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Algorithmic Thinking in Primary Education*

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Abstract

Use of algorithmic thinking in education has received significant attention as it is grounded on thinking and performing the necessary action in line with a clearly defined purpose. The current study aimed to probe prospective classroom teachers' views on algorithmic thinking skills and use of these skills in education. The research data were collected from 36 undergraduate students attending a state university in Turkey through an interview form developed by the researcher. Their responses to the interview questions were examined through content analysis and converted into themes and codes. The participants reported that teachers with well-developed algorithmic thinking skills tend to teach gradually, to follow a process that facilitates learning, to encourage students to be well-planned and neat and to help them develop/ improve their algorithmic thinking skills. They also suggested the use of such techniques as discovery learning, problem-solving, induction, brainstorming, concept mapping, games, discussion, fishbone and case study that require students' active involvement in the learning process in order to improve their algorithmic thinking skills. The study discusses further findings in detail and concludes with practical implications developed in the light the findings reported here and the existing literature.

Keywords: Algorithmic Thinking, Preservice Teachers, Primary Education

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INTRODUCTION

Algorithmic thinking is a concept that has just entered our lives, but it has always existed in human history. In order to understand algorithmic thinking, one has to look at the past. A closer look at the history of humanity reveals that the inventions of paper, printing press, telegraph, steam machine, engine, telephone and computer caused unprecedented changes in the lifestyle and culture of the societies, respectively. The most significant change among all was triggered by the transition to the industrial society thanks to the introduction of steam machines to the industry, followed by the use of electricity in the 18^{th} century. The use of electricity in power generation, in particular, largely accelerated the industrialization process. The humanity eventually began to rule the material world and to design and develop machines that could perform their own tasks such as railroad construction and packaging. What kind of philosophy lies behind the process of mechanization in concern? It is seen that a mindset was established by the necessity of a set of sequential processes that must be formed in order to produce complete and error-free products. This particular mindset is called algorithmic thinking. Algorithmic thinking is a way to find a solution by clearly defining steps. It is the process of analyzing the problem, implementing the solutions and producing a new solution in the next step. How this mindset has found its place in science and technique?

There is a strict and indispensable relationship between science and technique. As a matter of fact, scientific advancement leads to technical development while technical advancement allows the diversification of scientific disciplines and conducting more sophisticated research. An identical relationship exists between mathematics and technological developments. Mathematics and technology can emerge as a tool and a result, respectively in this relationship. History of mathematics indicates that it fulfils the function of language of developing technologies. Accordingly, mathematics might be considered as a tool that facilitates technological development and problem-solving processes. More specifically, it enables the development of many disciplines and creative thinking and makes it easier to overcome technological problems. Today, the term “new mathematics” is used to refer to mathematics integrated with science, technology, innovation, art and economy (Akpınar, Tuncel, & Özeren, 2016). Therefore, mathematics is considered to form the basis of algorithmic thinking.

Galileo remarked that mathematics is the language in which God has written the universe as it mediates our understanding of almost every aspect of this magical universe. A wide range of subjects and concepts are largely related to mathematics. Namely, computers are electronic devices that can process and store data quickly and perform many mathematical sequential operations. The operations in concern are performed by the execution of a set of written commands. Thereby, computers are able to perform processes ranging from simple story problems to the discovery of *pi* thousands of times faster than a human can do. Nonetheless, it requires a systematic procedure of which planning phase is called algorithm. The question of how to teach our mental processes to the computers necessitates algorithmic thinking that refers to a combination of systematic and detailed procedures to perform a job and to solve and/ or eliminate a problem (Türnüklü, & Yeşildere, 2014). Even though the concept of algorithm sounds somewhat unfamiliar, we actually see examples that have emerged with this concept in our daily lives. Namely, such procedures as solving a problem, putting ingredients in a pot in an order, folding a dress regularly, or washing the dirty laundry in the washing machine and processing the codes in order for a robot to perform the desired movements are directly related to this concept. In this vein, computer programming languages are grounded on operational, algorithmic and logical thinking. They enable individuals to interpret the world from different perspectives by using the processes of producing solutions, reasoning, creating algorithms and processing information together (Gülbahar, 2018). As they have significant potential for future careers of both teachers and students, they are viewed indispensable competences for 21^{st} century literacy to gain through age-dependent methods. Constituting the core focus of this research as well as the above-mentioned processes, the term algorithmic thinking is also described as a way to achieve a solution through clearly defined steps (Yıldız, Çiftçi & Karal, 2017). It plays a crucial role in analyzing a problem and developing and implementing strategies to solve it. In a similar vein, Csizmadia et al. (2015) posit that it is ‘the ability to think in terms of sequences and rules as a way of solving problems or understanding situations and that it is a core skill that pupils develop when they learn to write their own computer programs' (p. 7). It is now accepted as a competence that concerns not only computer scientists, engineers, mathematicians and people specialized in similar disciplines but anyone identified as 'a digital citizen' (Selby & Woollard, 2013; Wing, 2006). It is introduced as a skill that students of all ages and grades can gain by using an interdisciplinary approach (Gülbahar, Kert & Kalelioğlu, 2019). It is even more important for science and mathematics courses in that students tend to use algorithmic thinking processes to solve problems or to conduct experiments in a peripheral manner. In this way, they apply the necessary steps of identification, analysis and evaluation to find the solution of a given problem. What is important at this point is that they are supposed to acquire the skills to apply this thinking approach consciously under different conditions. Recently, it is seen that the most prominent terms or applications such as coding, design, modelling, STEM and robotics are based on algorithmic thinking. Although algorithmic thinking is best mirrored in computers, it is becoming more and more evident that this structure of thinking should be utilized in every area of life, especially to construct a successful education system.

As humans, we instinctively anticipate the outcome of a series of actions and plan them to achieve an intended result. Even some animals such as dogs, cats, mice and crows have been shown to do so to a certain extent. However, anyone with sequential thinking skills will be able to make accurate predictions about a much longer set of actions despite complex situations as the same action does not produce a different outcome. Algorithmic thinking is grounded on thinking and performing the necessary action in line with a clearly defined purpose. To achieve this purpose, Kalelioglu, Gülbahar and Kukul (2016) identify the following steps of algorithmic thinking: (i) abstraction and decomposition, (ii) data collection, data analysis, pattern recognition, conceptualization and data presentation, (iii) mathematical inquiry, creating algorithms and its processes, and working simultaneously, (iii) automation, modelling and simulation, and (iv) testing, debugging and making generalizations. Not surprisingly, introduction of algorithmic thinking to education has led to the rapid integration of coding trainings with the education system in recent years. Rapid technological developments indicate that the next century requires coding and sequential processing rather than a labour-intensive society. Therefore, the formation of algorithmic thinking in teachers and students is very crucial for the future of education and society.

The review of the relevant literature indicates that individuals with algorithmic thinking skills are open-minded, inquiry-oriented, good at math, courageous, honest, creative and confident people with the ability to produce solutions to prominent problems, to model data and to think systematically (Eguchi, 2016; Hromkovič et al.,2016; Milková, 2012; Milková, 2015; Paul & Elder, 2006; Zsakó & Szlávi, 2012).

Tsalapatas et al. (2012) note that 'teachers can facilitate the learning process and support students in overcoming cognitive obstacles and successfully engage in computational and analytical thinking practices' (p. 62). The researchers conducted a study with a focus on game-based programming towards developing algorithmic thinking skills in primary education and concluded that the implementation of the program encourage 'students to analyze problems, to identify core components of the solution, to critically snap together the different components, to optimize their solutions, and to reflect upon their thinking' (p. 62).

Teachers influence students with their personal and professional characteristics while contributing to them with their knowledge, skills and attitudes. Quite in line with this view, Çelik et al. (2015) reported that science teachers' algorithmic thinking skills influence their students' cognitive development. Furthermore, previous research has shown that the use of teaching methods and techniques that engages students in classroom activities, builds confidence in them, motivates them to learn, improves their problem-solving and analytical thinking skills as well as their coordination with each other (Çelik, Pektaş & Demirtaş, 2012; Bacanak, 2013). In a similar vein, Güven (2004) highlights that teachers should introduce meta-cognitive processes by creating a discussion environment appropriate to the content of the subject in addition to presenting information and observing the display of skills for effective teaching. Asking effective and challenging questions to the students is one of the most efficient ways to accomplish this. Liu, Li and Liu (2016) identify algorithmic thinking as a clear definition of a problem and a way to solve it rather than an answer to a given question and argue that it helps students develop a set of instructions or rules. Therefore, teachers could organize questions to evaluate students' outcome achievement, pace, problem-solving skills and higher-order learning levels such as analysis, synthesis and evaluation (Çelik et al., 2015). In this case, certain questions might require students to analyze and criticize pieces of knowledge. Consequently, teachers are expected to pose higher-order questions that allow students to improve their algorithmic thinking skills, to express their opinions with confidence, to criticize and to transfer their knowledge.

Stressing the significance of algorithm in curriculum design, Akçay and Çoklar (2016) defined curriculum as the development and implementation of an algorithm that is designed to teach an outcome. The existing literature informs that the curricula in use can improve students' problem-solving skills (Chao, 2016; Fessakis, Gouli, & Mavroudi, 2013; Gülbahar & Kalelioğlu, 2014; Kukul & Gökçearslan, 2014). It was also reported that problem-solving improves students' analytical/ algorithmic skills as it requires them to subdivide the problems (Saeli et al., 2011) and thereby increasing their motivation (Howland & Good, 2015). Factors that affect algorithmic thinking skills are outlined in two categories as positive and negative. Positive factors could be listed as having knowledge, ability to use knowledge properly and being strong-minded while negative factors are classified into internal and external factors (Çelik et al., 2015). Hence, teachers' attitude towards algorithmic thinking skills and their use in education gains more significance for the ultimate quality of educational processes as they are still the leading figures of the processes in concern no matter how student-centered classrooms are recommended in the relevant literature. In a recent study, Sands, Yadav and Good (2018) investigated in-service teachers' perceptions of computational thinking and reported that many educators have very little knowledge about what these skills are and lack awareness of how these skills can be implemented in their classrooms. The researchers concluded that there is much work to be done before in-service teachers are able to implement computational thinking in their classrooms. The fact that there is no study in the literature regarding the algorithmic thinking situations of teacher candidates makes this study different. To the best of the researchers' knowledge, pre-service teachers' attitude towards such skills has not been previously investigated; therefore, this particular research was intended to bridge this research gap. In addition, the attitudes of prospective teachers towards algorithmic thinking are very valuable in that they provide their students with an ordered, organized, principled and systematic education.

Accordingly, the following research questions were raised:

RQ1. What are the views of prospective classroom teachers on algorithmic thinking skills?

RQ2. What are the views of prospective classroom teachers on the use of algorithmic thinking skills in education?

Research design of the study is described and outlined in the following section.

METHOD

Design of The Study

This study employed a qualitative research design to investigate the views of prospective classroom teachers on the use of algorithmic thinking in education. Qualitative research allows researchers to reveal perceptions and events using qualitative data collection techniques such as observation, interview and document analysis in a realistic and holistic way in their natural settings (Yıldırım & Şimşek, 2011). In this study, phenomenology one of the qualitative research approaches has been adopted. Because the researches carried out in the phenomenological pattern try to reveal the experiences, perceptions and the meanings of individuals on a case (Johnson & Christensen, 2019). As current study aimed to outline a given situation in a broad sense, it was motivated to conduct an in-depth analysis of the afore-mentioned prospective classroom teachers' views on the educational use of algorithmic thinking skills.

Sampling

The research was conducted with the voluntary participation of 36 undergraduate students enrolled in a classroom teacher training program at a state university in Turkey (Female: 30; Male: 6). The participants were selected through criteria sampling method, which is recommended to explain the critical issues for the research phenomenon (Creswell & Clark, 2016). These students were exclusively chosen since their views on the use of algorithmic thinking in education are highly significant as they will be the first to teach a wide range of courses from science, social sciences and mathematics to art and physical education to primary school students. It is significant to note that they were third graders at the time of data collection and that they had already taken certain professional knowledge courses identified in the related curriculum (e.g. Introduction to education, educational psychology, educational assessment and evaluation, instructional technologies and materials development). Also, this study is limited to the classroom teacher candidates whose data are collected.

Data Collection and Analysis

The research data were gathered from a semi-structured interview form consisting of questions developed by the researcher subsequent to an extensive literature review. The questions in concern were finalized based on the expert opinion elicited from a faculty member with in-depth specialization in educational measurement and evaluation and a language specialist. The interviews were held individually at a predetermined date and time. The following are the open-ended questions posed to the participants during the interview.

1. What are the characteristics of individuals with algorithmic thinking skills?

2. What are the effects of good teachers 'algorithmic thinking on students' development? Please briefly explain.

3. As a prospective teacher, which learning methods and techniques do you prefer to improve your students' algorithmic thinking skills? Why?

4. Do you think that the questions you will ask for the evaluation of the course have an effect on the development of algorithmic thinking skills of the students? Please justify your answer.

5. Which factors prevent the development of students' algorithmic thinking skills? What should be done to eliminate these factors? Please explain.

6. What extra-curricular activities do you recommend for students to develop algorithmic thinking skills? Please justify your answer with examples.

It is noteworthy that the participants were coded to ensure student confidentiality in this particular research (S1, S2, S3...).

The data were analyzed through the Miles-Huberman Model (Miles & Huberman, 1994), which comprised of data collection, data reduction, data display and conclusions (drawing/ verifying). Accordingly, the transcribed interview forms were analyzed taking the research questions into consideration, converted into meaningful data and coded. Data elicited from the prospective teachers for each item were added to the code list and tabulated, respectively. Then, themes that were thought to represent these codes were created by the researcher. Finally, the codes and themes were re-tabulated in congruence with the research questions.

The data were analyzed through content analysis, which enables the data generated by the research questions to be organized according to the themes and presented by considering the questions used in the interview (Yıldırım & Şimşek, 2011). The elicited findings were organized and presented considering the sub-problems into account. Coding was simultaneously and independently conducted by the researcher in order to ensure coding consistency in data analysis. Inter-rater reliability was calculated quite high (.88) (Miles and Huberman, 1994). The codes were finalized after discussion with the expert in case of disagreement (Silverman, 2005).

FINDINGS

This section offers findings elicited from students' responses to the interview questions on algorithmic thinking skills and their use in education. Although it is not correct to give a percentage in qualitative research, the percentage parts are also given due to the high number of frequencies obtained in this study.

The first question was intended to obtain their opinions about the characteristics of individuals with algorithmic thinking skills. The codes, frequencies and percentages were drawn from the analysis of their responses and displayed in Table 1.

Table 1. Characteristics of individuals with algorithmic thinking skills

Codes	f	%	Codes	f	%
Systematic thinking	16	11,3	Making synthesis	4	2,8
Classification / Ordering	15	10,6	Meronymy	3	2,1
Planned	13	9,2	Successful	3	2,1
Problem solving	13	9,2	Researcher	2	1,4
Neatness	11	7,7	Visionary	2	1,4
Logical reasoning	8	5,6	Wise	2	1,4
Practicality in problem-solving	8	5,6	Practicality in using techniques	2	1,4
Proper comprehension of problems	6	4,2	Evaluation	2	1,4
Solving problems with ease	6	4,2	Well-disciplined	2	1,4
Easy learning	5	3,5	Smart	2	1,4
Getting to the root of the problem	5	3,5	Skillfulness	1	0,7
Analysis	5	3,5	Responsible	1	0,7
Establishing cause and effect relationship	4	2,8	Convincing	1	0,7
			Total	142	100

As indicated in Table 1, 26 codes were constructed from 32 sources. The participants stated that individuals with algorithmic thinking skills are expected to have such abilities as to think systematically (11,3%), to classify and order (10,6%), to plan (9,2%) and to solve problems (9,2%). They also reported that these individuals tend to be neat, logical and good at producing practical solutions, comprehending problems, solving problems with ease, learning easily, getting to the root of the problem, establishing cause and effect relationship and making analysis and synthesis. The following are the excerpts drawn from interview forms.

S3: "Anyone with algorithmic thinking skills can think systematically. S/he can easily implement solving strategies to the problems they encounter. S/he has the ability to classify, to identify basic foundations of the problems and to come up with an order."

S7: "Anyone with algorithmic thinking skills perfectly know how and what to teach in which order. They are neat and planned individuals. They know what to change or what phase to revise when they encounter a problem in any areas of their life."

S12: "Anyone with algorithmic thinking skills can achieve their goals by implementing carefully selected methods and techniques in a planned way. S/he does not make things harder or complicated when encountering a problem or question. Instead, they tend to follow logical steps to attain the intended result."

S29: "Anyone with algorithmic thinking skills has the ability to make analysis and synthesis. They disassemble and solve problems through meronymy. They also have well-developed synthesis skills.

As outlined in the excerpts, the prospective classroom teachers identify various characteristics for the individuals with algorithmic thinking skills are supposed to have. It can be concluded that individuals with algorithmic thinking skills are those who are supposed to be the desired outcomes of the education system. Hence, it will be exclusively beneficial for the in-service and pre-service teachers to internalize this thinking system, to use it in their daily lives and to transfer it to their students in their teaching for the ultimate success of education.

The prospective teachers' views about the effects of teachers with well-developed algorithmic thinking skills on students' development yielded two broad themes: (i) its influence on educational development (70,6%) and (ii) personal development (29,5%). Table 2 provides the related themes and codes obtained from data analysis.

Table 2. Prospective teachers' views about the effects of teachers with well-developed algorithmic thinking skills on students' development

Themes	Codes	f	%
Educational development	Knowledge transfer in a sequential manner	16	13,4
	Simplification of the learning process	13	10,9
	Engraining their way of thinking in students	11	9,2
	Permanent learning	10	8,4
	Meaningful learning (rather than rote-based learning)	9	7,6
	Providing clear information to students	8	6,7
	Gradual teaching	6	5,0
	Sequential implementation of teaching principles	4	3,4
	Preventing confusion	4	3,4
	Meronymy teaching	2	1,7
	Facilitating the understanding of the cause and effect relationship	1	0,8
Personal development Students...	Being planned and organized	13	10,9
	Gaining the ability of problem solving	9	7,6
	Success	6	5,0
	Competence in analysis	3	2,5
	Active citizenship	2	1,7
	Becoming researchers	1	0,8
	Expression with confidence	1	0,8
	Total	119	100

As shown in Table 2, the participants' responses revealed that knowledge transfer in a sequential manner is the most frequently cited code concerning the influence of teachers with well-developed algorithmic thinking skills on students' educational development (13,4%), followed by simplification of the learning process (10,9%), engraining teachers' way of thinking in students (9,2%), permanent learning (8,4%) and meaningful learning (7,6%). Concerning the dimension of students' personal development, the findings have demonstrated that having a teacher with well-developed algorithmic thinking skills helps students be planned and organized (10,9%), gain the ability of problem solving (7,6%), be successful (5,0%) and gain competence in analysis (2,5%). The following excerpts were taken from the interview forms to illustrate the effects of teachers with well-developed algorithmic thinking skills on students' development.

S23: "*Such teachers encourage students to be planned and organized. They can teach very challenging based on the principle from simple to complex and from easy to difficult. They can also help students gain competence in analysis, assembling and repeating patterns*."

S28: "*Teachers can transfer their knowledge and competence to their students. They need to develop themselves to illuminate their students. Consequently, teachers with well-*

developed algorithmic thinking skills can facilitate the development of these skills in their students."

S22: "*Such teachers can build an order in students' daily and educational lives. They facilitate permanent learning for students by revising random learning. They also help students become planned, organized, more successful and more active in their educational and social life*."

As depicted in the excerpts, the participants reported that teachers with well-developed algorithmic thinking skills can contribute to their students' personal and educational development by transferring these skills to them.

The second interview question was designed to elicit the prospective teachers' views on the instructional methods and techniques in order to improve their future students' algorithmic thinking skills. The themes and codes obtained from their responses are shown in Table 3.

Table 3. Instructional methods and techniques that prospective teachers are planning to use to improve students' algorithmic thinking skills

Themes	Codes	f	%
Student-centered	Discovery learning	14	15,6
	Problem solving	10	11,1
	Induction	9	10,0
	Brainstorming	7	7,8
	Concept mapping	7	7,8
	Drama / Role-play	5	5,6
	Experiment	4	4,4
	Experiential learning	4	4,4
	Research & Review	4	4,4
	5W & 1H questions	3	3,3
	Six hats	2	2,2
	5E model (engage-explore-explain-elaborate-evaluate)	2	2,2
	Discussion	2	2,2
	Fishbone	2	2,2
	Case study	2	2,2
	Prediction	2	2,2
	Cliff-hanger	1	1,1
Teacher-centered	Question & Answer	5	5,6
	Modelling	2	2,2
	Deduction	2	2,2
	Direct instruction	1	1,1
	Total	90	100

The codes elicited from the prospective teachers were categorized into two broad themes of instructional methods and techniques: (i) student-centered (88,9%) and (ii) teacher-centered (11,1%). The most frequently reported student-centered instructional techniques could be listed as discovery learning (15,6%), followed by problem-solving (11,1%), induction (10%), brainstorming (7,8%), concept mapping (7,8%) and drama & role-play (5,6%).

The teacher-centered instructional techniques that were most frequently reported to improve students' algorithmic thinking skills are question and answer drills (5,6%), modelling (2,2%), deduction (2,2%) and direct instruction (1,1%). All in all, the majority of the prospective teachers reported that they are planning to use student- rather than teacher-centered instructional techniques to improve their future students' algorithmic thinking skills (88,9%).

The following are to exemplify the prospective teachers' views on the instructional techniques they are planning to use in their teaching in order to improve their students' algorithmic thinking skills.

S23: "*The principle of teaching from simple to complex and from known to unknown, and such techniques as discovery learning, mind maps and concept mapping can be used to improve students' algorithmic thinking skills since the principle in concern allows children to create an order in their mind and to prioritize learning of simple subjects. Thereby, their algorithmic thinking skills improve*."

S30: "*I prefer to use problem solving technique because implementation of problem-solving steps requires and develops analytical thinking skills. Accordingly, I will ground my teaching on discovery learning".*

S34*:* "*I will employ question and answer drills to encourage my students to think algorithmically.*

The excerpts have revealed that they are planning to help students develop their algorithmic thinking through using a variety of methods and techniques.

Subsequently, the participants were requested to state their own views on how the evaluation questions designed to attain course outcomes influence the students' algorithmic thinking. The themes and categories drawn from their responses are presented in Table 4.

Table 4. Prospective teachers' views on the influence of evaluation questions on students' algorithmic thinking

Themes	Codes	f	%
Lower order thinking questions	Appropriateness to personal development	4	6,2
	Evaluation of initial learning	2	3,1
Higher-order thinking questions	Open-ended	10	15,4
	Applied	8	12,3
	Thought-provoking/Challenging	7	10,8
	Discouraging rote-learning	6	9,2
	Process-oriented	5	7,7
	Encouraging algorithmic thinking	5	7,7
	Completion	4	6,2
	Life-oriented (actual/ real)	4	6,2
	Requiring creativity	4	6,2
	Cause and effect relationship	3	4,6
	Seeking details	3	4,6
	Total	65	100

As displayed in Table 4, the prospective teachers' responses were evaluated into two categories as lower-order questions and higher-order questions. The former list is limited to two codes: (i) appropriateness to personal/ cognitive development (6,2%) and (ii) evaluation of initial learning (3,1%). The latter, on the other hand, include such codes as open-ended (15,4%), applied (12,3%), thought-provoking (10,8%), discouraging rote-learning (9,2%), process-oriented (7,7%) and encouraging algorithmic thinking (7,7%). Apparently, the majority of the prospective teachers advocated that student achievement should be evaluated through higher-order questions (90,7%). Below are the excerpts drawn from the interview forms.

S3: "*Teachers should check students' readiness prior to the course and inspire awareness in students as to what they have learned during that particular class hour. They can pose the following questions: What did we initially know? What did we need to do in order to learn this topic? Could we realize at least one of the steps that enable us to learn it? and What did we learn about this topic–if we could?*"

S26: "*I would ask such open-ended questions as, Why? Would it be different from the existing situation? How could it be improved? What would you do* if *you were?"*

S23: "*This thinking skill (algorithmic thinking) can be measured and improved especially in logic- and mathematics-driven courses. Namely, we can evaluate algorithmic thinking of the students by asking them to describe the way they solve a particular problem. This allows us to evaluate to what extent the course outcomes have been achieved*."

It can be concluded from the excerpts that the prospective teachers favor the evaluation questions designed to cover problem-solving processes of the students. This particular finding is of significance in that questions of such also enable the evaluation of course outcomes.

As a further question, the participants were asked to share their views on the factors that hinder improvement of students' algorithmic thinking skills. The related themes and codes constructed from their responses are indicated in Table 5.

Table 5. Prospective teachers' views on the factors that hinder improvement of students' algorithmic thinking skills

Themes	Codes	f	%
Teacher-oriented	Use of rote teaching techniques	11	9,5
	Non-gradual teaching	10	8,6
	Direct instruction	10	8,6
	Inadequate pre-service training	8	6,9
	Teacher's attitude	5	4,3
	Lack of application in class	4	3,4
Student-oriented	Passivity	12	10,4
	Failing to establish cause-and-effect relationship	6	5,2
	Insufficient problem-solving skills	5	4,3
	Avoiding asking questions	5	4,3
	Peer-pressure	1	0,9
Curriculum-oriented	Non-inquiry based	5	4,3
	Rote	5	4,3
	Non-activity based	3	2,6
	Non-multidisciplinary	3	2,6
	Inadequate workbooks/ supplementary materials	3	2,6
	Non-functional learning outcomes	2	1,7
	Education failing to meet the expectations	5	4,3
Environment-oriented	Family	6	5,2
	Over-protectiveness	5	4,3
	Inadequate teaching material	2	1,7
	Total	116	100

As seen in Table 5, the respondents' views on the factors that hinder improvement of students' algorithmic thinking skills were classified into four categories: (i) teacher-oriented (41,3%), (ii) student-oriented (25,1%), (iii) curriculum-oriented (22,4%) and (iv) environment-oriented (11,2%). The most frequently reported teacher-oriented factor is use of rote teaching techniques (9,5%), followed by excessive use of direct instruction (8,6%), use of non-gradual teaching techniques (8,6%) and teachers' having inadequate pre-service training (6,9%). Passivity (10,4%) and failing to establish cause-and-effect relationship (5,2%) were, on the other hand, the most frequently reported student-oriented factors while family (5,2%) and over-protectiveness (4,3%) were primarily reported as the environment-oriented factors that hinder the improvement of students' algorithmic thinking skills. All in all, the prospective teachers expressed that the hindering factors are mostly teacher- and student- rather than curriculum- and environment-oriented. The following were extracted from their responses to the relevant interview question.

S32: "*I believe that boring and rote-based education, environmental and familial pressure and traditional educational system hinder improvement of students' algorithmic thinking skills. Furthermore, in-service teachers tend to organize their teaching in congruence with the principles of traditional method rather than the constructivist approach. These are the other hindering factors. Children should be set free in the learning environment. They should be allowed to learn through games and to develop mentally/ cognitively using thought-provoking questions*."

S22: "*Students' algorithmic thinking skills cannot develop once they learn from a teacher who does not have these skills. So, I am of the opinion that pre-service teachers should be encouraged to develop their algorithmic thinking skills and to display attitude and behaviors that facilitate the development of these skills in students*."

S29: "*Students might suffer from peer-pressure. They might feel shy and be unwilling to ask questions. As they cannot find answers to the questions in their mind, they will fail to establish cause-and-effect relationship*."

S2: "*Rote learning definitely hinders improvement of students' algorithmic thinking skills. In order to prevent that, students should be encouraged to reach the conclusion through discovery learning and posing questions rather than providing knowledge to them through direct instruction*."

The afore-noted excerpts clarify that the participant teachers reported a variety of factors that prevent students improving algorithmic thinking skills.

As a follow up question, they were requested to state extra-curricular activities that could improve students' algorithmic thinking skills. The themes and codes obtained from their responses to the question in concern are given in Table 6.

Table 6. Prospective teachers' suggestions for extra-curricular activities to improve students' algorithmic thinking skills

Themes	Codes	f	%
Games	Intelligent / Strategy games	17	18,5
	Puzzles / Toy block	8	8,7
	Drama	6	6,5
	Street games	4	4,3
	Mathematical operation games	3	3,3
Scientific activities	Nature activities	9	9,8
	Scientific fair visits	3	3,3
	Project assignment	2	2,2
	R & D visits	1	1,1
	Reading	1	1,1
Problem solving	Solving real-life problems	15	16,3
	Solving pattern problems	6	6,5
	Seeking practical solutions	2	2,2
Design	Teaching robotics coding	7	7,6
	STEM training	3	3,3
	Game design	3	3,3
	Original product design	2	2,2
	Total	92	100

As given in Table 6, the prospective teachers suggested extra-curricular activities to improve students' algorithmic thinking skills in four thematic categories: (i) games (41,3%), problem-solving (25%), scientific activities (17,5%) and design (16,4%). Among the games, intelligence games proved the most frequently suggested extra-curricular activity to improve students' students' algorithmic thinking skills (18,5%), followed by puzzles/ toy block (8,7%), drama (6,5%), street games (4,3%) and mathematical operation games (3,3%), respectively.

Solving real-life problems, on the other hand, emerged the mostly recommended code under the theme of problem-solving (16,3%), followed by solving pattern problems (6,5%) and seeking practical solutions (2,2%). Nature activities revealed the most frequented code among the scientific activities suggested for improving students' algorithmic thinking skills (9,8%), followed by science fair visits (3,3%), project assignments (2,2%), R&D visits (1,1%) and reading (1,1%). Finally, the participants mostly suggested teaching robotics coding to students among the extra-curricular activities that were evaluated under the theme of design (7,6%), followed by STEM training (3,3%), game design (3,3%) and original product design (2,2%). To this end, they tend to suggest such extra-curricular activities as games and problem-solving in order to improve students' algorithmic thinking skills. The following are taken from their responses to the relevant interview question.

S33: "*Such activities as intelligence games, chess, educational games, sports, music, playing the piano, painting, sculpture, cinema, theatre and story/ poem writing can improve students' algorithmic thinking skills*."

S1: "*Awareness studies can be recommended to improve students' algorithmic thinking skills. Nature activities could be organized with the participant of students' families. The students might be encouraged to visit science fairs and scientific centers and to participate in technology programmes. For example, we can go out and observe traffic with the students to find solutions to the problems we identify*."

S31: "*Teachers can organize a classroom equipped with materials that are needed to solve real-life problems. In such a setting, students learn to think systematically and learn by doing*."

S30: "*Teaching robotics coding and STEM training are the keys to keep up with the modern age. I believe games like puzzles help students to improve their algorithmic thinking skills as they are step-by-step in nature and require trial-and-error*."

It is understood that the prospective teachers a plenty of suggestions for the extra-curricular activities to develop students' algorithmic thinking skills. The diversity of the suggestions might be an indicator of that these skills could be acquired and improved in different ways.

DISCUSSION AND CONCLUSION

It is very important for teachers, who have an indisputable place in the education system, to be well-trained as they are supposed to prepare students, who constitute the other basic component of the system, for the future. Moving from this viewpoint, the current study was primarily motivated to investigate the prospective teachers' views on algorithmic thinking and its use in education. Based on the research objective, the participants were initially requested to identify characteristics of the individuals with algorithmic thinking skills. Their responses portray that these are well-planned and logical individuals with the ability to think systematically, to classify, to order, to comprehend problems easily, to generate practical solutions and to learn with ease. These findings are compatible with the existing literature (Eguchi, 2016; Hromkovič et al., 2016; Milková, 2012; Milková, 2015; Paul & Elder, 2006; Zsakó & Szlávi, 2012).

Secondly, the participants were asked to share their views as to how teachers with well-developed algorithmic thinking could influence students' development. Their responses showed that learning from such teachers is believed to make invaluable contributions to the education process as well as personal development of the students. Bacanak (2013) contends that teachers are the primary figure in enabling students to learn essential knowledge and skills since they indispensably influence their students with their knowledge, skills and attitude while teaching them. Quite similarly, the prospective teachers participating in this research reported that teachers with algorithmic thinking skills tend to teach gradually, to follow a process that facilitates learning, to encourage students to be well-planned and neat and to help them develop/ improve their algorithmic thinking skills. Besides, students' algorithmic thinking skills could be improved by encouraging them for multi-faceted thinking and enabling them to gain competence in problem-solving, establishing cause-and-effect relationships and meronymy.

The participants' views have also indicated that teachers with well-developed algorithmic thinking skills affect their students' cognitive development. This finding also coincides with other researches (Çelik et al., 2015; Tsalapatas et al., 2012).

Even though teachers are supposed to follow a curriculum, they are free to choose materials, methods, techniques, and types of assessment in their teaching. In this respect the participants suggested the use of such techniques as discovery learning, problem-solving, induction, brainstorming, concept mapping, games, discussion, fishbone and case study that require students' active involvement in the learning process in order to improve their algorithmic thinking skills. They also suggested to use of such teacher-centered techniques as question-and-answer drills, modelling, deduction and direct instruction. Nonetheless, the former group of teaching techniques were overwhelmingly reported in comparison to the latter. Thus, the finding in concern also approves the existing literature (Bacanak, 2013; Chao, 2016; Çelik, Pektaş & Demirtaş, 2012; Fessakis, Gouli, &Mavroudi, 2013; Gülbahar & Kalelioğlu, 2014; Howland & Good, 2015; Kukul & Gökçearslan, 2014; Saeli et al., 2011).

Another interview question required the participants to share their views on the type of evaluation questions teachers should use at the end of the lesson. Their responses revealed that what they suggested mostly fell into the category of higher-order questions. Additionally, analytical thinking skills are needed to increase the efficiency of outcome-oriented evaluation questions. The following are the effective teaching strategies proposed by Marzano, Pickering and Pollock (2001): (i) identifying similarities and differences, (ii) summarizing and note taking, (iii) reinforcing effort and providing recognition, (iv) homework and practice, (v) non-linguistic representations, (vi) cooperative learning, (vii) setting objectives and providing feedback, (viii) generating and testing hypotheses, and (ix) questions, cues, and advance organizers. In this respect, the participants mostly suggested the use of thought-provoking and challenging open-ended questions that encourage the students to think analytically rather than simple questions. This finding is in full agreement with previous research (Güven, 2004; Liu, Li & Liu, 2016).

The participant prospective teachers listed factors that hinder improvement of students' algorithmic thinking skills in four broad categories: teacher-oriented (e.g. non-gradual teaching, inadequacy of pre-service teacher training and direct instruction) student-oriented (e.g. passivity of students, failing to establish cause-and-effect relationships and lack of confidence), curriculum-oriented (e.g. non-inquiry based, rote-based, non-activity oriented and lack of supplementary materials) and environment-oriented (e.g. family and over-protectiveness). These findings largely conform to Çelik et al. (2015) who previously reported that such factors as test anxiety, test quality, rote-based learning, familial attitude and school infrastructure hinder improving students' analytical thinking skills. The findings in concern are partially in line with Çelik et al. (2015) in that both studies reported on internal (student-oriented) and external factors (teacher-oriented, curriculum-oriented & environment-oriented).

Analysis of the prospective teachers' responses about the extra-curricular activities that improve students' algorithmic thinking skills indicated that they mostly favored games (e.g. intelligence/ strategy games, puzzles and street games) and problem-solving activities (e.g. solving real-life problems and pattern problems). Extra-curricular activities help students develop positive attitude towards science and learning by providing students with the opportunities hardly offered at school (Balçın & Topaloğlu, 2019). Therefore, it is of great significance to train teachers who observe and inquire their students, produce and transfer knowledge, solve problems, think critically and express with confidence.

In the context of the research results, some suggestions are presented below;

The extensive use of student-centered educational techniques is believed to make more significant contributions to students' development. In addition, activities that improve students' algorithmic thinking skills should be integrated into textbooks.

Students should be encouraged to choose problem-solving steps on their own and provided assistance to improve their mental processes. They should also be provided education appropriate to their cognitive characteristics.

Lastly, training teachers on the skills and competences of the time and providing them with printed and electronic materials is believed to contribute to students' cognitive development.

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