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Exploring Pre-Service Science Teacher Methods and Strategies for The Driving Questions in Research Inquiry: From Consulting an Instructor to Group Discussion

Miraç Aydin
Elementary Science Education, Department of Primary Education Karadeniz Technical University, Fatih Faculty of Education, Trabzon, TURKEY

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An important stage in any research inquiry is the development of research questions that need to be answered. The strategies to develop research questions should be defined and described, but few studies have considered this process in greater detail. This study explores pre-service science teachers' research questions and the strategies they can engage in during inquiry. A total of 59 pre-service science teachers who attended an undergraduate Fieldwork Course participated in the study. A single, holistic case study design was used along with an open-ended questionnaire and documents for data collection. The questionnaire was conducted at the end of the course, and documented inquiry reports were analyzed. The results indicate there are 11 methods for defining driving questions. These range from consulting an instructor to group discussion; 21 different strategies can be produced using these methods. These research question defining methods and strategies should be applied as a coding scheme for future studies and expanded. Any research question defining strategies unfamiliar to pre-service science teachers, such as field trips, brainstorming, and concept maps, should then be taught.

Keywords: inquiry, driving question defining strategies, pre-service science teachers.

INTRODUCTION

One of the important stages in any inquiry is the development of driving questions that need to be addressed (Creswell, 2013; Robinson, 2013). Driving questions to address can be called authentic questions, probing questions, or an ill-defined problem, ill-structured problem, ill-posed problem, a major research question or a real-world problem. They can elucidate the understanding of subject

Correspondence: Miraç Aydin,
Karadeniz Technical University, Fatih Faculty of Education, Department of Primary Education, Elementary Science Education, Trabzon, TURKEY
E-mail: miracaydin81@gmail.com
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matter, drive the activities, organize concepts, and influence artifacts (BIE, 2013; Blumenfeld et al., 1991; Krajcik, Blumenfeld, Marx, & Soloway, 1994; Stefanou, Stolk, Prince, Chen, & Lord, 2013). However, it can be very hard to identify and describe these questions precisely because the task is complex, and it must be authentic. The task can also produce multiple solutions (Jonassen, 2000). Defining and converting these questions into a researchable form remains a challenge for many pre-service science teachers (Ay, 2013; Robinson, 2013). Since pre-service science teachers have limited knowledge and ability about doing such an inquiry, they may have difficulty when trying to define driving questions (Marshall, Petrosino, & Martin, 2010).

Theoretical framework

Previous studies on defining research questions have focused on three primacy topics. The first is the aspect of a good research question, then determining a viable criteria for testing it, and finally, knowing the goal of the project and its relationship with either group size or the number of individuals in that group (Apedoe, Ellefson, & Schunn, 2012; Colley, 2008; Krajcik et al., 1994). Apedoe et al. (2012) posit that if the objective of the inquiry is to reach basic knowledge, group size or the number of individuals in a group remains unimportant; however, if a complex and high-level question is identified, then the number of individuals in that group should be only three or four. The second topic involves the pitfalls related to discerning the right strategies (Burgaz & Erdem, 2006) and the relationship between these question defining strategies and higher order thinking skills, such as creative thinking, critical thinking, problem-solving, and decision-making (Ennis, 1985; Yang, 2015).The third topic is the ways recommended to identify a research question and the relationship of these ways to the number of individuals actually in the group who are assigned to make an inquiry. Some of the ways are working with groups (Colley, 2008) intensive thinking on an area of interest or the challenges (Colley, 2008; Katz & Chard, 2000), conducting field trips (BIE, 2013; Kisiel, 2006; Robinson, 2013; Tortop & Özek, 2013), brainstorming (Colley, 2006), creating a topic web that organizes the ideas for the project (Katz & Chard, 2000), and using concept maps (Rye, Landenberger, & Warner, 2013). Some of the inquiries can also be instructor-selected since the research question is usually given directly by the teacher. However, the teacher's role should be one of an advisor or offering guidance instead of only instructor (Katz & Chard, 2000; Singer, Marx, & Krajcik, 2000). Robinson (2013) concluded that the number of groups is a significant factor in the actual process of identifying the problem in small courses. In small groups, students can select a research question in accordance with their interests; however, the research problem should be communicated by the teacher or instructor in larger groups.

Although several studies have reported on the different methods for defining research questions, there were no current studies that have examined these methods in more detail. It is possible for students to combine two or more methods and call it strategy while defining driving question. Studies on the organization of the strategies and the issues regarding their frequency of use have also been limited.

The goal of this study is to explore the strategies of pre-service science teachers when defining driving questions in an undergraduate course, as they engage in a specific inquiry. To achieve this goal, the following research question was addressed:

What are the methods and strategies that pre-service science teachers use for defining the driving questions of an inquiry?

METHODOLOGY

METHOD

An embedded, single-case study design was used in this study. Yin (2009) stated that this type of study includes more than one subunit and several units of analysis for a single case. The case study here is on a Fieldwork Course which pre-service science teachers were engaged in to explore pedagogical or pedagogical content learning, and it involved two units of analysis (subunits). The first unit included the methods, while the second revealed the different strategies that were formed by combining two or more methods and pre-service science teachers used to define their driving questions. Two different instruments were used to collect data for each subunit (Creswell, 2013; Yin, 2009).

Participants

The participants in the study were 59 pre-service science teachers' enrolled in a graduate level Fieldwork Course, an elective course in their senior year. The intent was to conduct this study with 93 science student teachers who attended the course; however, 34 of didn't response the research instruments. to volunteer. The group was made up of the education faculty at a state university in Northeast Turkey, and 36 females and 23 male student teachers participated in the study with their ages ranging from 24 to 30. The study was carried out in the academic year 2013-2014.

The fieldwork course

This course was an undergraduate course that met two hours each week and lasted 14 weeks. There were two sections the 14-week course; 5 weeks were theoretical, and 9 weeks were practical. The course was delivered under the supervision of four instructors who were researchers studying at science education.

The theoretical segment

In the theoretical segment, using direct instruction, the instructors introduced the participants to how they could design and evaluate an inquiry in science education. Specifically, the instructors introduced relevant topics, such as the basics of educational research, qualitative and quantitative approaches to inquiry, data analysis, and the writing of research reports.

The practical segment

Before starting this segment, the participating science student teachers were divided into thirty groups in which there were 3 or 4 students. Each group was assigned to create and complete an inquiry on science education, such as science learning, science teaching, educational technology, and environmental education in 7 weeks, and then introduce their topics to their peers during 2 weeks. They were allowed to study together on their investigations. Each group also was liaised with a science instructor who could help the student teachers with their investigations. Thus, two instructors supervised the 7 groups, while the other two instructors provided guidance to 8 groups both in class and outside the classroom. Each driving question, as defined by the group members, was reviewed by instructors.

After the driving question was acknowledged and approved, the groups implemented their inquiry and prepared a research report that included the driving question, the rationale, the participants, the procedure or method, data analysis, conclusions, and references. They then explained their work to the whole class using PowerPoint presentations to summarize their inquiry. Instructors used formative assessment to score the achievement of the science student teachers efforts. They observed group-work, and examined reports, and observed the presentations. Examples of the inquiries included examining 8th grade students' misconceptions on heat and temperature in a middle school; exploring reasons for not using a laboratory while teaching science, and exploring the different views of experienced science teachers on socio- scientific issues.

Procedure

This study related to the Fieldwork Course and specifically was about the period of time during which a problem was identified. The data was collected during and after the pre-service science teachers had completed their inquiries.

Instrumentation

Data sources included an open- ended questionnaire and documents (project reports) as qualitative data. Creswell (2013) noted that data may be collected through such tools as open-ended questions and documents, but what matters is collecting as much data as possible using multiple data sources.

The open-ended questionnaire

An open-ended questionnaire was adopted to clearly identify the methods and strategies used to define the driving questions in the student teachers' inquiries. It was administered at the end of the Field Work Course. These open-ended questions were sent to 93 student teachers; however, only 59 were returned because the others did not want to participate in the study. The open- ended questions asked the student teachers to write down their driving question, describe how they defined them, how long it took to define them, and what aspects they took into consideration when selecting a driving question. The questions were developed by the researcher and reviewed by two science educators to provide good content validity. The questionnaire was piloted with 10 science student teachers and as result the following items were removed due to their irrelevant responses and explanations: why it was important to define a driving question in an inquiry; and why they chose to research their research topics.

Research reports as documents

The project reports produced by the 59 pre-service teachers following the implementation of the driving questions were used to identify the topics of the inquiries. The project reports that were prepared by 30 groups were used for the document analysis.

Coding scheme for question defining methods and the data analysis

The research question defining strategies were determined in accordance with the problem defining methods. First, the methods were defined and then strategies were formed by combining the methods. Previous research studies (Colley, 2006, 2008; Katz & Chard, 2000; Kisiel, 2006; Robinson; 2013; Rye et al., 2013; Tortop & Özek, 2013) were reviewed to define methods recommended and each method recommended were given a symbol. Throughout the process of reviewing 7 methods (FT, In, B, CM, I, D, and L) were determined and presented in Table 1. While coding the written answers in the questionnaire were carried out with 59 pre-service teachers, 4 more methods (E, O, C, and Cr) which were not mentioned in the literature were identified and represented by symbols in Table 1.

Each of the 59 responses and the reports from 30 groups was given a number and they were coded to define research question defining methods for each group in accordance with the coding scheme presented in Table 1. To provide reliability, all the questionnaires were coded by 2 coders with a similar background and generated by an inter-coder agreement. The codes were organized until a consensus was achieved. The frequencies of these methods are presented in Table 2.

The symbols used for the methods were also used and combined together for the strategies; however, new symbols were produced to explain each strategy clearly. For example, for the symbols, X represented a research question, $X_{1,2}$ represented two or more driving questions, X^{I} represented the changed driving question in line with the instructor feedback, X_1 represented the question selected to use from the questions by the instructor and X_3 represented a suggested driving question by the instructor, as the questions offered by the pre-service science teachers were not regarded as researchable. For example, strategy L-$X_{1,2}$-I-X_3 (S16) (see Table 3) indicates that after the literature review (L), two or more driving questions were identified ($X_{1,2}$) and the instructor commented on them (I), However, these questions could not be studied and thus, a new problem was suggested by the instructor (X_3). In another example, strategy L-X-I-X^{I} (S12) (see Table 3) indicates that, following the literature review (L) the question was identified (X), the instructor was consulted (I), and the problem was changed in line with the instructor's suggestions (X^{I}). By combining the methods in this way, 21 strategies were identified. To ensure the reliability of the coding, another researcher working in the field of science education examined all the strategy codes, and the strategies were finalized by reaching a common consensus on their coding.

Table 1. Symbols, names and descriptions for driving question defining methods

	Symbol	**Name**	**Description**
Those from the literature			
	FT	Field trip	Conducting field trips
	In	Investigation an area of interest	Investigating a subject of interest
	B	Brainstorming	Brainstorming
	CM	Concept map or topic web	Creating a topic web or using concept map
	I	Consulting the instructor	Consulting the instructor to have the identified problem checked or to identify a problem
	D	Discussion	Making discussion between group members to make a choice from the identified problems
	L	Literature review	Examine previous studies conducted on selected topics
Others (Those included in this study)			
	E	Using experiences	Using learning experience
	O	Observation	Making observation in faculty or practice school
	C	Curiosity	Selecting a problem or issue of curiosity among the subjects identified
	Cr	Studying current issues	Studying the topics discussed recently

RESULTS

The data analysis results are presented in two separate sections on methods and strategies to define the driving question. Driving question defining strategies were also divided into two parts, the first pertaining to the frequency of use and the second to the starting method used.

Methods used to define the driving questions based on frequency of use

The pre-service science teachers used 8 out of 11 methods listed in the coding scheme as presented in Table 2. It shows that consulting the instructor (I, f=30) had the highest frequency of these 8 methods. This method was applied in two ways, namely, to consult the instructor to have an identified question checked and help identify a question.

The method defined as literature review for identifying a question or reviewing the scientific studies conducted on a selected topic (L, f=21) was ranked second. This method was followed by curiosity (C, f=8), observation (O, f=6), studying current issues (Cr, f=5), using experience (E, f=2), investigating an area of interest (In, f=2) and discussion (D, f=2). The pre-service science teachers did not undertake a field trip (FT), brainstorming (B) and drawing a concept map or topic web (CM) as methods

Strategies used to define the driving questions

The driving question to define strategies for frequency of use

The pre-service science teachers identified their driving questions using 11 methods in various rankings; the researcher defined 21 strategies used for this process (see Table 3).

As seen in Table 3, the strategies were divided into 2 groups (multi or single use) in terms of their frequency of use. S1 is the most preferred among the multi-used strategies, followed by S2, S3, and S4. The strategies S5 to S21 were used only once. In other words, 4 strategies were used multiple times, while 17 strategies were used only once.

Table 2. Frequency of driving question defining methods

Symbol	Method	Frequency
I	Consulting the instructor	30
L	Literature review	21
C	Curiosity	8
O	Observation	6
Cr	Studying current issues	5
E	Using experiences	2
In	Investigation an area of interest	2
D	Discussion	2
FT	Field trip	-
B	Brainstorming	-
CM	Concept map or topic web	-

Table 3. Frequency of research question defining strategies

No	Strategy	Symbol	Frequency
1	L-X-I-X	S1	6
2	L-Cr-$X_{1,2}$-I-X_1	S2	3
3	I-X	S3	2
4	Cr-$X_{1,2}$-I-X_1	S4	2
5	O-X-I-X	S5	1
6	O-L-X-I-X	S6	1
7	O-C-X-I-X	S7	1
8	O-C-L-X-I-X	S8	1
9	O-C-$X_{1,2}$-I-X_1	S9	1
10	O-C-L-$X_{1,2}$-I-X_1	S10	1
11	L-C-X-I-X	S11	1
12	L-X-I-X^I	S12	1
13	L-$X_{1,2}$-I-X_1	S13	1
14	L-Cr-C-$X_{1,2}$-I-X_1	S14	1
15	L-Cr-D-$X_{1,2}$-I-X_1	S15	1
16	L-$X_{1,2}$-I-X_3	S16	1
17	E-C-L-X-I-X^I	S17	1
18	E-L-X-I-X	S18	1
19	In-X-I-X	S19	1
20	In-C-L-X-I-X	S20	1
21	D-$X_{1,2}$-I-X_3	S21	1

The driving question defining strategies for starting methods

The strategies were also grouped as those starting with observation (O), those starting with a literature review (L), those starting with using experience (E) and investigating the area of interest (In) and those starting with studying current issues (Cr), discussion (D) and consulting the instructor (I).

Strategies starting with observation (O)

It can be followed symbols by starting with the symbol O to see all strategies detailed in Figure 1. Strategies starting with observation (O) were divided into two main groups for their eventuation as shown in Figure 1.

As can be seen in Figure 1, **in the first strategy**; only one question was identified (X), the instructor assessed the problem (I) and adopted the problem as is (X). In this class four strategies were defined. These strategies were S5, S6, S7, and S8. For example, in S5, the participants observed the classroom (O), defined a driving question (X), and the instructors checked it as the participants needed assistance (I). **In the second strategy**; two or more questions were identified ($X_{1,2}$), the instructor examined the problems (I) and chose one (X_1). In this group, 2 strategies were identified. These strategies were S9 and S10. For example, in S9, the student teachers observed the learning environment (O), wondered (C), defined their questions ($X_{1,2}$), the instructors checked them (I) and then chose one (X_1).

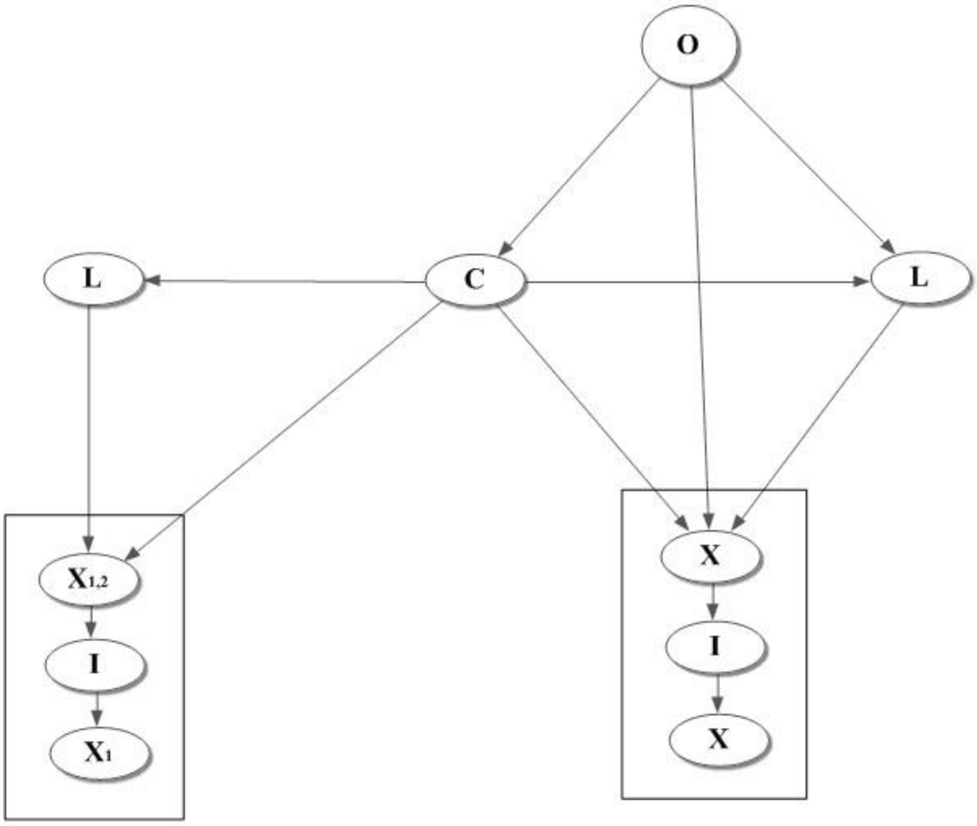

Figure 1. Research question defining strategies started with observation

Strategies starting with a literature review (L)

Strategies that started with a Literature review (L) were divided into four main groups in terms of their eventuation. They are presented in Figure 2.

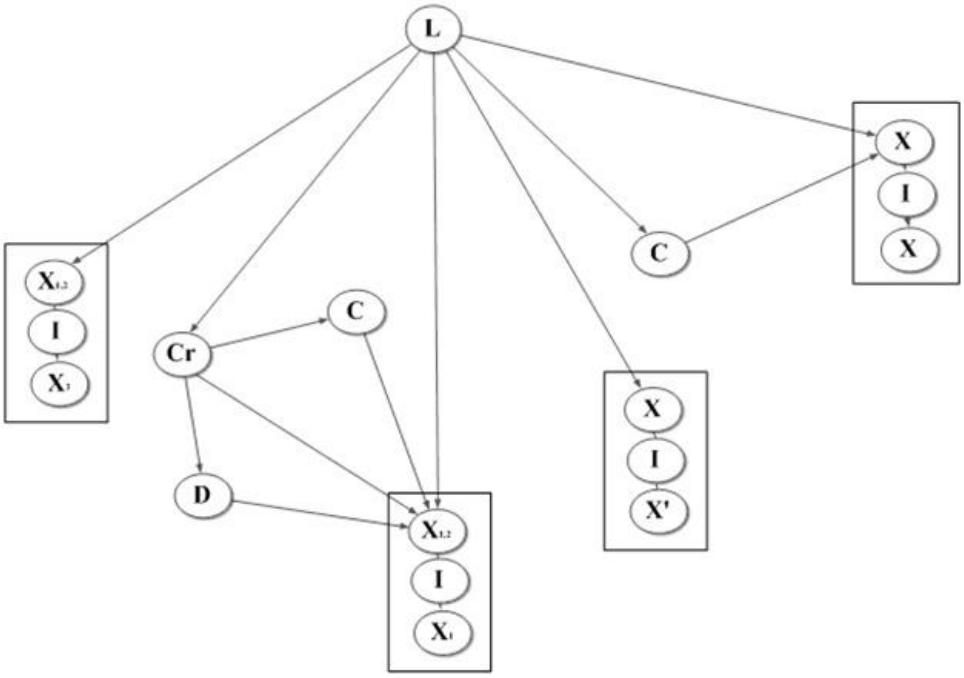

Figure 2. Research question defining strategies started with literature review

As can be seen in Figure 2, **in the first strategy** one question was identified (X), the instructor assessed the problem (I) and adopted the problem as is (X). Two strategies were determined in this group. These strategies were S1 and S11. **In the second strategy**, a question was identified (X), the instructor assessed the problem (I) and adopted the question after making a small change on it (X^I). S12 was determined in this group. **In the third strategy**; two or more questions were identified ($X_{1,2}$), the instructor examined them (I) and adopted only one (X_1). In this class, 4 strategies, namely, S4, S13, S14, and S15 were determined. **In the fourth strategy**; two or more questions were identified ($X_{1,2}$), the instructor examined them (I), but did not choose any of them. Instead, a new offered question (X_3). S16 was grouped within this group.

Strategies starting with using experiences (E) and topics of interest (In)

Since using experiences (E) and investigating an area of interest (In) had similarities in terms of their eventuation, they are presented together in Figure 3.

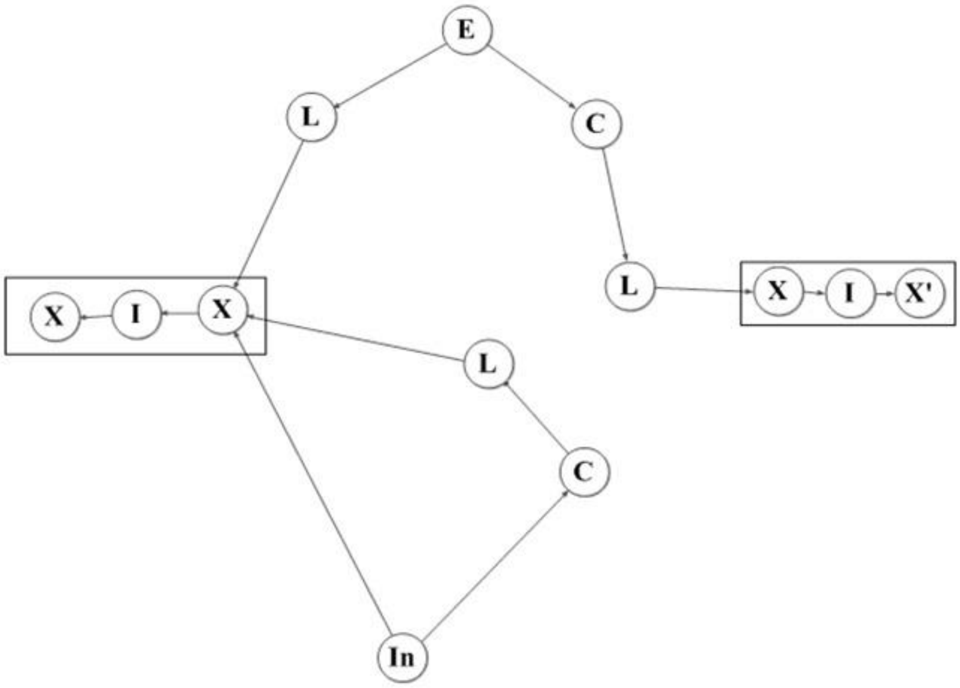

Figure 3. Research question defining strategies started with using experiences and topics of interest

Strategies starting with experience (E) were divided into two main groups in terms of their results. **In the first group**, a question was identified (X), it was assessed by the instructor (I) and a small change was made to it (X^I). In this class, one strategy, which was S17, was determined. **In the second group**; a question was identified (X), it was assessed by the instructor (I) and adopted as is (X). As in the previous group, one strategy, S18, was determined in this group.

Both S19 and S20 were found in this group.

Strategies starting with studying current issues (Cr), discussion (D), and consulting the instructor (I)

A total of 3 strategies were found here, including one starting with studying current issues (Cr), one starting with discussion (D), and one starting with consulting the instructor (I). They are presented in Figure 4.

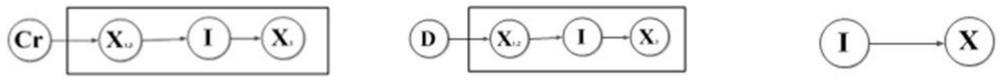

Figure 4. Research question defining strategies started with studying current issues, discussion and consulting the instructor

In the strategy starting with studying current issues (Cr), two or more questions were defined ($X_{1,2}$), and they were assessed by the instructor (I) and one was adopted (X_1) (S4). In the strategy starting with group discussion (D), two or more questions were defined ($X_{1,2}$), and they were checked by the instructor (I); however, none was adopted by the instructor since the instructor did not consider them appropriate and instead suggested a new question (X_3) and then requested the pre-service science teachers to study that new problem (S21). In the strategy starting with consulting the instructor, the question (X) was directly given by the instructor (I). The pre-service science teachers had no role in this process and simply studied the question given them (S3).

DISCUSSION AND CONCLUSIONS

Eleven methods that were used by the studied pre-service science teachers during the identification process of research question were determined (See Table 1). Of these methods a field trip (FT), investigation of an area of interest (In), brainstorming (B), a concept map or topic web (CM), consulting the instructor (I), discussion (D), and literature review (L) were already defined in the literature; while using experience (E), observation (O), curiosity (C), and studying current issues (Cr) were identified in this study (see Table 1).

Further, eight out of the 11 methods determined were actually used (see Table 2). It was found that the pre-service science teachers did not use certain of the specific methods, such as field trip (FT), brainstorming (B) and concept map or topic web (CM), already defined in the literature. This result can be explained, as pre-service science teachers did not know how to use these methods when identifying a driving question, and therefore, they did not employ these methods. Bulunuz (2011) concluded that pre-service science teachers do not undertake any investigations at all from elementary school to university; they make their first investigation during university study. Why pre-service science teachers did not use methods like field trip (FT), concept map or topic web (CM) and brainstorming (B) which is also relatively unknown to them becomes much more understandable now.

Marshall et al. (2010) noted that pre-service science teachers only have very general information about inquiry- based instruction, and this situation remains the same despite the education they receive. Ay (2013), however, stated that pre-service teachers are unfamiliar with inquiry-based learning, and thus, they find it difficult to undertake it; however, they will develop more positive attitudes, as they study this issue. Taking this point of view, it can be concluded that pre-service science teachers will define the driving questions using the methods they know best.

Consulting by the instructor (I) was the most-employed method of these 8 methods (see Table 2). The reason why the participants needed instructor consulting for identification of the question in each inquiry may be explained by the fact that the pre-service science teachers required support in order to actually identify a driving question. Toh, Ho, Wan, & Ang (2006) revealed that, in Eastern societies, students need strict guidance from their instructors in the learning process. In this sense, the findings obtained from this study are similar to those obtained earlier by Toh et al. (2006).

A total of 21 strategies were determined after defining the 11 methods used by the pre-service science teachers to identify research questions in various rankings. Meanwhile, 30 research questions were identified using 21 strategies (see Table 3).

The question defining strategies were divided into two groups, including those used once or multiple times (see Table 3). The number of inquiries in which these strategies were used was higher than the number of inquiries where the strategies were used multiple times.

Based on their eventuation, the strategies were classified as those accepted by the instructor as they were, those changed by the instructor, and those directly given by the instructor (see Table 3). The number of problems accepted by the instructor as was 14, namely, about half of all the inquiries (see Table 3). In other words, only half of the pre-service science teachers were able to define a researchable question.

In terms of their starting method, the strategies were grouped as those started by observation (O), those started with a literature review (L), those started by using experiences (E), those started by an investigation of an area of interest (In), those started by studying current issues (Cr), those studied through group discussion (D), and those started by consulting the instructor (I) (see Figures 1, 2, 3, and 4). When examined in terms of their starting methods, it can be seen that 8 out of the 21 strategies started with a literature review (L). In other words, the number of strategies starting with a literature review (L) was higher than for the others (see Table 3). This finding is thought to be caused by the fact that the pre-service science teachers needed a literature review to see prior investigations and find a new topic.

Research question defining methods should be applied as a coding scheme for future studies and can be expanded. Research question defining methods, such as a field trip, brainstorming, and a concept map or a topic web, should be introduced during the inquiry process of a class. These research question defining strategies can be taught to pre-service science teachers throughout their process of doing investigations.

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