

The Effects of Inquiry-Based Learning on Students' Learner Autonomy and Conceptions of Learning

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ABSTRACT

The purpose of this study is to compare the effects of inquiry-based learning and the regular science curriculum on students' learner autonomy and conceptions of learning. The students in the experimental group engaged in inquiry beginning with structured, continuing with guided and ending with open, while the students in the comparison group followed the materials used in the regular science curriculum. All students individually participated in three times 40-minute weekly sessions during a 14-week period. Data were gathered through individual interviews which were conducted with six students in total (three from the experimental group and three from the control group). Results showed that the inquiry-based learning caused students to move from participatory roles towards constructive ones, whereas the regular science curriculum did not alter participatory roles. Inquiry-based learning also enabled students' reproductive conceptions to change towards constructive conceptions. Students in the control group did not change their reproductive conceptions.

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Introduction

Students' acquisition of scientific thinking skills and learning scientific concepts, facts or principles meaningfully through inquiry, is the emphasis of many science curricula (Turkish Ministry of National Education [MoNE], 2013; National Research Council [NRC], 2011). While scientific inquiry is defined as scientific practices resulting from the work of scientists (Choi et al., 2014), these practices include the use of reasoning and evidence to construct and revise of argument, and to accept and evaluate alternative arguments. Moreover, it also requires sharing the argument in a community (Tan, 2018). Inquiry requires the accomplishment of complex learning tasks such as examining the cognitive structure, establishing a connection between existing information and new information, and using higher-order scientific thinking such as evaluation and analysis (Marshall et al. 2017). Students who cannot master these tasks may adopt conceptions such as copying or rote learning of new information without assimilating it (Malmberg et al., 2013; Salovaara, 2005). National examinations, which students have to take in order to determine their academic achievement in science courses, may orient them to think that science is equal to answering test questions correctly (Tsai, 2004; Wong et al., 2019). Furthermore, students may continue to hold conceptions of memorizing or testing although inquiry allows students to determine the content of what they wish to learn, to use their own specific learning methods, and to assess whether they have achieved their goals (Lin et al., 2012).

Inquiry provides a learning environment in which the students can decide independently what is to be learned according to their viewpoints, and in which students can encounter different outcomes at the end of the study (Levy et al., 2009). The degree of learner role possessed by the student is a challenge in the inquiry process. Zhang (2016) states that there is a conflict between the researchers who argue that open inquiry conducted in a guided way hinders student learning due to heavy cognitive overload (e.g. Kirschner et al., 2006), and the researchers who argue that teachers, by giving general explanations, provide support to students for inquiry through scaffolding (e.g. Hmelo-Silver et al., 2007). While empirical studies report that students' engagement in structured or guided inquiry improves their scientific skills in classroom contexts (e.g. Atikoh & Prasetyo, 2018; Di Mauro & Furman, 2016; Mulyeni et al., 2019; Wang et al., 2010), and achievements (Nasution, 2018) the effects of an inquiry whose openness level is gradually increased on students' understandings about the role that they have perceived and their conceptions about how they have learned are not clear (Lazonder & Harmsen, 2016). For example, if learner autonomy is increased, might the student perhaps suffer from a lack of confidence due to a task that he considers unable to carry out alone? Or, can student can make mistakes because he/she determines the stages of the inquiry, the student's conclusions may not be compatible with the scientific knowledge, and can the student perceive inquiry-based learning as a process that threatens his/her success (Harris & Rooks, 2010)? Further evidence should be provided for investigating how students' views about learner autonomy and conceptions of learning are affected when level of inquiry is changed. In this context, the purpose of this study is to investigate ongoing changes more deeply in students' autonomy in inquiry and their conceptions of learning.

Inquiry-based Learning

Inquiry is defined as a learning process of formulating questions and hypotheses, developing procedures to answer questions, gathering data by doing experiments or making observations, reaching a conclusion and communicating this conclusion (NRC, 2011). The inquiry starts with the students formulating an authentic research problem to seek answers to interesting ideas (Ku et al., 2014). When students are looking for answers to their research problem, they review their previous knowledge, determine which materials they will need, and generate a strategy to use (Chan, 2011). The students collect data through doing experiments, measuring and observing to test their hypothesis (Pedaste et al., 2015). The students use reasoning in order to draw a conclusion from their evidence, and creates a justification for this conclusion or revises the created justification (Zhang et al., 2015). Finally, the students communicate their conclusions with their colleagues in spoken or in written way. It is thought that inquiry, rather than progressing linearly on a straight line beginning with expressing a problem that the student is curious about and ending with the reached conclusion, has a more spiral structure in which the student advances by controlling his learning. For example, after gathering data, students can both go back in order to change the research problem and go forward in order to develop a new experimental design (Wu & Hsieh, 2006). Therefore, we think that students who are engaged in the inquiry process can change learning speeds by themselves and determine ways of learning by themselves.

Learner Autonomy in Inquiry

For elementary students, the role that they have in the inquiry process is important. To determine the role of the learner in inquiry, Herron (1971) separated inquiry into stages in term of questioning, material and results/outcomes characteristics. Later researchers defined these characteristics in more detail as questioning/theory, planning/problem, implementing/procedure, concluding/results/conclusion and reporting/communication (Buck et al., 2008; Chang et al., 2011; Cuevas et al., 2005). In confirmation inquiry, the students' aim is to answer a closed-ended question the answer of which is already known (Litmanen et al., 2012). In structured inquiry, the problem and method are given to the students, and the students are expected to reach a conclusion (Buck et al.

2008). In guided inquiry, only the problem is given to the students. And, the students are expected to find the method and result (Cheung, 2007). In open inquiry, however, all the stages are determined by the students (Janssen et al., 2014).

While researchers state that the students will be occupied with certain characteristics depending on the inquiry levels, it is considered that at inquiry levels, the autonomy of the students needs to be made more apparent. In this study, in order to determine the autonomy of the students according to the structured, guided and open inquiry levels, the receiving, participation and constructive participation categories were taken into consideration which are suggested by Valenčič-Zuljan (2007). According to Valenčič-Zuljan, these roles are explained as follows. First, receiving role is defined as the students' following the content as explained by the teacher and asking questions when they do not understand the content. Second, participation role identified as the students' having more freedom while relating their views, suggestions and comments regarding the content in addition to the teacher's explaining the content. Third, constructive participation role described as the students' deciding on the content just like the teacher and offering new viewpoints. The receiving role can be carried out at the level of inquiry where the students decide on the reporting/communication characteristics and the teacher decides on all the other characteristics. In order to investigate the problem determined by the teacher, the students follow a procedure previously specified by the teacher, and their role are limited to state the reached conclusions or inquiring about the parts they do not understand. Participation is a role in which the students play an active role in the characteristics of implementing, concluding and reporting, however the teacher decides on the problem, planning and also partially the implementation of the inquiry. Although students appear to have a more advanced role in the classroom with the participation role, since they do not in fact use minds-on skills and have a completely active role. On the other hand, a learner who has a constructive participation role has a deciding role in all the characteristics of the inquiry, and contributes to developing new viewpoints on the content learned by investigating different problems. Inquiry-based learning allows students to actively build knowledge while they realize learning self-directed rather than being passive receivers (Cairns, 2019). Although studies can be found which reveal the effects of different levels of inquiry on students' content knowledge and science process skills (Fang et al., 2016; Thoron & Myers 2011), there is limited number of studies in which students engaged in these levels explain in person how they perceive or how they change their autonomy. The study of Silva & Galembeck (2017) revealed that learning environments in which the students determined the stages of inquiry changed their perception of the confirmation inquiry level towards the open inquiry level. Furthermore, it has been revealed that students who conduct their own research processes themselves with open inquiry collaborate more with their colleagues than students dealing with guided inquiry, that they take more interest in a task that they are dealing with because they feel responsible for the performed task. As a result of this feeling of responsibility, they are more willing both to complete their tasks and to produce good quality work (Buchanan, 2018; Sadeh & Zion, 2012; Baldock & Murphrey, 2020). Similarly, Ramnarain (2020) found that through the participation of students in investigative inquiry projects that their autonomy increased in the stages of problem determination, planning the inquiry, conducting their inquiry and making conclusions.

In the light of the literature, there can be several questions to be answered. Considering that students with hands-on and minds-on skills have different competences despite belonging to the same learning environment, what kind of approach can be followed for determining inquiry level? Thinking more specifically, if we consider the changing continuum between confirmation and open inquiry, which level will it be more suitable for a specific class? Briefly, it is evident that for students who are just beginning inquiry to overcome the problems stated by the researchers, they will have more need of teachers' guidance, and that through this, they will gradually be able to reach a stage where they can conduct their research on their own (Cuevas et al., 2005). MoNE (2013) proposed a similar path for students moving up from elementary to middle school, based on structured inquiry for 3rd and 4th grades, guided inquiry for 5th and 6th grades, and open-ended inquiry for 7th and 8th grades. In this study, students' handling of inquiry activities at changing levels is targeted rather than their

engagement with the same level during the study. In this study, for the stages of inquiry, the five characteristics were selected which are suggested by Buck et al. (2008), Chang et al. (2011) and Cuevas et al. (2005) and as well as Buck et al.'s structured, guided and open levels. In the study, which are conducted over a 14-week period, it is aimed for fourth grade students to experience the designed activities according to the structured, guided and open inquiry levels. It is specified that the stages of inquiry as problem, planning, implementing, concluding and reporting, and beginning with the problem stage and moving towards the reporting stage according to the gradually increased the students' autonomy. Therefore, when naming the stages, in addition to the structured, guided and open levels specified by Chang et al., Cuevas et al. and Buck et al., its is decided that it was necessary to also include buffer zones between structured and guided inquiry, and between guided and open inquiry, that can be named guided to structured and guided to open levels. While students in the experimental group were taught with the aforementioned approach, students in the control group received instruction with structured inquiry. However, in this study, in contrast with previous studies, rather than comparing the effects of different inquiry levels on students, it is attempted to give an account based on students' viewpoints about learner autonomy in stages of inquiry at different levels.

Conceptions of Learning

Lin et al. (2012) define the conceptions of learning as a belief that allows us to understand how a learner's experiences related to a general or specific learning domain occur, and the reasons for these experiences. In Saljö (1979)'s study, the five definitions of learning, now widely accepted, they are presented as (1) an increase in knowledge; (2) memorizing; (3) an acquisition of facts or principles, which can be retained and used in practice; (4) an abstraction of meaning; and (5) an interpretive process aimed at understanding reality. Later, in Marton et al. (1993)'s studies, which show that conceptions of learning can change according to culture-specific content, a revised form of Saljö's conception of "changing as a person" was added to his study. Biggs (1994) stated that an individual could have different qualitative or quantitative viewpoints regarding learning. An individual may regard learning with a quantitative outlook, in which it is combined into independent pieces of information in order to know more, or with a qualitative outlook, in which it is advanced in spiral fashion by associating a new learning situation with previous knowledge. Establishing a connection between Biggs' viewpoint and Saljö's conceptions, Dart et al. (2000) stated that the first three conceptions bore the marks of a quantitative outlook, while the other two conceptions bore those of a qualitative outlook. For example, Tsai (2004) revealed in his study that students evaluated learning products in different ways, namely "How much have I learnt?" (quantitative) and "How well have I learnt?" (qualitative). By highlighting the quantitative structure of the first three conceptions determined by Saljö, these conceptions are identified as lower-level, whereas by highlighting the qualitative structure of the other conceptions, these are referred to as higher-level (Marshall et al., 1999).

Researchers have suggested that a students' conception can have a developmental structure, that is, it may begin at a lower level such as memorizing and change towards a higher level such as "changing as a person" as the learning activities are completed (Chiou et al., 2013). Moreover, it is argued that students' conceptions depend on educational contexts and knowledge domains (Chiu, 2012). Science-specific conceptions are defined as conceptions related to (a) what science is and to (b) which components the science learning process consists of (Benson & Lor, 1999). In Tsai's study, in which Taiwanese students' science conceptions were analysed with phenomenography, the conceptions of learning science were identified as "memorizing", "preparing for tests", "calculating" and "practising tutorial problems", "the increase of knowledge", "applying", "understanding", and "seeing in a new way". In a limited number of studies in which primary students' conceptions are examined (Y.H. Lin et al., 2012; Tsai & Kuo, 2008), the conceptions determined by Tsai and Saljö are taken as the reference. When examining students' conceptions in this study, since this study both

investigated students' conceptions specific to science and attempted to determine students' conceptions based on their explanations rather than with a questionnaire, it is also used the conceptions determined by Tsai. Regarding how the students learn the subject, since students learn subject "a" through lectures, they have a "memorizing" conception regarding this subject. On the other hand, since they learn subject "b" via inquiry-based learning, they have a "seeing in a new way" conception in this regard (Lee et al., 2008). However, the fact that the learning environment to which students are exposed is teacher- or student-centered may not necessarily result in these students having the same conceptions as each other. For example, even if they have had teacher-centered learning experiences, students may not regard the learning as acquisition of knowledge transferred from the teacher and as the repetition of that knowledge, but may emphasize learning as learning information from multiple sources and generating new meanings from this information (Lee, 2009).

Although the relationships between conceptions of learning and approaches to learning (Chiou et al., 2012) or epistemological beliefs (Chan, 2011; Shen et al., 2016) has been extensively studied in the field of science education, there are few studies focused on "What are students' conceptions prior to an inquiry-based learning environment?" and "How do these conceptions change as the level of inquiry changes?". For instance, within the scope of the topics of heat and temperature, force and buoyancy, and mixture and compound, through the inquiry-based learning, students who evaluate themselves by considering the assessments of their peers or teachers have developed the belief that they themselves are responsible for their learning and their own self-assessments are also valuable (Tuan et al., 2005). In conclusion, there is a need for a study that investigates students' learner autonomy and conceptions of learning in a learning environment in which inquiry levels are changed. Accordingly, in the present study, an inquiry-based learning environment organized for the domains of physics and astronomy is explored. The objectives of the study are to examine the effects of levels beginning with structured inquiry, continuing with guided inquiry and ending with open inquiry on over a 14-week period and of the regular science curriculum on students' a) learner autonomy and b) conceptions of learning.

Methods

This study is a part of a general project. In the project the students in the experimental group engaged in inquiry-based activities, while the students in the comparison group followed the materials used in the regular science curriculum. All students participated individually in three 40-minute weekly sessions during a 14-week period. In this study, the learner autonomy and conceptions of learning of participant students in both the experimental and control group were investigated before and after the intervention, while those of participant students in the experimental group were also examined throughout the 14-week period.

Participants

70 students in the fourth grade participated in the project. The students attended in two classes in a state school located in Bursa in the western region of Turkey. The students at the school are mostly from the middle socioeconomic level. All the students who took part in the study were appointed from regular science classes with mixed abilities and were from the same socioeconomic level. One class at the school was randomly selected as the experimental group, while another class was randomly selected as the control group. Within the scope of the project, the groups were given the achievement tests developed by the researchers for the "Light and Sound" and "Our Planet Earth" units as the pretest. The results revealed no significant difference between the two groups for scores obtained in the achievement tests ($F_{33}=2.44$, $t=0.352$, $p>0.05$; $F_{33}= 1.12$, $t=0.265$, $p>0.05$, respectively). Both groups were taught by the second author, who was both students for the master of science degree and had taught science at elementary schools for six years. 38 of the students were male (20 in

the experimental group and 18 in the control group), and 32 were female (15 in the experimental group and 17 in the control group). The students were between 10 or 11 years of age.

In order to determine the participant students in the experimental and control groups, it was necessary to define the terms of reference (Willig, 2013). With this aim, both the students' learner autonomies and their conceptions of learning were determined with pre-interviews. The students were placed in the categories of "constructive", "participatory" and "reproductive" (Valenčič-Zuljan, 2007) for inquiry autonomy and "memorizing", "preparing for tests", "calculating", "practicing tutorial problems", "the increase of knowledge", "applying", "understanding", "seeing in a new way" (Tsai, 2004) and "achieving" for conceptions of learning. The views of the participants revealed that they belonged to the categories of "reproductive" and "participatory" (n = 32, 38, respectively) and "memorizing" and "achieving" (n = 30, 40 respectively). Next, three students, each having a different level, were selected from each of the experimental and control groups, making a total of six students. While selecting these six participant students from each level, it is consulted with the class teachers and the teachers' approval was obtained regarding the validity of the groups that the students had been appointed to. The reason for selecting students with three different levels was to reveal how the views of students at different levels changed and what kind of differences occurred among the students.

The target students are Merve, Ayşe and Beril (all used names are pseudonyms). Of these students, Merve got the highest score, Ayşe got a moderate score, and Beril got a low score from the "Our Planet and Earth" and "Light and Sound" achievement tests, which were applied as a pre-test in the study. The classroom teacher stated that Merve's level of success was high both in the science lesson and in other lessons. Merve participated in science lesson with an interest in the research process. The second student, Ayşe, is an introverted student, according to the opinions of her class teacher, who hesitates to attend the class because she is afraid of making mistakes. The third student, Beril is a student who generally does not get good grades in exams, but expresses herself well in writing and verbally. However, Beril thinks that science is a very boring lesson. Three students stated that their teachers decided on the problem, method and result-interpretation stages of the inquiry before the research. This situation shows that the students have knowledge at the confirmatory inquiry level.

Context

In Turkey, all lessons from the first grade to the fourth grade are taught by the same teachers. The second author of this research taught the students in the experimental and control groups during a 14-week period for the study. The author was in fact a classroom teacher in another state school. Since a study in which her own students were included might result in a biased approach towards the students by the author, the researchers included students attending a different state school in the study. Starting from this viewpoint, the researchers aimed to determine the students' level of science process skills before starting the intervention. While a maximum score of 36 was obtainable from the "Science Process Skills Test" developed by the second author (Demirci, 2015), the mean score obtained by the students in the experimental group was 6.17. The aim in presenting this score was not to focus on the effect of inquiry-based learning on the students with this test, which is in fact used as a posttest within the scope of the project. Rather, the aim was to determine the crucial points in which students participating in this study would find it difficult to conduct an inquiry before they began our implementation. An attempt was made to eliminate these deficiencies with a study entitled "bean germination", which was conducted separately from the study, prepared at the structured level and lasting in three lesson periods. After the students had been given the problem, equipment and procedure, the researchers helped the students with forming a hypothesis and then with using the skill of controlling variables. To gather data, the students recorded the changes that they observed in their beans every day. After the study had been completed, since the students were observed to have

difficulty with the skills of hypothesis forming and controlling variables, they were allowed to practice these skills by being presented with new situations.

Design Procedure

In the study, inquiry-based instruction was carried out via 15 activities during a period of 14 weeks (Table 1). Two activities were completed in the first week. Since there was no laboratory at the school, the intervention was carried out in the classroom. Heterogeneous groups of five students each were formed based on the scores obtained in the Science Process Skills Test applied to the students. Firstly, the obtained scores by the students in this test were listed from the highest score to the lowest. Then, the students were classified in three groups as high, medium and low scores. A total of seven groups were formed in such a way as to include at least one student from each classification in each group. Throughout the study, the students in the experimental group did not receive instruction according to only one single inquiry level, but engaged in different levels of inquiry. Table 1 shows inquiry stages used by the students according to the activities organized for the units in each week. Some of the activities in the textbook were rearranged according to the aim of the research and the level of clarity of some activities was completely changed.

Table 1

Matrix of Inquiry Skills to Be Used by Students According to Activities Organized for Units

<i>Name of Activity</i>	<i>Pr</i>	<i>Pl</i>	<i>Im</i>	<i>Co</i>	<i>Re</i>	<i>IL</i>
<i>Light and Sound</i>						
1. What is Needed for us to See?	T	T	T	T + S	S	
2. Does Light Allow us to See?	T	T	T	T + S	S	St
3. Is Everything that Shines a Source of Light?	T	T	T	T + S	S	
4. Is Light a Kind of Energy?	T	T	T + S	S	S	
5. Let's be Properly Lit.	T	T	T + S	S	S	G↔St
6. Let's Make Sounds with a Balloon, Paper and a Ruler.	T	T	T + S	S	S	
7. Does every Sound Have a Source?	T	T + S	S	S	S	
8. Is Sound a Kind of Energy?	T	T + S	S	S	S	G
9. I'm Observing	T	T + S	S	S	S	
<i>Our Planet Earth</i>						
10. Let's Get to Know our Earth	T + S	S	S	S	S	
11. The Earth is Made of Strata!	T + S	S	S	S	S	G↔O
12. Rocks, Minerals and Soil	T + S	S	S	S	S	
13. It Takes Centuries for Soil to Form	S	S	S	S	S	
14. What if there were no Soil?	S	S	S	S	S	O
15. Let's Create a Project	S	S	S	S	S	

Note. Pr = Problem, Pl = Planning, Im = Implementing, Co = Concluding, Re = Reporting, IL = Inquiry level, T = Teacher, S = Student, St = Structured, G = Guided, O = Open

In the first unit, "Light and Sound", the students dealt first of all with structured inquiry (activities numbered 1, 2, and 3 in Table 1). In these activities, the students were given the research problem and plan, they examined these stages, and they were then shown how they were to carry out the experiment by the researcher. Finally, the students and the researcher made conclusions together and the students completed their research by using their reporting skills. The activities 4, 5 and 6 in Table 1 correspond to an inquiry level beyond structured inquiry but not yet corresponding to guided inquiry. That is, in the structured to guided inquiry, the students were given the research problem and plan. The students now began to gather data by themselves using the equipment, with following how

the experiment was to be carried out by the researcher. The students made conclusions to report their conclusions. By the end of the structured to guided inquiry activities, students were moved on to the guided inquiry level (7, 8, and 9). The research problem was given to the students, and the equipment was explained to them. Starting from this information that at hand, the students decided on the experimental design. The students were given the opportunity to gather data by themselves in their groups. They completed the research by carrying out the concluding and reporting stages. Now, in the "Our Planet Earth Unit", which was a new subject, during the activities numbered 10, 11 and 12 in Table 1, they completed the guided to open inquiry activities. In these activities, both the researcher and the students decided on the research problem. They completed the research by carrying out the implementing, concluding and reporting stages. Finally, in activities 13, 14 and 15, the students decided what they were to do at all stages of the research by themselves. In this way, the aim was for a student to improve his autonomy by increasing the number of decisions that he made in the inquiry stages (open inquiry).

Although the content learned in the experimental and control groups was the same, the control group was taught these subjects through teacher-centered instruction. The students in the control group learned the information by reading the textbook, repeating the read information, and taking notes. They worked by doing practical or problem-solving activities from the textbook. These activities were conducted at the structured inquiry level, where each stage was given to the student except the conclusion.

Data Collection

This study was intended to analyze how inquiry-based learning affects students' learner autonomy and how their conceptions of learning change. The data were collected by means of individual interviews which are conducted with selected target students from the experimental and control groups before beginning the intervention and after completing the intervention. The views of participants' students in both the experimental group and the control group were focused on to establish a solid evidence-based relationship between possible changes in participant students resulting from inquiry-based learning. It was also necessary to learn the views of the students in the control group in which inquiry-based learning was not included. On the other hand, since the aim of the study was to determine how inquiry-based learning affected the views of the participant students in the experimental group, the changes in views of the participant students in the control group were not included. Regarding learner autonomy in inquiry, the questions "What is the role of the teacher and student?" and "How should the teacher prepare the classroom environment for you to learn a topic?" were asked. With regard to conceptions of learning, the questions "What is your aim when learning a topic in science class, and how do you learn science?" and "What do you do while learning?" were asked (Marshall et al., 1999; Tsai, 1998). As mentioned earlier, students learnt science based on lecturing until the fourth grade. Therefore, students' preliminary views may be considered as a mixture of their views related to science and their views related to other subjects. Written questions were principally used with the aim of examining in depth how the views of participant students in the experimental group changed during the intervention.

The questions asked during the 14 weeks were the same in form as the questions in the pre- and post-interviews, but they were changed in a way appropriate to the subject content. Our aim was both to determine the views of students specific to the content and to prevent them repeating the answers they had given in the previous interview. The students' answers were collected in two stages: a) answers about learning conceptions collected before starting an inquiry activity, and b) answers about learner autonomy following completion of an inquiry activity. For example, the students answered the question "What is your aim in learning the topic of light and energy", and "How does being about to learn this topic make you feel?" before commencing the activity, and they answered the question "What did you do during the activities in the lesson", "What did the teacher do in the

lesson”, and “What were the resources and materials that you used?” after completing the activity. Interviews were conducted with each student and each interview were at least 15 minutes

Data Analysis

Interviews were audio-recorded. The researchers listened to the recordings and put them in writing. Moreover, the students’ written answers over the 14-week period were examined and the interview recordings and written responses were analyzed by the two researchers. Each researcher read the answers of the six students one by one, words or phrases that could represent the students’ views were noted, and these notes were compared with the notes made by the other researcher. The two researchers together summarized the views of each student and gave them their final form. In order to determine the qualitative differences between students’ views, these views were grouped into specific categories. The categories were formulated according to the existing frameworks in Valenčič-Zuljan (2007)’s study for learner autonomy in inquiry. The categories for learner autonomy are “receiving”, “participatory” and “constructive”. In this study, “memorizing”, “testing”, “achieving”, “understanding” and “applying” conceptions defined by Tsai are used directly. Besides, the conceptions of “curiosity” and “inquiry” were also formulated. The names of the codes and explanations related to learner autonomy and learning conceptions are presented in Table 2.

Table 2

Names of the Codes and Explanations Related to Learner Autonomy and Learning Conceptions

	Codes	Explanations	Examples of students’ views
Learner autonomy	Receiving	The student follows the teacher’s explanations of the content or the teacher’s instructions. A student who is passive, obedient and does not disrupt the flow of the lesson.	When our teacher explains, I learn. I use the information that the teacher has taught.
	Participatory	The student answers questions, makes comments, and makes suggestions related to the content explained by the teacher.	The teacher gives the student research homework. The student researches. Student writes down what student has researched, brings it to class and shows it to the teacher.
	Constructive	The student’s interpretation, participation and encouragement give a new perspective to the content (content studied), and together with the teacher, contribute to improvement of the content.	I ask questions related to that topic. I then make a plan to learn the topic. I determine how I will do the research and what I will investigate. I determine the place where I will do the research.
Conceptions of learning	Memorizing	The student memorizes or repeats the information conveyed by the authority.	I learn to memorize the topic very well.
	Testing	The student answers the test questions according to the learnt content.	What the teacher gives us are questions and exams. If our test exam is good, it means we are successful.
	Achieving	The student wishes to obtain high grades in exams and be considered successful by his teacher or friends.	I learn in order to get good marks in exams and to do better than my other friends in the class, such as student A. If I do better than him, I am successful.
	Curiosity	The student accesses information while seeking the answer to a problem that he is	I learn the subject of science in order to satisfy my curiosity by doing experiments, projects and research.

Understanding	curious about. The student utilizes his previous knowledge in order to access new information. He establishes a relationship between his previous knowledge and the new knowledge.	I know that light illuminates us. Light is the thing which is necessary for us to see. What can I do to increase light? I will use this knowledge to understand the topic very well.
Applying	The student establishes a relationship between previous knowledge/experiences and new information, and builds a bridge between what has learnt and daily life.	I want to learn new knowledge and to use this. We will prevent the destruction of trees; we will inform everybody.
Inquiry	The student uses scientific method to access information.	I wonder what the result of this experiment will be; I inquire as to what kind of result can be obtained in the experiment. The person who is to conduct the experiment must create a problem statement. He must ask himself what changes in the experiment there might be, what the hypotheses could be. Then he should conduct research in the laboratory. He should do experiments by writing down the things that he wonders about and his predictions.

While the students' views were being placed in the specified categories, the researcher used the most dominant category as explained by the student to represent their own views about learner roles and conceptions of learning, in the way suggested by Tsai and Kuo (2008). When coding was done independently by the two researchers, the concordance percentages calculated for each category were 95% for learner autonomy and 89% for learning conceptions.

Findings

Analysis of Students' Views on Learner Autonomy

The analysis of the learner autonomy of the students in the experimental and control groups prior to and following the inquiry is presented in Table 3. Prior to the intervention, some students (Merve, Enes and Tunahan) had adopted a participatory role. The teacher specified what the students were to learn (the content) and conveyed the content to the students. The students then carried out the assignments given by the teacher in order to deepen their knowledge. These assignments were selected from topics that the students were curious about. According to Merve, inquiry means "We will investigate the assignments given by the teacher...(Inquiry) we will inquire into the things we do not know via the internet and present (our findings) to our friends". This explanation shows that this student defined inquiry as seeking information. On the other hand, Ayşe, Beril and Elif considered that they did not have previous knowledge related to the content. The teacher should teach the lesson, in response to which, the students should listen carefully to the teacher and repeat what he has explained. Therefore, these students had adopted receiving roles.

Following the intervention, Elif, Tunahan and Enes (the control group) still had a participatory role. For instance, according to Enes, "Inquiry means learning the research topics given by the teacher through doing research on the internet or in the library, and putting our homework into

files and showing them to the teacher". On the other hand, the roles of Merve, Ayşe and Beyza (the experimental group) had changed. These students now considered themselves as scientists, since they were people who determined the aim of research, designed experiments, gathered data, formulated conclusions about the inquiry and discovered information. For example, in Merve's opinion, "The

Table 3

Learner Autonomy of the Students in the Experimental and Control Groups Prior to, During and Following the Inquiry

Group		Pre	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Post
Exp.	Merve	P	P	P	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	Ayşe	R	P	P	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	Beyza	R	P	P	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Con.	Elif	R																P
	Tunahan	P																P
	Enes	P																P

Note. Exp.=Experimental, Con.=Control, P=Participatory, R=Receiving, C=Constructive

teacher gives the students clues. We come to understand the topic as if we are solving a puzzle. The students do experiments and design experiments. They find the results of these experiments". Therefore, the inquiry-based learning environment was effective in the students' adoption of constructive roles for themselves.

The participatory or receiving roles possessed by the students prior to the intervention did not immediately change towards constructive roles after the intervention. When continuing with the structured inquiry activities (1, 2, & 3 in Table 1), Merve, Ayşe and Beyza still regarded inquiry as seeking information. For instance, in Ayşe's opinion, "The teacher gives the student an inquiry assignment. The student then conducts research. He writes down his research, brings it to class and gives it to the teacher". In this case, structured inquiry did not enable students to change their participatory roles. It is seen that the continuation of this role was related to the laboratory experiences that the students had engaged in before the intervention. That is, Merve, Ayşe and Beril stated that they had participated in inquiry activities at a confirmatory level before the intervention. For example, with the view that "Our teacher specifies the problem. The teacher does the experiment and tells us the result", Beril states that the teacher decides upon all stages of the inquiry and even that the teacher explains the result of the inquiry before the inquiry begins. Since the students had been given a high level of guidance by the researcher during structured inquiry, they may have considered that the teacher still played a determining role in learning.

When the students had completed the structured inquiry activities and moved on to the following Activity#4 (Is Light a Kind of Energy?), they took on a constructive role and made statements which showed that they had taken responsibility for their learning. For instance, Merve explained her duties undertaken in the inquiry process as follows:

In class, I feel as if I am working in a laboratory. We do the experiments and write down our observations. Then, we try to find the results and write them down... We did the experiments. We had a lot of fun while doing the experiments. I touched 4 bottles with different pencils and different sounds were produced. Then I moved my finger around the rim of the glass. A sound wave was produced. I wrote everything down on the worksheet. I wrote down the results of the experiment. This is very enjoyable. I wish we could do research and experiments in all our lessons.

The inquiry, in which the students decided on the implementation with their teachers, but concluded and reported on their own, made the students aware of the fact that their participatory roles had changed. The students maintained this newly adopted role until the end of the intervention.

Following the open inquiry activities, Merve, Ayşe and Beyza stated that they carried out all the stages of inquiry themselves. In short, the students realized that in the inquiry-based learning environment, there had been a change in their roles as learners from a participatory one towards a constructive one. However, this change did not occur all of a sudden, as structured inquiry was not effective in changing the roles that the students had carried over from the previous learning environment. In order for students to notice a change in their roles, they had to participate in inquiry activities where their autonomy increased during the implementation, concluding, and reporting stages (structured to guided inquiry).

Analysis of Students' Conceptions of Learning

The analysis of the learning conceptions of the students in the experimental and control groups prior to and following the inquiry process is presented in Table 4. Prior to the intervention, some students (Merve, Ayşe, Elif, Tunahan and Enes) had achieving learning conceptions. That is, the aim of these students was to succeed, gain the appreciation of their teacher or become more successful than their friends by obtaining high grades in their exams. Beyza had conceptions of memorizing. Following the intervention, students in the control group had still conceptions of achieving. On the other hand, the conceptions of the students in the experimental group changed. Merve and Beyza mentioned discovering information, being curious about the answer to a question, and trying to answer this question by conducting research like a scientist (inquiry). Ayşe mentioned understanding the content and using the knowledge that she had learnt in new situations or in daily life (applying). This change shown by the students reveals that the inquiry-based learning environment had enabled the students' conceptions to change in a constructive way.

Table 4

Learning Conceptions of the Students in the Experimental and Control Groups Prior To, During and Following the Inquiry

Group		Pre	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Post
Exp.	Merve	A	A	A	A	A	A	A	A+U	A	U+C	U+C	U+C	C	U+C	U+C	AP	I
	Ayşe	A	A	A	A	A	A	A	A+U	A	U+C	U+C	U+C	C	U+C	U+C	AP	AP
	Beyza	M	A	A	A	A	C	C	A	M	U+C	U	C	C	U	C	U+C	I
Con.	Elif	A																A
	Tunahan	A																A
	Enes	A																A

Note. Exp.=Experimental, Con.=Control A=Achieving, M=Memorizing, U=Understanding, C=Curiosity, AP=Applying, I=Inquiry

Although this change shown by the students reveals the effect of the inquiry-based learning environment, the analyses of the interviews processes reveal the situations that appeared while the intervention was in progress. The clearest situation which appeared during the structured inquiry was that the three students regarded the aim of learning as obtaining high grades in their exams. For example, before the intervention began, Merve was of the opinion that "The science lesson is a lesson in which we constantly memorize the content that is conveyed to us, write a summary for this content and solve test questions. The science lesson is a bit boring". This situation reveals that the students' pre-intervention learning experiences still had an effect on their conceptions. During the structured inquiry activities (1, 2, 3 in Table 1), the teacher helped the students to create experimental design by offering them guidance. Due to this guidance, the students may still have considered that they needed to repeat the things which the teacher did, as they had done before the intervention, since by this

means, they would obtain high marks. For example, the interview held after Activity#1 reveals that as a learner, Ayşe still perceived herself in a passive role where she expected to obtain information:

I have explained the research that we prepared. I have answered the questions my teacher asked me. I have listened to my teacher.

When the students moved on to the activity named “Is Light a Kind of Energy?” (Activity#4) for which they were required to give an oral presentation of an investigative report, the three students were very excited. Merve reflected the excitement she felt before beginning the lesson with the statements “I am happy and very excited. I’ll be explaining my research on the board for the first time. My friends are going to ask me questions”. However, the reasons for the excitement felt by the students towards learning were “being very successful in class” for Merve, “wondering if our teacher will like my assignment and if it is correct” for Beyza, and “being successful in science class” for Ayşe. In fact, although the three students were able to explain in detail the things that they had done during the inquiry process, they attached more importance to how their learning product would be evaluated. Ayşe had used presentation skills in class before the intervention began, yet she was afraid of being unsuccessful in front of her teacher or her classmates.

Sometimes, I ask questions in class. Sometimes, I am shy. I hesitate to ask questions that come to my mind. I hold back, because I think that my classmates will make fun of me.

It can be said that the students, who had never used reporting skills before, wished to avoid encountering a negative assessment that might be made about their presentations by the teacher. In short, the students’ learning experiences prior to the intervention still had an effect on their conceptions. These experiences led the students, during the inquiry activities 1-4, to maintain conceptions either of being more successful than the others or to wish to avoid appearing unsuccessful to the others or to their teachers. After students had completed their presentation about “Is Light a Kind of Energy?” (Activity#4), Beyza stated that she felt like a scientist: “I explained the assignment that I had prepared like a scientist. I wrote ‘Beyza the scientist’ in front of me”. Differently from Ayşe and Merve, this experience of Beyza bore the hallmark of a threshold activity for her conception of achieving to change. In the following activity named “Let’s be Properly Lit!” (Activity#5), an apparent difference between Merve, Ayşe and Beyza emerged. Beyza stated for this activity that: “We will investigate the subject just like a scientist. I am very excited. (My aim is) to learn by investigating the subject well”. In this way, Beyza, when stating her aim, instead of mentioning how others (her teacher or friends) would evaluate her presentation, now mentioned her interest and willingness towards research. Therefore, she had conceptions of curiosity. This situation reveals that the inquiry, in which only the teacher was active at the problem and planning stages, was sufficient for Beyza’s achieving conceptions to change, whereas it was not sufficient for Ayşe’s or Merve’s conceptions to change.

Regarding the three students, another surprising situation is as follows: After the students had completed the activities between structured and guided level, they moved on to the conducting activities at the guided inquiry level (Activities#7, 8, 9). At the beginning of these activities, the teacher stated that the students would design their own investigations by themselves, but that she would assist them if they had any difficulties. In Activity#7, “Does every Sound Have a Source?”, the students were curious to know what kind of research they would carry out, but a new situation such as designing the research was regarded as a challenge for them. As the students were curious about how to design their own research, Ayşe and Merve oriented to conception of understanding but continued their understanding of achieving. Beyza abandoned her conception of curiosity and tended towards achieving. The students, who had not previously taken part in the activities between structured and guided inquiry, may have believed that in order to cope with difficulties that a new situation might create, they had to continue conceptions of achieving. When the students moved on to Activity#8 (“Is Sound a Kind of Energy?”), it was determined that Ayşe and Merve maintained their achievement goals (e.g. Ayşe: “I want to learn the topic very well and be successful”, Merve: “I want to do the experiment very well and get a very good mark in the science exam”). In contrast to Ayşe and Merve, however, Beyza, with the view that “I am excited. We have brought candles to class. I am wondering what kind of experiment we will do with the candles. I want to satisfy my curiosity”, had

abandoned her achieving conception and oriented towards a conception of curiosity. As shown in Table 4, from Activity#9 (“I’m Observing”) onwards, Ayşe and Merve also abandoned their achieving learning conception and altered their conceptions to curiosity and understanding. For instance, according to Merve, the aim of learning this activity was expressed as “Our teacher gave us research homework related to how we could develop a tool for increasing the volume of sound. First, we made a plan. We researched into devices for increasing the intensity of sound. We decided to develop the hearing aid further. Inventing our own device makes me very happy; I am curious”. Therefore, Activity#9, in which they themselves decided on almost all stages of the research apart from the problem, was effective in changing the three students’ achieving conceptions. Especially in Activity#11 (“The Earth is Made of Strata!”), Ayşe and Merve stated that even though they thought the subject was difficult, they were really curious about the Earth’s strata and they wanted to learn about them. For example, Ayşe stated that “I feel very happy. Our teacher wanted us to bring modeling clay. I really wonder what we are going to do. How will we make the strata? I think the topic of strata is difficult. My aim is to learn this topic well”. In addition to this, when Ayşe and Merve specified their conceptions in the final activity, named “Let’s Create a Project”, they mentioned applying the knowledge that they had learnt to their everyday experiences. For example, this situation stated by Ayşe as “to be beneficial to nature”; by Merve as “we will prevent the destruction of trees; we will inform everybody”). However, Beyza continued with her understanding and curiosity.

In conclusion, students who had conceptions of achieving or memorizing prior to the intervention did not experience a dramatic change in their conceptions when they took part in the structured inquiry activities. When they moved on to the last structured to guided inquiry activity, their conceptions changed to curiosity and understanding yet. While Merve, Ayşe and Beyza maintained their understanding and curiosity conceptions until the end of the study, Merve and Ayşe had applying conceptions in the final open inquiry activity.

Discussion

This study presents the effects of an inquiry whose inquiry levels was gradually increased over a 14-week period and of the regular science curriculum on students’ learner autonomy and learning conceptions. By conducting process-based analysis, the situations that emerged in students’ learner autonomy and learning conceptions, both during one level of inquiry and when moving from one level to another, were presented. Previous studies had compared the effects of structured, guided or open inquiry levels on students’ cognitive outcomes (Maxwell et al., 2015; Tao & Zhang, 2018). This study, however, instead of comparing the effects of inquiry on different groups, presents the effects of different levels of inquiry on the same group. Moreover, in comparison with previous studies that were mostly conducted with structured or guided inquiry (Di Mauro & Furman, 2016; Ergül et al., 2011), this study provides evidence about the effects of levels beginning with structured inquiry, continuing with guided inquiry and completed with open inquiry on students.

The inquiry-based environment caused experimental group students’ participatory roles related to learning to change towards a constructive one, whereas the regular science curriculum did not alter control group students’ participatory roles. In this way, inquiry-based learning enabled students to leave behind the roles that they had previously defined for inquiry, which were seeking information, preparing a report and presenting it to the teacher (Jalil et al., 2009). As the activities progressed, the teacher’s guidance was gradually reduced and the students then began to conduct all stages of the inquiry by themselves as independent learners. It can be said that a mechanism with which the students themselves decided on the direction and speed of the inquiry was effective in their adoption of a constructive role.

When the students were individually investigated, the inquiry proceeding at the structured level was not effective in changing the students’ participatory role. Since students in the structured inquiry process learned by focusing on the instructions given by the teacher, listening to the teacher and repeating him, they may have believed that they still continued in their participatory roles

(Bunterm et al., 2014). On the other hand, when they participated in structured to guided inquiry activities where their autonomy increased during the implementation, concluding, and reporting stages, the students adopted constructive roles and maintained these roles until the end of the study. This implies that beginning with structured inquiry and continuing with guided inquiry, this approach gradually gave the students the opportunity to develop their roles (Zion & Mendelovici, 2012). In this way, the students were able to work on their research more independently compared with structured inquiry, and since they engaged in tasks in a way which made them feel that they could accomplish certain stages of an inquiry by themselves, they gained self-confidence (Bevins & Price, 2016). Similarly, the students who were participated in the study of Archer-Kuhn et al. (2020) felt autonomous as learners and enjoyed learning in open inquiry process when they decided what to learn and how to learn. Romadhona and Suyanto (2020) state that the students who were instructed with open inquiry have the opportunity to search for and think information without the directions of their teachers according to the students who were instructed with guided inquiry.

In this study, inquiry-based learning enabled students' reproductive conceptions such as achieving, memorizing and practicing tutorial problems to change towards constructive conceptions like applying and inquiry (Cano & Cardelle-Elawar, 2004). Students in the control group, however, did not change their conceptions. Similarly, Mupira and Ramnarain (2018) found that the inquiry learning cycle was effective in changing students' mastery goal orientation. Whereas Lin et al. (2012) found that a direct didactic approach was not effective in changing students' mastery goal orientation. Furthermore, this study provides process-based evidence revealing what kind of change occurs when a student moves from one level of inquiry to another. When the intervention began, the students did not immediately adopt applying or inquiry conceptions. While the structured and structured to guided inquiry was in progress, just as they had done before the intervention, the three students continued to regard the conceptions of learning as obtaining high marks. Similarly, Belenky and Nokes-Malach (2012)'s study revealed that students, despite participating in an open inquiry environment, it could not alter their achieving conceptions.

To sum up, structured or structured to guided inquiry was not sufficient for students' conceptions to display a radical change. On the other hand, when the students were engaged in the first guided to open inquiry, they experienced a conflict between their previous conceptions and their new conceptions. Ayşe and Merve, instead of completely excluding conceptions that contradicted their new roles, adopted a synthetic approach by combining new conceptions with their previous conceptions (understanding and achieving). In fact, this situation, in which students had more than one conception, may be evidence that they had a more sophisticated viewpoint towards learning than a naïve learner has (Chiou et al., 2012). However, the sophisticated viewpoint did not enable the students to improve their conceptions in a qualitative viewpoint, but instead they saw the conception of achieving as a component supporting the conception of understanding (Tsai et al., 2011). However, Beyza could not maintain a situation where conceptions of curiosity were changed, and took refuge in an achieving conception in order to handle the new learning situation. The students, in the absence of the teacher's guidance, may not have felt comfortable in an environment that required them to take responsibility for their own learning (Zion & Mendelovici, 2012). In fact, even students with a constructive goal may feel confused or inadequate, since they do not know whether or not they are on the right path in an open inquiry environment, or they may have doubts on whether they are competent enough to deal with a task given to them (Levy & Petrulis, 2012). This conflict experienced by the students was resolved by their taking possession of conceptions of curiosity or understanding following the second guided to open inquiry activity. Moreover, compared to structured or guided inquiry, only guided to open inquiry appears to have effects deep enough to bring about changes in students' conceptions. The most striking finding was that Merve and Ayşe, who abandoned their achieving conceptions, had goals of implementing the knowledge that they had learnt in the final open inquiry activity in their daily lives.

Conclusion and Implications

To enable change in students' conceptions of learning, the experiences that they have must last longer than the time spent for change in their autonomy in inquiry, since during guided inquiry, students still have conceptions of achieving. In this case, in a structured or structured to guided inquiry learning environment, while the conceptions of learning constitute a more central component, the learner's role comprises a more peripheral component. While structured to guided inquiry are sufficient for the peripheral component to change, they are not enough for the central component to change. Since the inquiry levels specific to this study might not be valid for other studies, according to the scope of the study, it may be necessary to start and continue with different inquiry levels.

This study, in which the data gathered only by means of interviews, is limited in the sense that it did not achieve data triangulation related to learner autonomy and learning conceptions. For example, although a Turkish adaptation of the "Conceptions of Learning Science Questionnaire" (Bahçivan & Kapusuz, 2014) exists for pre-service teachers, there is a need for a tool that can be used for students in fourth grade. On the other hand, it is considered that the fact that the research lasted for 14 weeks allowed students to spend as much time as necessary for them to be able to recognize their learning autonomy and their conceptions of learning. Since the conceptions that emerged in the study were valid for the students who took part in this study, studies in which student participation with different characteristics may be helpful for making the relationships among the patterns more explanatory or for revealing more generalizable patterns. Not having included more students from different groups can be seen as a limitation but it is have tried to overcome this limitation by choosing at least one student to reach convincing results.

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