with a series of questions such as "How will you find out if you are right?", "What would you say to someone who disagreed with you?", "What if someone said that they thought that both strings should work equally well?", "What if they said it was the acoustical guitar was made of wood and wasn't plugged in?" from Yerrick (2000) to warm up the prospective science teachers. Afterwards, they are presented with some propositions from Osborne (2005) such as "Day and night occur as a result of Earth's rotation", "Plants use  $CO_2$  which is in the atmosphere" and "Matter is composed of atoms" where they may meet in an ordinary science class and they are also asked to determine which of these are true and explain why they think to be true. The second lesson started with the materials from Lederman & Abd-el Khalick, (1998, p. 88-90) named Trick Tracks which show tracks exposed from an archaeological dig. The prospective science teachers are asked to imagine and discuss about what may have been the cause of such tracks. This activity is followed by the graph activity of Osborne, Erduran, Simon & Monk (2001) offering two possible graphs (one correct and the other is mistaken) related to the change in tempera-

ture with time as ice heated to steam. Prospective science teachers are asked which of the graphs are true with explaining their claims with reasons. The aim of these activities is to make prospective science teachers explain and justify their ideas with plausible reasons and construct their arguments by pointing out data-evidence-reason-claim relation. The third lesson is about how to compose an argument from a given event and how to analyze the structure of an argument by mapping. They were introduced with *construction of an argument* part which is explained above through simple scenarios extending from everyday issues to scientific ones. A sample scenario was analyzed by the researcher to whole class through mapping by explaining the parts of an argument: data, evidence, reason, backing, qualifier, and rebuttal. The reasoning was also completed by reading the map. Afterwards, students were given scenarios and asked to map the arguments in groups. After checking for their argument maps, they were given two scenarios which are similar with the ones during the treatment as homework for the following lesson. The fourth lesson started with controlling the home works by sharing and discussing with the whole class and making prospective science teachers to revise their argument maps accordingly. Finally, they are told how to support their inquiry with the argument maps as explained in *treatment in experimental group* part.

#### Data Analysis

The data were analysed in two steps. Firstly the analysis of gathered data from each data collection tool which are qualitative in nature was conducted and scores were obtained. Secondly, the statistical analysis took place over these scores.

For the data collected through SPST, while each question in the first part was evaluated over 2 points (1 point for the correct choice and 1 point for the correct and full explanation), each scenario in the second part was evaluated over 4 points (4 points for the correct and full answer, 3 points for the partly correct answer –including more than one science process skills with reasons-, 2 points for inadequate correct answer –including single science process skills with its reasons, 1 point for poor answer –including single science process skills but no reason, 0 point for the irrelevant answer). The highest score that can be obtained from SBST is 34 (18 points from the first 9 questions and 16 points from the 4 scenarios). The answers were evaluated for two times in a three week interval by the same researcher. The level of agreement between two scorings of the researcher was found to be 0.97 as for providing the reliability of the evaluation.

The data obtained through EVQ was analyzed by using the rubric developed by Ünal Çoban, Ateş & Kaya Şengoren (2010). This rubric evaluates the answers by classifying from an immature understanding of science that is not able to distinguish the scientific activities and thoughts to mature understanding of science that is the scientific knowledge is the product of thought testing in a fair manner. The summary of the scope and scoring of the rubric is given in Table 1.

**Table 1. The scope and scoring of the rubric used for EVQ (Ünal Çoban and et. al, 2010).**

Score	Content
0	Irrelevant answer or no answer. (0 point)
1	She or he is not able to distinguish the scientific activities and thoughts. The scientific activities are not well defined and undetermined. The required motivation for completing and sustaining a scientific activity is established over succeeding the activity itself not constructing or testing ideas. (1 point)
2	She or he realizes the importance of thoughts for science and scientific activities. However, one has no definite idea how this occurs. Although she or he starts to understand the importance of thinking, the nature and kind of thinking is undetermined. (2 point)
3	She or he realizes that thoughts are justified by fair testing through experiments and activities. She or he knows that justification of scientific knowledge leads believing it. She or he distinguishes thoughts, experiments and results of experiments. She or he has the idea of hypothesis testing. (3 point)



According to Table 1, the highest score that can be obtained from EVQ is 15 since 3 points is given to full answer for each question. The rubric was piloted on the answers of another 10 prospective science teachers. The answers were evaluated for two times in a four week interval by the same researcher. The level of agreement between two scorings of the researcher was found to be 0.93.

The dependent variables of the research are post-test scores of SPST (POST-SPST) and post-test scores of EVQ (POST-EVQ). Independent variables of the research are Pre-test Scores of SPST (PRE-SPST), Pre-test Scores of EVQ (PRE-EVQ) and Inquiry Supported by Argument Maps (ISAM) as the method of teaching. Simple descriptive statistics (mean, SD), correlations were calculated. In order to test the hypothesis, MANCOVA was conducted, because it can equate groups on one or more independent variables and be used for multiple dependent variables.

## Results of Research

Before comparing the means of both groups, the researcher conducted descriptive statistics. The results are given in Table 2.

**Table 2. Descriptive Statistics related to SPST and EVQ scores.**

	Experimental Group		Control Group	
	Pre	Post	Pre	Post
<b>Scores on SPST</b>				
N	29	29	31	31
Mean	24.17	28.21	25.58	26.25
SD	3.90	2.45	3.73	3.13
Skewness	-0.54	-0.64	-0.24	-0.32
Kurtosis	-0.96	-0.62	-1.34	-1.04
<b>Scores on EVQ</b>				
N	29	29	31	31
Mean	7.31	7.10	6.64	5.90
SD	1.58	2.21	1.30	1.01
Skewness	0.25	-0.887	0.52	0.41
Kurtosis	-0.31	2.49	-0.76	-0.60

Table 2 indicates basic descriptive statistics related to the pre and post SPST and EVQ scores. The highest scores that might be obtained from SPST would be 34. The mean SPST score of experimental group was smaller than that of the control group in the pretest, whereas it was higher in the posttest. The mean scores of both groups were increased to some degree from the pretest to the posttest. The mean increase for the experimental group (28.21-24.17) was 4.84 and the mean increase for the control group was (26.25-25.58) was 0.67. The highest score that might be obtained from EVQ would be 15. The mean EVQ score of the experimental group was higher than that of the control group both in the pretest and the posttest. The mean scores of both groups were decreased to some degree from the pretest to the posttest. The mean decrease for the experimental group (7.31-7.10) was 0.21 and the mean decrease for the control group was (6.64-5.90) was 0.74. All skewness and kurtosis values were in the acceptable range known as the skewness and the kurtosis values are expected as near 0 and 3 respectively for a normal distribution (Ferguson & Takane, 1989, p. 78-79).

In order to determine the covariates as potential confounding factors of the study covariates were determined. It was seen that the independent variables, PRE-SPST and PRE-EVQ had significant correla-



tions with at least one of the two dependent variables and low correlations among themselves (Table 3). Therefore, they were taken as covariates for MANCOVA (Stevens, 2002, p. 345).

**Table 3. Significance of test correlations between dependent and independent variables.**

Variables	Correlation Coefficient			
	PRE-SPST	PRE-EVQ	POST-SPST	POST-EVQ
PRE-SPST	1	0.191	0.283*	-0.094
PRE-EVQ	0.191	1	0.273*	0.270*

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

All the assumptions of MANCOVA (normality, homogeneity of regression, equality of variances, multicollinearity and independency of observations) were tested and verified. The MANCOVA was used in this research to detect the effect of the ISAM on the collective dependent variables of the POST-SPST and POST-EVQ when the PRE-SPST and PRE-EVQ were controlled. The null hypothesis, claiming that there were no significant effects of ISAM on the population mean of the collective dependent variables of the POST-SPST and POST-EVQ when the PRE-SPST and PRE-EVQ were controlled, was rejected according to the MANCOVA results. The findings of Wilks'  $\Lambda = 0.79$ ,  $F(2,55) = 7.43$ ,  $p < 0.001$  showed that there was a significant mean difference in favor of ISAM on the collective dependent variables of the POST-SPST and POST-EVQ when the PRE-SPST and PRE-EVQ were controlled.

In order to test the effects of the ISAM on each dependent variable, ANCOVA was conducted as follow-up test. Table 4 shows the ANCOVA results. The method of dividing hypothesis-wise alpha level by the number of dependent variables (0.05/2) and testing each ANCOVA at alpha level of 0.025 to control experiment-wise alpha level was used in this study to control for Type I error across the multiple procedure. Since the researcher is obligated to consider the error rate (probability of making a type I error) in terms of the experiment, not merely in terms of each comparison (Jacobs, 1976).

**Table 4. Comparisons for scores of Science Process Skills and Epistemological Views.**

	df	F	Sig.	Eta Squared	Observed power
POST-SPST	1	8.7	0.005	0.134	0.83
POST-EVQ	1	4.4	0.041	0.072	0.54

The result of the ANCOVA revealed that the ISAM has significant effect on the POST-SPST,  $F(1, 59) = 8.7$ ,  $p < 0.025$ ,  $\eta^2 = 0.134$ , but no significant effect on the POST-EVQ,  $F(1, 59) = 4.4$ ,  $p > 0.025$ ,  $\eta^2 = 0.072$ . As  $\eta^2 = 0.134$  showed, 13.4% of variance of POST-SPST was associated with ISAM. In addition, the observed statistical power for POST-SPST was 0.83 indicating that a high probability (83%) of finding this difference (or significant effect) in the population.

## Discussion

The current study investigated the effectiveness of the ISAM on prospective science teachers' science process skills and epistemological views. The descriptive statistics results showed that the ISAM improved the mean SPST scores of students more than inquiry as both groups were increased their scores to some degree from the pretest to the posttest and the mean increase was higher for the experimental group (Table 2). However, the ISAM could not help students' improve their epistemological views since the mean EVQ scores of both groups were decreased to some degree from the pretest to the posttest. It is also interesting that the ISAM seem prevented a more mean decrease in EVQ scores compared to inquiry. It may be claimed that, although epistemological issues are not directly and explicitly presented in both methods of teaching, inquiry supported by argument maps led an epistemological awareness.



Following the descriptive statistics, when the comparisons for scores of SBST and EVQ are examined for statistical significance (Table 4), it is seen that the inquiry supported by argument maps made significant effect on prospective science teachers' science process skills but no significant effect on prospective science teachers' epistemological views. The effect size (0.134) and the observed statistical power (0.83), calculated for POST-SPST showed that the change in prospective science teachers' science process skills could be explained by the study which has also practical significance over the entire population. In other words, inquiry supported by argument maps significantly affected the prospective science teachers' science process skills.

The result of this study regarding the science process skills has similarities with the previous researches. For example, Kelly & Takao (2001), studying with university students about inquiring by writing down arguments in geology lesson, found that student generation of scientific argument derived from real earth data improved their scientific inquiry skills. Lawson (2002), in his study with prospective biology teachers where they submitted written arguments as lab reports, also found out that when students were able to manipulate observable hypothesis causes they argued well and understood and developed adequate hypothesis-testing skills. Moreover, Sampson & Gleim (2009) claimed that the argument-driven inquiry model where the laboratory task is presented to the students as the problem and they produce arguments based on laboratory experiences in groups has the potential of fostering scientific literacy since the students actively involved in science process skills during argument sessions.

The results related to epistemological views are in conflict with Yerrick's (2000) research result which concluded that inquiry instruction improved the high school students' views in consistent with the nature of the scientific arguments including students' tentativeness of knowledge claims, students' use of evidence, and students' views regarding the source of scientific authority. However, Newton and et al. (1999) offered that taking part in activities require students to argue the basis on which knowledge claims are made and as a result they begin to gain an insight into the epistemological foundations of science itself. The results obtained from the descriptive statistics (Table 2) may address this kind of awareness showing a slighter decrease in epistemological view scores when compared to inquiry. This finding corroborates with claims of Von Aufschnaiter and et al. (2007) revealing that lessons based on argumentation seem to have no direct impact on students developing a new understanding in a sense that it emerges within the discourse directly rather it helps students to improve what they already know. Therefore, it may be concluded that although inquiry supported by argument maps made no significant effect, it helped prospective teachers raise epistemological awareness.

The results also points out that explicit teaching about the nature of science or scientific epistemology is required for improving the epistemological views of prospective science teachers (Bell, Lederman & Abd-El-Khalick, 1998). Moreover, when the studies conducted with other instructional methods on the epistemological views are examined, such as model based education (Ünal Çoban, 2009) and inquiry (Caliskan, 2004), it was seen that it is hard to change the epistemological views as they are fed by different fields such as psychology, content knowledge, attitude and etc. (Chin & Brewer, 1993; Sandoval, 2005). Besides the explicit teaching about epistemology of science and students' resistant to change their epistemological beliefs, another point to pay attention should be the duration of the treatment in the experimental group. As the partially less decrease of the mean EVQ scores of the experimental group may offer thinking that as the duration time of the study gets longer better results might be obtained.

The above results may also due to the fact that getting individuals to adopt argumentation is a long term and difficult process (Osborne, 2005; Erduran, 2006, Prain & Hand, 1996) including the individual differences. These individual differences may range from willingness and preparedness to learn from engaging in argumentation and epistemological beliefs to having mistaken views about argument as a disagreement and resulting in not appreciating the role of argumentation as a normal part of the working of science (Nussbaum et al., 2008, p.1978; Nussbaum & Bendixen, 2003; Duschl & Osborne, 2002; Bell & Linn, 2000). Therefore, at this point, the prospective science teachers' understanding and perception about argumentation should be taken into account.



## Conclusions and Implications

The current study showed that inquiry supported by argument maps had significantly affected the science process skills of prospective science teachers. However, it was found to be not affective on the epistemological views of prospective science teachers. The results of this research suggest that inquiry supported by argument maps may be used in order to create a significant difference in science process skills. On the other, it may take some time to see the effects of inquiry supported by argument maps on the epistemological views.

It may be concluded that prospective science teachers' use of inquiry supported by argument maps is useful for both displaying and internalizing the science process skills as a means of scientific literacy. This study also revealed that the curricular emphasis on inquiry should be supported by practises in order to have a significant gain in science process skills. This study also mapped out a route for inquiry teaching through use of argument maps to overcome the obstacles about inquiry teaching mentioned in the introduction session. As a method of teaching it not only gives insight about how to structure argument and solve problems, it also helps prospective science teachers how to conduct inquiry in their future classrooms.

However, it is thought that the study should be repeated with different groups of prospective science teachers in order to raise the external validity of the research. It also needs to be tested for longer periods of time in order to see its effect on epistemological views. Another point that requires testing is to see the effects of argumentation (or indirect teaching) and explicit or direct teaching of the scientific epistemology on epistemological views. For this, a new set of inquiry supported by argument maps should be designed for teaching the scientific epistemology based on true stories from the history, philosophy, sociology and psychology of science in order to see the effects of the method on epistemological views by treating directly on.

Moreover, as a follow up study, examining the argumentation patterns of the prospective science teachers worths examining since they reveal the level of coordination of evidence and theory as a kind of reasoning process. The results may be helpful for finding ways of improve the method of inquiry supported by argument maps.

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