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What is the Relationship between Students' Computational Thinking Performance and School Achievement?

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Abstract

This study investigates the relationship between computational thinking performance and general school achievement and explores to see if computational thinking performance can be predicted by algebra and informatics achievement. The sample group of 775 grade 8 students was drawn from 28 secondary schools across Kazakhstan. The students responded to a Computational Thinking Performance test of 50 multiple-choice questions and Computational Thinking Scale questionnaire. The test covers the concepts: logical thinking, generalisation and abstraction. The validity and reliability of the multiple-choice questions are tested using the Item Response Theory. The Likert type questionnaire covers five factors: creativity, algorithmic thinking, cooperation, critical thinking and problem solving. School achievement results (secondary data) include scores for a number of school subjects. The results of the study showed that the multiple-choice questions are valid and a reliable tool to measure computational thinking performance of students. Algebra, general school achievement and students' perception of their computational thinking skills were significant predictors of computational thinking performance. The results revealed no gender difference in computational thinking performance and perceptions of computational thinking. The findings regarding the relationship between computational thinking performance, the students' general school achievement and perceptions of computational thinking skills are compared and discussed.

Keywords: computational thinking, student achievement, testing, predictors, multiple-choice questions, item response theory

1. Introduction

The idea of integrating computational thinking into the school curriculum as one of the essential abilities of children was first introduced in the 1980s by Seymour Papert (1980), and has now become popular with the widespread development of STEM education and 21st century skill sets. There is much debate regarding the nature of the teaching of computational thinking; questions include definition, teaching and measuring, universal values and the transferability of skills of computational thinking to other areas of learning. As computer programming enhances computational thinking (Brennan & Resnick, 2012; Selby, 2014; Werner, Denner, & Campe, 2015) and since 8th grade students (aged 12 to 14 years) are familiar with basic programming skills such as variables, conditional statements, logical operators and loops in informatics lessons, then it might be expected that informatics scores could be a predictor of computational thinking performance. Likewise, as computational thinking is related to problem solving skills (Román-González, Pérez-González, & Jiménez-Fernández, 2016) and academic success (Ambrosio, Almeida, Franco, & Macedo, 2014; Durak & Saritepeci, 2017; Gouws, Bradshaw, & Wentworth, 2013), then students' general school achievement and especially algebra performance could be predictors. Korkmaz et al. (2015) developed the Computational Thinking Scale, a self-reported questionnaire as a measurement of computational thinking skills. It is used to measure the perception of computational thinking in this study.

The main aims of this study are to validate a computational thinking performance test, measure the computational thinking performance of the 8th grade students and thus to determine whether general school achievement, algebra achievement, informatics achievement and perception of computational thinking are predictors of computational thinking. The following questions are addressed by this research:

RQ1: Is the computational thinking performance test valid and reliable?

RQ2: Is algebra performance a predictor of students' computational thinking performance?

RQ3: Is informatics performance a predictor of students' computational thinking performance?

RQ4: Is perception of computational thinking skills a predictor of students' computational thinking performance?

2. Computational Thinking

The idea of computational thinking is not novel, but it is a current trend in education. Computational thinking is a cognitive process, which reflects the ability to think in abstractions, algorithmically and in terms of decomposition, generalisation and evaluation (Selby, 2014, p.38). Algorithmic thinking, logical reasoning, decomposition and abstraction are, if taken separately, individually established and have a long history. However, when combined to construct computational thinking, it is not yet agreed what to expect from mastering it. The multi-definition of computational thinking, the lack of evidence supporting the transfer of computational thinking skills to other fields and difficulty of measuring computational thinking level bring a complication in description and hardship in teaching (Guzdial, 2015; Denning, 2017). Big claims on the universal value of computational thinking are exaggerated and they should be softened (Denning, 2017), as there is no evidence of the transfer of knowledge from computer science to daily lives (Guzdial, 2015). The following concepts of computational thinking are introduced by several organisations: algorithmic thinking, logic, abstraction, decomposition, generalisation and evaluation (Barefoot, 2014; CS Unplugged, 2016; Google for Education, 2015). Computational thinking can be found in a semi-resident state, which can only be effectively used when it is taught and developed. Computational thinking can be described as a focused approach to real-life problems that is applied by transforming these problems into computable chunks and applying solutions in an efficient way (Barefoot, 2014; ISTE & CSTA, 2011). Although there is no single accepted definition to computational thinking, there are common concepts, such as, logic, abstraction, generalisation, decomposition and evaluation. Any person, not just computer scientists, can utilise either one of these concepts or the set of computational thinking skills. Since computational thinking is a thought process (Wing, 2011), it can be found in a semi-resident state in people, which can be activated and effectively used when it is taught and developed.

The idea of teaching computational thinking and ways of delivering it are still in the early stage of development. The educational reform in Kazakhstan, along with shifting from 11-year to 12-year school and three-language education has also integrated the computational thinking into the updated informatics curriculum. In the Kazakhstani updated informatics curriculum for 5^{th}-9^{th} graders, computational thinking is presented as a separate section among computer systems, information processes and health & safety with the following subsets: modelling, algorithms, and programming (National Academy of Education, 2016).

Among the main objectives of this updated curriculum two points are closely related to computational thinking (National Academy of Education, 2016):

a) Teaching students to tackle a variety of tasks by means of analysis, abstraction, modelling, and programming.

a) Enabling students to gain the abilities, such as, thinking logically and algorithmically, finding patterns, thinking in terms of generalisation, decomposition and evaluation.

By comparing items a and b above with the UK programme of study (Csizmadia et al., 2015), it is possible to see the similarities between the UK and Kazakhstani computational thinking concepts. Having analysed this updated curriculum (National Academy of Education, 2016), annual plans and the new informatics textbook (Shaniyev et al., 2017), it was concluded that 8^{th} grade students in Kazakhstan are familiar with concepts, such as, algorithm, generalisation, logics, and abstraction, as expected by Chuang et al. (2015). For this reason, the study narrowed its focus to the following concepts of computational thinking: logical thinking, abstraction and generalisation.

2.1 Evaluation studies of computational thinking

Without considering evaluation and assessment, computational thinking is unlikely to successfully advance in any curriculum. In addition, in order to judge the effectiveness of any curriculum integrating computational thinking, measures must be approved that would allow teachers to assess what children learn (Grover & Pea, 2013). Many studies on computational thinking have a small sample size between 7-30 participants (Ambrosio et al., 2014; Grover, 2011, 2015; Moreno-Leon, Robles, & Román-González, 2016; Oluk & Korkmaz, 2016; Werner, Denner, Campe, & Kawamoto, 2012) that cannot be generalised or they are self-reported studies (Durak & Saritepeci, 2017; Korkmaz, Çakir, & Özden, 2017; Korkmaz, Çakır, & Özden, 2015; Korucu, Gencturk, & Gundogdu, 2017), which do not measure performance. There are a lack of large-scale studies (Kallia, 2017) that could uncover the questions around how computational thinking skills are related to other disciplines and academic achievement. Studies on computational thinking differ on their findings regarding the gender factor. Therefore, gender variable is included this study. Since computational thinking is a multi-dimensional and complex phenomenon, it is hard to measure. Multiple-choice items are considered the most suitable format for assessment of higher order cognitive skills and abilities, such as problem solving, synthesis, and evaluation (Downing & Haladyna, 2006) and more efficient for a large sample size (Becker & Johnston, 1999; Dufresne, Leonard, & Gerace, 2002).

3. Methodology

3.1 Research Design

This study has a quantitative research design. For the primary data collection, the multiple-choice questions, delivered through an online quiz, were designed to measure the computational thinking performance of the secondary school students. In addition to multiple-choice questions, the computational thinking scale questionnaire (Korkmaz et al., 2017; Korkmaz, Çakır, & Özden, 2015) is used to measure perceptions of computational thinking skills in a standardised online form. As for the secondary data, the results of the General Achievement Test were taken. The secondary data relating to the individual respondent's general ability is drawn from the General Achievement Test results taken by all students of the Bilim Innovation Lyceums in Kazakhstan. The schools have integrated curricula of the natural-mathematical subjects and the test is taken termly.

The validity and reliability of the multiple-choice questions are tested using the Item Response Theory (IRT). The item difficulty and discrimination coefficients are calculated. In addition, item characteristic curves for each question and test information functions for each quiz are generated.

The research seeks to identify, through the analysis of variables, if a relationship exists between the prior measures and the computational thinking levels of 8th grade students. A regression analysis is used to predict computational thinking performance based on the predictor variables (Field, 2013). 50 multiple-choice items were carefully constructed and validated to measure computational thinking performance of the participants. The sample group respondents are 775 (549 boys, 226 girls) 8th grade students aged

13-14 years from 28 selective Bilim Innovation schools located in different parts of Kazakhstan. The national curriculum, Informatics textbooks (Shaniyev et al. 2017), annual lesson plans of informatics for 7th and 8th grades of Bilim Innovation schools have been reviewed and the following topics related to computational thinking were discovered: logics, algorithm, abstraction and generalisation.

3.2 Instruments

The first instrument is a multiple-choice test for measuring the computational thinking performance of the participants. The multiple-choice questions have been carefully developed in line with the context relevant recommendations on writing good multiple-choice items provided by the authors Downing & Haladyna (2006), Frey et al. (2005), Gierl et al. (2017) and Reynolds et al. (2009). Then, these test questions were approved by two reviewers with experience in assessing computational thinking. The concepts of computational thinking included in this test are abstraction, generalisation and pattern, algorithmic thinking and logic. The test questions are designed to measure the computational thinking performance of 8th grade students taking into consideration the national curriculum topics and students' experience with problem solving.

Each item in this multiple-choice test has four response options, with one correct answer and three distractors. The test has 50-multiple-choice questions (A set of 5 quizzes with 10 questions each) with a maximum score of 50 and is conducted online. There was a time duration of 100 minutes. Sample questions from the computational thinking performance test are presented in appendices A to E.

The second instrument used in this study is the Computational Thinking Levels Scale originally developed by Korkmaz et al. (2017) in 2015 for university students, which later was adapted to secondary school level (Korkmaz et al. 2015). The scale consists of 22 items with a 5-pont Likert type scale and has five factors each with the following number of items: "Creativity" - 4 items, "Algorithmic thinking" - 4 items, "Cooperation" - 4 items, "Critical thinking" - 4 items and "Problem solving" - 6 items. Each one of the items in the factors has been scaled as never (1), rarely (2), sometimes (3), generally (4), always (5), in which the maximum total score is 110.

The General Achievement Test is used as secondary data in this study. It is a multiple-choice test taken four times a year (once per term) in Kazakhstan from the following subjects: algebra, geometry, physics, chemistry, biology, computer science, English language, Kazakh language, Kazakh literature, Russian language, world history, history of Kazakhstan and geography. There are 160 multiple-choice questions in total in this test with maximum score of 320. The scores for algebra and informatics have a maximum score of 20.

3.3 Variables

The following variables are used in this study: CTP, CTS, GAT, ALG, INF and G. CTP (Computational thinking performance) is a sum of scores measured by 50 items of multiple-choice questions covering the following concepts: logic, algorithmic thinking, generalisation, and abstraction. CTS (Computational thinking scale) is a sum of scores measured by 22 items questionnaire covering five areas of computational thinking: creativity, algorithmic thinking, cooperation, critical thinking, and problem solving. GAT (General Achievement Test) is a sum of average scores of 4 tests that cover the following subjects: Physics, Chemistry, Biology, English language, Kazakh language, Kazakh literature, Russian language, Algebra, Geometry, Computer Science, General history, History of Kazakhstan and Geography. ALG (Algebra) is a 10-item subscale of the General Achievement Test that measures algebra performance. ALG (Algebra) is a 10-item subscale of the General Achievement Test that measures algebra performance. INF (Informatics) is a 10-item subscale of the General Achievement Test that measures informatics performance. G (Gender) is a binary variable.

3.4 Data analysis

The Mean values and Standard Deviation of each variable are calculated for all participants as well as for each gender group. In the multiple regression analysis, CTP is a dependant variable and GAT, ALG, INF and CTS are independent variables. The Cronbach alpha for CTS and CTP are calculated. The coefficients of item difficulty and discrimination, the item characteristic curve plots and the test information plots using a 2-parameter IRT model are presented for each quiz separately.

4. Results

Descriptive statistics, reliability and multiple regression analysis are presented in this section of the article.

4.1 Descriptive statistics

775 8th grade students from 28 schools in Kazakhstan participated in this research study. The descriptive statistics are presented in Table 1.

Table 1. Means and SD of variables CTP, CTS GAT, ALG and INF

	N	Mean	SD	Gender	N	Mean	SD
CTP	775	14.8	5.2	Boys	549	14.8	5.5
				Girls	226	14.8	4.3
CTS	775	74.3	12.3	Boys	549	74.5	12.7
				Girls	226	73.7	11.5
GAT	775	157.6	34.3	Boys	549	150.1	32.0
				Girls	226	175.7	32.9
ALG	775	13.3	3.7	Boys	549	12.9	3.4
				Girls	226	14.3	2.9
INF	774	9.1	2.7	Boys	548	9.1	2.7
				Girls	226	9.3	2.5

Boys (M=14.8, SD=5.5) did not significantly outperform girls (M=14.8, SD=4.3), in computational thinking performance test t(526)=-0.2, *p*=.851.

Boys (M=74.5, SD=12.7) did not significantly differ from girls (M=73.7, SD=11.5), in the computational thinking scale questionnaire t(773)=0.8, *p*=.853.

4.2 Computational Thinking Performance

The multiple-choice questions are tested for item difficulty and discrimination using a 2-parameter IRT model. All item characteristic curves for items fit well. The difficulty coefficients of items are between the range of -0.7 and 1.3. Three outliner items are item #1 and item #6 in the Abstraction quiz and item #7 in the Pattern figures quiz with the difficulty coefficients of 3.0, 1.8 and 2.0 respectively. The discrimination coefficients are close to 1 for each item in all quizzes. The test information for each quiz show that the average ability is tested the best. The item characteristic curves for each quiz can be found in appendix F-J. The Cronbach Alpha (Field, 2013) coefficient for all 50 items is 0.87. Therefore, it can be concluded that the test is a valid and reliable tool to measure computational thinking performance.

4.3 Computational Thinking Scale

The adapted version of the Computational Thinking Scale (CTS) instrument was tested for validity and reliability with 241 7th and 8th grade school students in Turkey (Korkmaz, Çakır, & Özden, 2015). Korkmaz et al. (2015) have conducted exploratory factor analysis, confirmatory factor analysis, item distinctiveness analyses, internal consistency coefficients and constancy analyses and concluded that the CTS questionnaire is a valid and reliable measurement tool to measure computational thinking skills of students. In this study to see the reliability of this instrument with 775 participants, the Cronbach alpha coefficients for each subscale are listed in Table 2.

Table 2. Computational Thinking Scale reliability test

Factor	**Number of items**	**Mean**	**Cronbach alpha**
CTS_CR (Creativity)	4	3.8	.599
CTS_AT (Algorithmic thinking)	4	3.5	.834
CTS_CO (Cooperation)	4	4.0	.841
CTS_CR (Critical thinking)	4	3.7	.738
CTS_PS (Problem solving)	6	2,5	.749
CTS (Total)	22	3.7	.838

The result of the reliability test of the CTS questionnaire Cronbach alpha for all 22 items is 0.838, which shows good reliability of the instrument. When each five factors are tested, it was found that the subscales' coefficient are greater than 0.7, except for the creativity subscale with Cronbach Alpha of

0.599. Students' perception on computational thinking differs between 2.6 and 4.2, and the mean is 3.7. The mean values of subscales are greater than 3.0, creativity 3.8, algorithmic thinking 3.5, cooperation 4.0, critical thinking 3.7. Except for the lowest one; the problem-solving subscale with 2.5. The authors of the instrument, Korkmaz et al. (2015) found the Cronbach alpha for the total items as 0.809, where 241 students from 7th and 8th grade participated. Therefore, the CTS questionnaire can be considered as a reliable tool.

4.4 Regression

A multiple linear regression was calculated to predict the computational thinking performance based on general school achievement, algebra achievement, informatics achievement and perception of computational thinking skills in Table 3. The result of the multiple linear regression indicated that the general school achievement, algebra achievement and perception of computational thinking skills are significant predictors for computational thinking performance; informatics achievement is not a significant predictor for computational thinking performance. The Table 3 contains the final step of a 4-step regression analysis.

Table 3. Multiple regression analysis

	B	**SE B**	**β**
Constant	4.73	1.33	
GAT	0.03	0.008	.17*
ALG	0.20	0.07	.13*
INF	0.03	0.08	.02*
CTS	0.04	0.01	.09*

Note: R2=,08. For Step 1, ΔR2=,01. For Step 2, ΔR2=0 For Step 3, ΔR2=,01. For Step 4 ($p<.05$).

5. Discussion and Conclusion

In this study, multiple-choice questions mainly focused on logics, abstraction and generalisation were constructed to measure students' computational thinking performance. Additionally, as a perception of computational thinking skills, a CTS questionnaire with a five-point Likert type scale with 22 items was used. As a general school achievement, the results of the General Achievement Test were obtained. The study reveals that the computational thinking performance test is a valid and reliable tool to measure the computational thinking performance of students (RQ1). The results also show that students' general school achievement, algebra achievement (RQ2) and perception of computational thinking skills (RQ4) can be predictors of their computational thinking performance. One finding is that the students' problem-solving subscales in a CTS questionnaire are lower than other subscales, which is similar to what Korkmaz et al.(2015), the authors of the CTS instrument found. This might indicate that the participants were less confident in their problem-solving skills. However, self-reported measures do not actually show that they can affect their problem-solving abilities (Guzdial, 2015). The results show that the informatics score is not significant in being a predictor of students' computational thinking performance (RQ3). As we explore the informatics annual plan for 8th graders, we see that there is not only programming but also other topics, such as measuring data, hardware network and spreadsheets. Although students are familiar with programming skills, perhaps they were simply not engaged in programming activities during the data collection in this study. The finding of this study that the general school achievement and algebra scores are significant predictors of computational thinking corresponds to the idea that computational thinking skills are closely related to problem-solving (Román-González et al., 2016) and academic success (Ambrosio et al., 2014; Durak & Saritepeci, 2017; Gouws et al., 2013).

All the multiple-choice questions were carefully designed to measure higher-order thinking, specifically the level of computational thinking of 8th grade students, as multiple-choice items are an efficient method for large-scale studies (Becker & Johnston, 1999; Dufresne et al., 2002). However, applying computing ideas in daily problems by transferring the knowledge of computing into real life problems is hard to prove (Guzdial, 2015).

The limitation of multiple-choice questions might be in their diversity and that they may not fully assess and reflect complex performance (Gayef, Oner, & Telatar, 2014; Hancock, 1994; Martinez, 1999; Paxton, 2000; Simkin & Kuechler, 2005). Another limitation might be that the Kazakhstan context makes a difference. All participant students speak English, their science lessons at school are conducted in English and every single question of the computational thinking performance test was carefully written using simple English. Nevertheless, the language barrier might also play a role in measuring computational thinking performance as all the test questions were in English for Kazakhstani 8th grade students. The sample groups are all from selective schools, meaning that the students' abilities and performance on average are higher than those of the general school population. The implications from this study might differ to other sample groups. As Weintrop et al. (2016) claim that there are other disciplines that explicitly link with computational thinking concepts, it is important that students understand these concepts and terms (Denning, 2009).

The future direction of this investigation will be, refinement and replication of the computational thinking test, obtaining more secondary data on general school achievement and determining whether promoting computational thinking skills increases students' general achievement.

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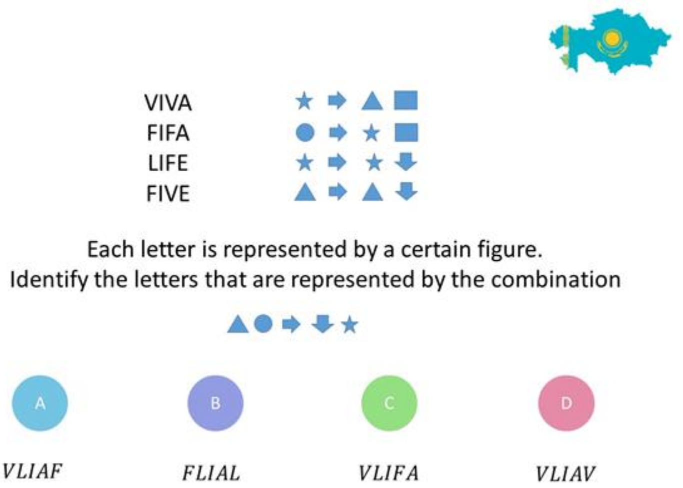
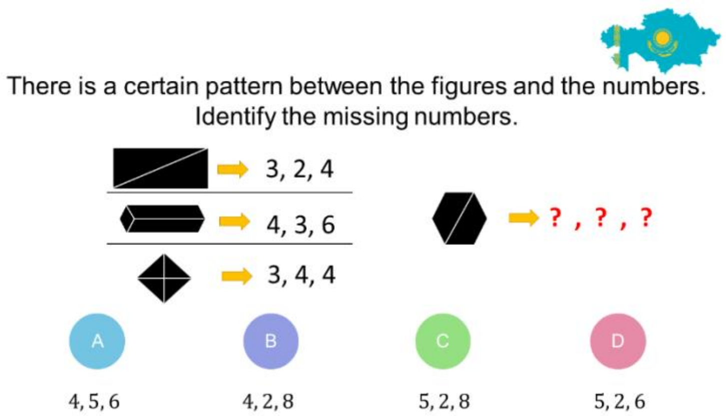
Appendix A

Sample question on Pattern figures



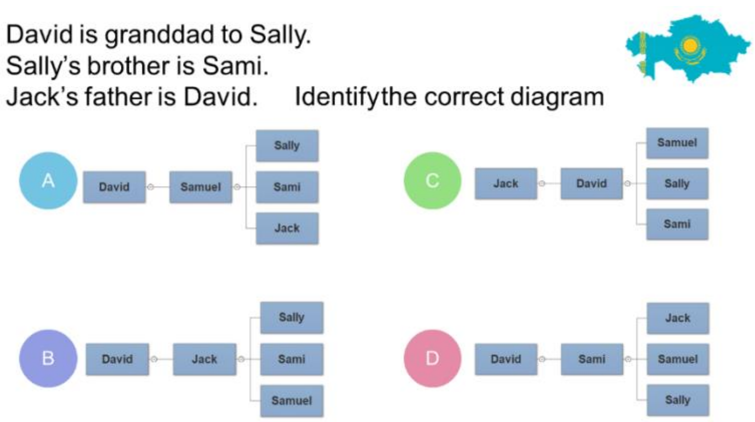
Appendix B

Sample question on Pattern numbers



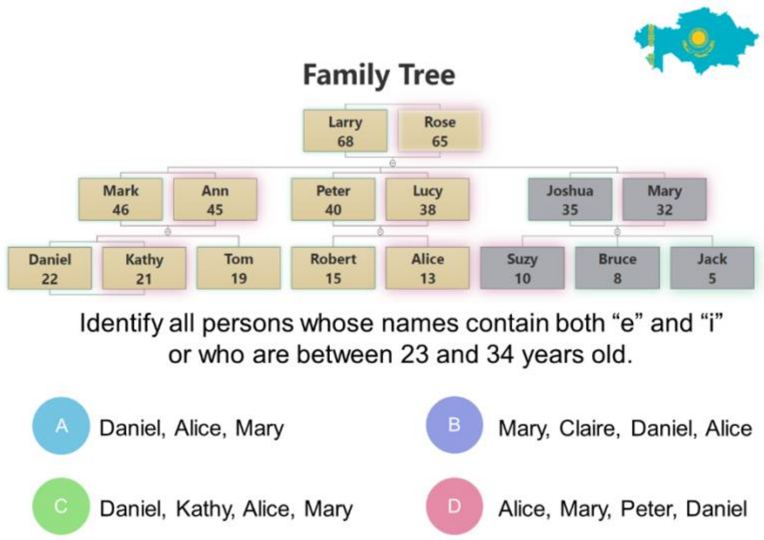
Appendix C

Sample question on Abstraction



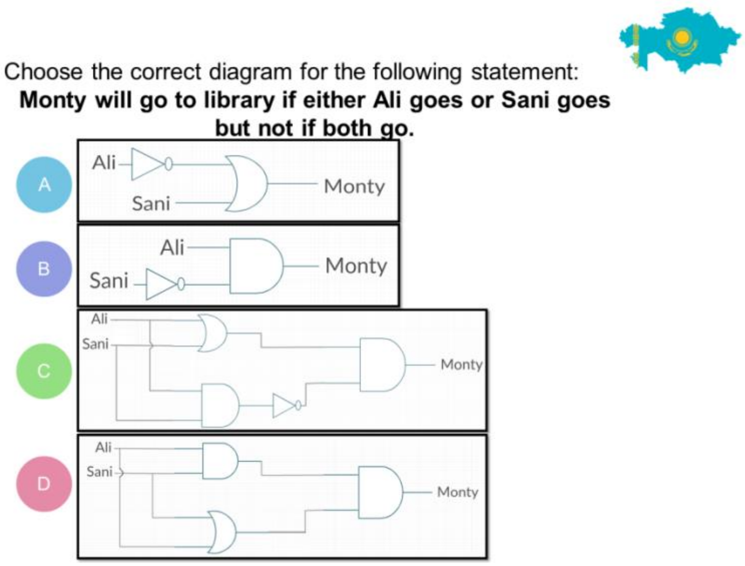
Appendix D

Sample question on Logic



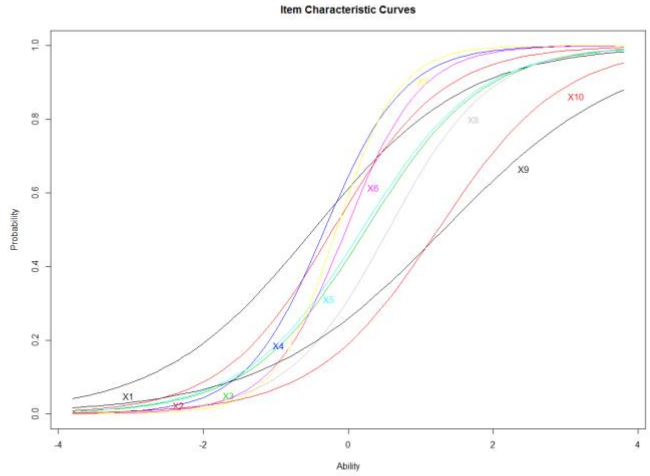
Appendix E

Sample question on Logic Narrative



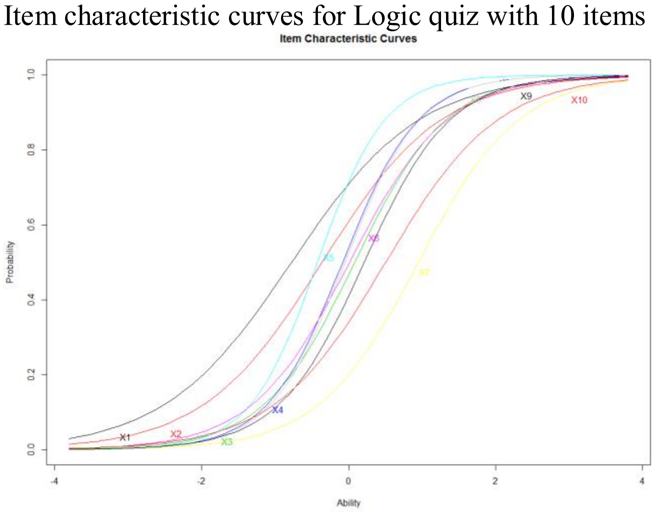
Appendix F

Item characteristic curves for Logic Narrative quiz with 10 items



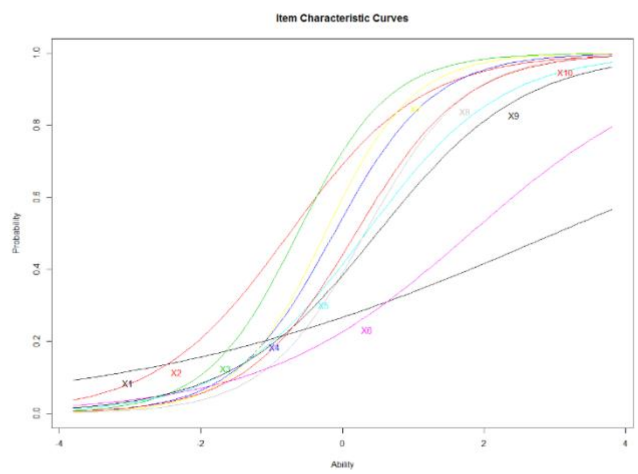
Appendix G

Item characteristic curves for Logic quiz with 10 items



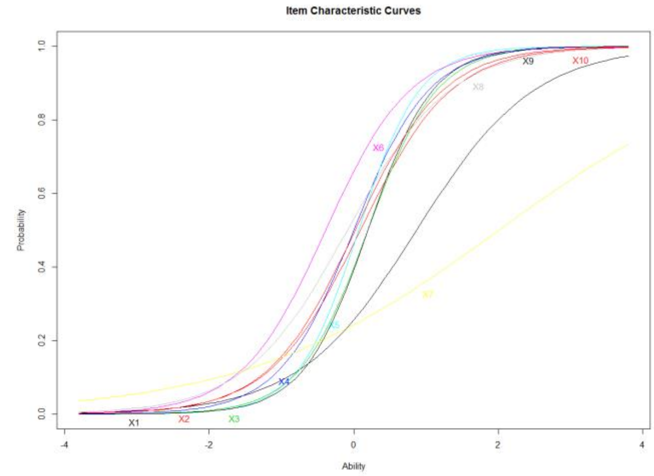
Appendix H

Item characteristic curves for Abstraction quiz with 10 items



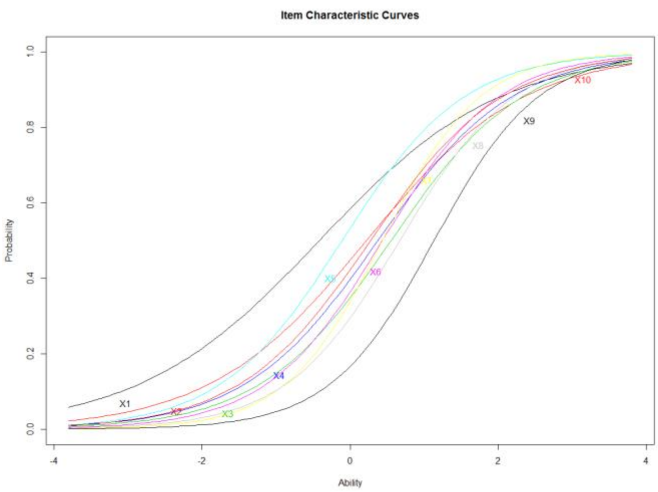
Appendix I

Item characteristic curves for Pattern numbers quiz with 10 items



Appendix J

Item characteristic curves for Pattern figures quiz with 10 items



The Impact of Children's Long-Term Participation in STEM Clubs on Their Attitudes towards STEM Subjects

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Abstract

In this report we investigated the impact of after school STEM clubs on children's attitudes to STEM related subjects. 236 children aged 8-12 took part in this study. For the purpose of this study, a quantitative research method was adopted where a survey prior to the STEM activities and at the end of 30 weeks of after school club have been used to make sense of children's perspectives on STEM related subjects. The study also explored whether the age and gender of the children would influence their attitudes towards these subjects.

Key words: STEM, Engineering, Cross curricular, Computer Science, Primary education

1. Introduction

STEM stands for science, technology, engineering and mathematics. The STEM term was introduced by Judith A. Ramaley, the former director of the U.S. National Science Foundation's Education and Human Resources Division in 2001. There is no agreed definition of STEM. Kelley and Knowles (2016) describe STEM as a teaching approach and learning activities with a purpose of connecting science, mathematics, technology and engineering concepts and applications to enhance students learning. Moore and colleagues (2014) focusing on integrated STEM education defines STEM as "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p. 38). According to Allsop (2016) the aim of STEM education is "to blend scientific inquiry and technological design processes through project based learning that focus on developing students' critical thinking, problem solving, logical reasoning, technical, communication, collaboration, self-directing and creativity skills" (p. 120) This is also supported by Watson and colleagues, who explained STEM as 'a teaching approach that involves teaching science, technology, engineering and mathematics concepts in an integrated way from early years to higher education' (2013).

We define STEM as a teaching approach that aims to integrate learning in four main disciplines; science, technology, engineering and mathematics through project based activities. This is very important as Huber and colleagues (2005) noted, making connections between different curriculum, disciplines, knowledge and practice can provide learners with a deeper understanding of concepts. Furthermore, STEM learning provides children a platform to investigate a concept or an idea in many different contexts and then connect their learning across disciplines. STEM education helps learners to understand how a tool or a mechanism Works and increases their technological skills (Bybee, 2010). Especially at K-12 level, STEM education enables learners to develop knowledge and skills that are crucial for life and economic development (National Research Council, 2011). The definitions above show that STEM involves integration of disciplines for preparing students to solve real life problems.

1.1. Why STEM?

In order to answer this question we need to approach it from different aspects:

1. Economic and technological aspects: STEM education received much interest from industries that were having issues with skill shortages. A recent study completed by the EU Committee on Employment and Social Affairs (2015) reported that "A sufficient labour supply equipped with STEM skills is essential to implement the European Agenda for Growth and Jobs". The report also noted that by 2025, there will be 7 million jobs that will require STEM skills (2015, p.8). Furthermore, this report discussed the importance of schools for transforming learners' attitude towards science through STEM activities.
2. Real life aspect: Preparing people for life is not the aim of education; in short, life is a constant education. STEM focuses on real-life problems, which allows children to face crucial problems, and then think about formulating solutions for these.
3. The link between education and industry: One of the aims of education is to prepare people for job prospects. According to the Intel Report (2015); Science, technology, engineering, and math (STEM) disciplines play an increasingly important role in employability.
4. Developing transferrable skills: STEM education enables children to develop 6C skills (critical thinking, collaboration, communication, creativity, citizenship and character education) that are vital for designing solutions to real-life problems.

2. Methodology

For the purpose of this study a quantitative research method has been used for making sense of children's attitudes towards STEM related subjects. 236 children aged between 8 and 12 took part in a 30 week long STEM club in 2008 at the Payas STEM Centre. 135 students were male and 105 of them were girls. The sessions included a mixture of mathematics, science, robotics and coding activities. The children completed a pre and post survey to describe their experience of taking part in the STEM club which helped us to gain an insight into their learning process and attitudes towards STEM subjects.

3. Findings and Discussions

In the analysis of the data; descriptive statistics; frequency, percentage, mean, standard deviation values are presented. An Independent paired t-test was used to examine whether the mean measurements of the pre-test score changes of the study groups were different. The paired chi-square test was performed to examine whether the study group pre and post-test ratios were different. Correlation analysis was performed to determine the relationship between age, pre-test and post-test. P values less than 0.05 were considered statistically significant ($\alpha = 0.05$). The analyses were done using the SPSS 22.0 package program.

Table 1. Student characteristics

Age	N	%
8	22	9,3
9	59	25,0
10	69	29,2
11	52	22,0
12	34	14,4
Gender	**N**	**%**
Male	131	55,5
Female	105	44,5

It was determined that 9% of the students participated in the study were 8 years old, 25% were 9 years old, 29% were 10 years, 22% were 11 years and 14% were 12 years old. 56% of the students were male and 44% were female.

Table 2. Evaluation of Pre-Test and Final Score by Gender

Statements		Pre-club		After Club		P
		n	%	n	%	
I have information about Stem	Yes	126	53,4%	217	91,9%	**0,01***
	No	110	46,6%	19	8,1%	
The use of Stem activities in the lesson is fun	Yes	231	97,9%	234	99,2%	0,63
	No	5	2,1%	2	,8%	
I'm not interested in Stem activities	Yes	11	4,7%	0	0,0%	0,13
	No	225	95,3%	236	100,0%	
Designing courses improves my creativity	Yes	228	96,6%	235	99,6%	0,11
	No	8	3,4%	1	,4%	
Stem activities create a desire to study	Yes	209	88,6%	209	88,6%	0,99
	No	27	11,4%	27	11,4%	
Stem activities improve performance	Yes	227	96,2%	232	98,3%	0,90
	No	9	3,8%	4	1,7%	
I'm interested in using technology in Stem events	Yes	230	97,5%	223	94,5%	0,52
	No	6	2,5%	13	5,5%	
I love mathematics	Yes	218	92,4%	230	97,5%	0,24
	No	18	7,6%	6	2,5%	
I did mathematical modelling before	Yes	102	43,2%	204	86,4%	**0,01***
	No	134	56,8%	32	13,6%	
I like the science course	Yes	227	96,2%	230	97,5%	0,65
	No	9	3,8%	6	2,5%	
I love group work	Yes	227	96,2%	228	96,6%	0,92
	No	9	3,8%	8	3,4%	
I've heard the term Arduino before	Yes	58	24,6%	56	23,7%	0,95
	No	178	75,4%	180	76,3%	
I've heard the term Scratch before	Yes	93	39,4%	86	36,4%	0,42
	No	143	60,6%	150	63,6%	
I've heard the term microbit before	Yes	64	27,1%	86	36,4%	**0,03***
	No	172	72,9%	150	63,6%	
I've heard code.org before	Yes	34	14,4%	203	86,0%	**0,01***
	No	202	85,6%	33	14,0%	

* significant difference, p values were analysed by chi-square test.

The students' responses of the item “I have knowledge about stem” are different from the pre-test and post-test responses and the level of thinking that the students have knowledge about Stem in the post-test responses is higher than the pre-test ($p = 0.01$, $p < 0.05$). The students' responses of the item “I did mathematical modelling before” was different from the pre-test and post-test responses, and the post-test responses of the students were found to have higher levels of mathematical modeling than the pre-test ($p = 0.01$, $p <0, 05$).

It was determined that the distributions of the responses given to the pre-test and post-test differed from the students in terms of the “Microbit term was previously heard” statement, and the students' hearing rates were higher in the post-test responses than in the pre-test ($p = 0.03$, $p < 0.05$). The students' responses of the item “I have heard code.org before” are different from the pre-test and post-test responses, the difference in the post-test response of the students' pre-test rate was found to be higher than the levels ($p = 0, 01$, $p <0.05$).

Table 3. Pre and after club survey analysis in relation to gender

Statements		Pre-test				Post-test			
		Male		Female		Male		Female	
		n	%	n	%	n	%	n	%
I have information about Stem	Yes	65	49,6%	61	58,1%	120	91,6%	97	92,4%
	No	66	50,4%	44	41,9%	11	8,4%	8	7,6%
The use of Stem activities in the lesson is fun	Yes	127	96,9%	104	99,0%	131	100,0%	103	98,1%
	No	4	3,1%	1	1,0%	0	0,0%	2	1,9%
I'm not interested in Stem activities	Yes	6	4,6%	5	4,8%	0	0,0%	0	0,0%
	No	125	95,4%	100	95,2%	131	100,0%	105	100,0%
Designing courses improves my creativity	Yes	129	98,5%	99	94,3%	131	100,0%	104	99,0%
	No	2	1,5%	6	5,7%	0	0,0%	1	1,0%
Stem activities create a desire to study	Yes	118	90,1%	91	86,7%	112	85,5%	97	92,4%
	No	13	9,9%	14	13,3%	19	14,5%	8	7,6%
Stem activities improve performance	Yes	125	95,4%	102	97,1%	130	99,2%	102	97,1%
	No	6	4,6%	3	2,9%	1	0,8%	3	2,9%

I'm interested in using technology in Stem events	Yes	127	96,9%	103	98,1%	126	96,2%	97	92,4%
	No	4	3,1%	2	1,9%	5	3,8%	8	7,6%
I love mathematics	Yes	121	92,4%	97	92,4%	127	96,9%	103	98,1%
	No	10	7,6%	8	7,6%	4	3,1%	2	1,9%
I did mathematical modelling before	Yes	56	42,7%	46	43,8%	110	84,0%	94	89,5%
	No	75	57,3%	59	56,2%	21	16,0%	11	10,5%
I like the science course	Yes	125	95,4%	102	97,1%	130	99,2%	100	95,2%
	No	6	4,6%	3	2,9%	1	0,8%	5	4,8%
I love group work	Yes	124	94,7%	103	98,1%	126	96,2%	102	97,1%
	No	7	5,3%	2	1,9%	5	3,8%	3	2,9%
I've heard the term Arduino before	Yes	27	20,6%	31	29,5%	31	23,7%	25	23,8%
	No	104	79,4%	74	70,5%	100	76,3%	80	76,2%
I've heard the term Scratch before									
	Yes	51	38,9%	42	40,0%	51	38,9%	35	33,3%
	No	80	61,1%	63	60,0%	80	61,1%	70	66,7%
I've heard the term microbit before	Yes	38	29,0%	26	24,8%	49	37,4%	37	35,2%
	No	93	71,0%	79	75,2%	82	62,6%	68	64,8%
I have information about Stem	Yes	20	15,3%	14	13,3%	112	85,5%	91	86,7%
	No	111	84,7%	91	86,7%	19	14,5%	14	13,3%

For the purpose of calculating the average scores, the students who select Yes for the questions with positive content got 1 point score; got 1 point score for the negative expression (I am not interested in Stem Activities). Students who select different options receive 0 points. The higher the score means, the higher the level of knowledge and awareness about the Stem System.

Table 4. Students' knowledge and awareness level of STEM education

Measurement	Test	Mean	S.D.	p
Stem System Information and Awareness level	Pre	10,59	1,85	0,01*
	Post	12,33	1,43	

** Significant difference, paired t test was applied.*

The data presented that the levels of Knowledge and Awareness about Stem System before and after education were different. It can be said that the reason for the difference is higher than the pre-education level and the level of knowledge and knowledge is effective (p = 0.01, p <0.05).

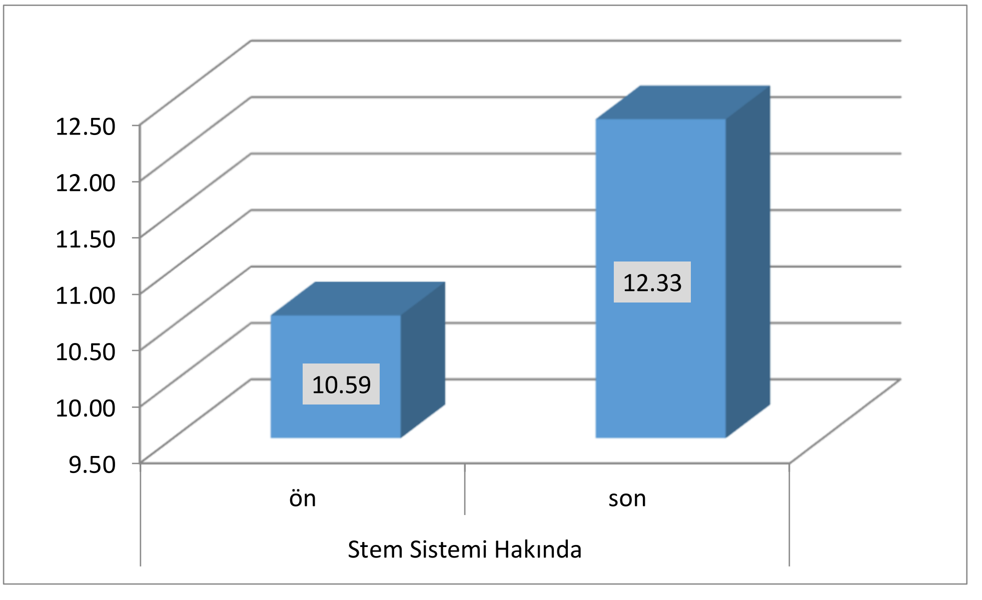

Figure 1. Students knowledge and awareness of STEM learning

Table 5. Students knowledge and awareness of STEM learning in relation to Gender

Gender	Steam Test	Mean	S.D.	p
Male (n=131)	Pre	10,52	1,80	0,01*
	Post	12,34	1,43	
Female (n=105)	Pre	10,68	1,92	0,01*
	Post	12,30	1,42	

** Significant difference, paired t test was applied.*

The data shows that male students have different levels of knowledge and awareness about Stem System before and after education. It can be said that the reason for the difference is higher than the pre-education level and the level of knowledge and knowledge is effective (p = 0.01, p <0.05). It was determined that female students had different levels of knowledge and awareness about Stem System before and after education. It can be said that the reason for the difference is higher than the pre-education level and the level of knowledge and knowledge is effective (p = 0.01, p <0.05).

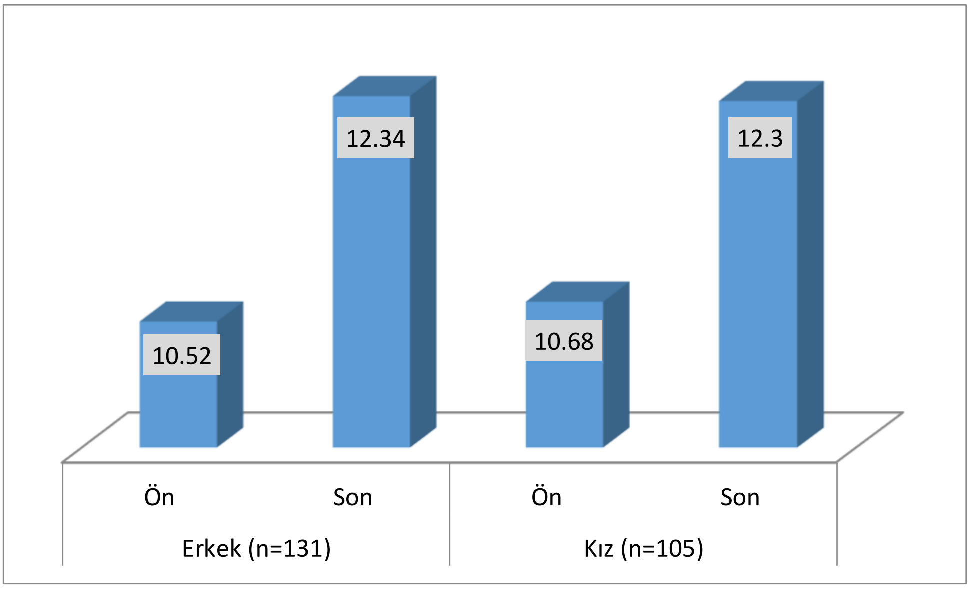

Figure 2. Knowledge and Awareness Level of Stem System in terms of Gender

Table 6. Students' knowledge and awareness of STEM learning in relation to age

Variables		Pre	Post	Age
Pre Test	r	1		
	p			
Post Test	r	0,06	1	
	p	0,34		
Age	r	0,47*	0,16*	1
	p	0,01	0,01	

It was determined that there was no significant relationship between pre-test scores and post-test scores. It was determined that the pre and post test scores of the students changed without being dependent on the pre-test scores ($r = 0.06$, $p > 0.05$).

There was a positive correlation between pre-test scores and age. Pre-test scores of high-age students were also found to be high ($r = 0.47$, $p < 0.05$).

It was determined that there was a positive, significant correlation between the post-test scores of the students and their age, at a very weak level. Post-test scores of high-age students were also found to be high ($r = 0.16$, $p < 0.05$).

Table 7. Knowledge about the Stem System by Gender and Relationship between Awareness Level and Age

Gender			Pre	Post	Age
Male	Pre	r	1		
		p			
	Post	r	0,04	1	
		p	0,64		
	Age	r	0,45**	0,17*	1
		p	0,01	0,04	
Female	Pre	r	1		
		p			
	Post	r	0,09	1	
		p	0,37		
	Age	r	0,49**	0,16*	1
		p	0,01	0,04	

* Correlation analysis showed significant difference.

There was no significant correlation between pre-test scores and post-test scores of male students. Male students' pre and post test scores were found to change without being dependent on the pre-test scores ($r = 0.04$, $p > 0.05$). It was determined that there was a positive, significant relationship between pre-test scores and age of the male students at a moderate level. Pre-test scores of male students with high ages were also found to be high ($r = 0.47$, $p < 0.05$).

It was found that there was a positive, significant correlation between the post-test scores of the male students and the age of the students at a very weak level. Post-test scores of male students with high age were also found to be high ($r = 0.17$, $p < 0.05$). There was no significant relationship between pre-test scores and post-test scores of female students. It was determined that the female students' pre-and post-test scores changed without being subject to change pre-test scores ($r = 0.09$, $p > 0.05$).

Data presented that there was a positive, significant relationship between pre-test scores and age of the girls and a moderate level. Pre-test scores of female students with high age were found to be high ($r = 0.49$, $p < 0.05$). It was determined that there was a positive, significant correlation between the post-test scores of the female students and their ages at a very weak level. The final test scores of the high school girls were also high ($r = 0.16$, $p < 0.05$).

4. Conclusion

In this report we investigated the impact of after school STEM clubs on children's attitudes to STEM related subjects. 236 children aged 8-12 took part in this study. Data analysis shows that children have developed positive attitudes towards STEM areas after long and planned STEM trainings which was applied to 236 students aged 8-12. The data also presented that participating in long-term STEM clubs had positive effect on children's learning. In order to meet the need for workforce in STEM areas in the world in the future, it is crucial to plan and implement long term STEM clubs. This would also be useful for raising the interest of young students in STEM occupations.

In longitudinal and planned Stem training, there was no significant difference in the increase in the interest in the Stem areas in the 8-12 age groups, but it can be said that the ratio is slightly higher in boys. From this point of view, it is possible to state that girls are directed to the STEM areas when they are offered equal opportunities. Participation of girls in the labour force in Stem areas will contribute greatly to the economies of that country.

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Reflections on the TALKING CELLS PROJECT: A STEAM Approach to Learning

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Abstract

This small-scale action research reports on a design and implementation of a 'Talking Cells' project which aims to teach students the subject of "Cell" through an integrated STEAM approach. For this project, the school's ICT teacher, science teacher and educational technology specialist worked collaboratively to design a series of activities that provided a context for children to solve real-life problems. In total 3 teachers from different subject fields worked as a team on this project with 51 sixth grade students. The students experimented with the ideas by designing solutions for real-life problems that were given to them. The students transformed organelles from cells into objects by using different materials and programming these using digital tools and electronics. The study which took place during lessons totaling 400 minutes, allowed students to experiment with STEAM concepts and skills. The study found that learning through solving real-life problems using programming and STEAM skills had a significant effect on students' performance.

Key words: STEM, STEAM, 21st Century skills, Technology, Cell, Organelle, Programming, Makey Makey

1. Introduction

For some students learning mathematics has been a challenging experience mainly because of their mathematics anxiety (MA). Ma and XU (2004) defines mathematics anxiety as a state of discomfort caused by performing any form of mathematical tasks. Ashcraft & Ridley (2005) describes MA as the negative emotional response to situations involving math which can cause stress and avoidance behaviour (Ashcraft & Ridley, 2005). This state of discomfort or negative emotional response can be observed in many different ways such as feeling worried, being frustrated, having a fear, disliking (Ashcraft & Ridley, 2005; Wigfield & Meece, 1998). A number of studies have shown that there is a strong relationship between MA and children's performance in mathematics (Ashcraft & Kirk, 2001; Hembree, 1990; Ma, 1999). Similar issues were also reported by some children, during science lessons, where students develop a fear towards learning science concepts and any situations that involving science (Mallow, 2006). Likewise, the link between science anxiety and performance was reported by number of studies (Udo, Ramsey, Reynolds-Alpert, & Mallow, 2001). The difficulty in helping students who might develop mathematics or science anxiety is the reasons and causes can be very diverse, making it very hard to identify. We propose teaching mathematics and science concepts through a STEM approach where the focus will move on to developing concepts through a project-based approach rather than learning of domain specific knowledge under each subject. This integrated teaching of different curriculum subjects was also supported by Huber and colleagues (2005) who argued that making connections between disciplines can support learners to develop a deeper understanding of concepts. Moore and colleagues (2014) focusing on integrated STEM education, defines STEM as "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (p. 38).

Some studies suggested that integrating art into STEM based learning would engage learners and has potential to improve cognition (Henriksen, 2011; McGrath & Brown, 2005). These views encouraged educators to include Art in STEM education and focus on STEAM rather than STEM. Wang and colleagues (2011) studied the way subjects were taught in schools. Focusing on three different class teachers, they reported on their observations at the end of each day. When they observed the mathematics teacher, they suggested that the teaching was teacher-led, and the lessons did not encourage students to question or investigate the concepts. The second teacher taught the same grade and subject for seven days using real-life problem-solving approach. The teaching was defined still as teacher-led and students couldn't relate to the issue or formulate questions. The final teacher used interdisciplinary methods and provided the children with a problem that was all about building an adult-sized cardboard chair that could hold someone that weighs 150-200 pounds. The teacher let the students figure out their own solutions, through the planning and design process, allowing them to use their own creativity. As a result, the students were supported to develop their problem solving, design & engineering skills. They were therefore able to analyse the problem and manage their own learning process. They were able to design their own research and questioning methods.

The studies we discussed above influenced the way that we developed and taught the Talking Cells project. This will be explained in Section 3.

2. Methodology

An action research approach was used for investigating our own teaching approaches to children's learning of concepts from different domains in an integrated manner. We followed the stages of action research process suggested by Altrichter and colleagues (2007). Data was collected through unstructured observations and questionnaires. The students and their interactions were observed by the branch teachers whilst working on their project. Any behaviour, words or description that would provide us with an insight into their learning and engagement was written down. The students' prior knowledge on the subject, knowledge during the course and the output knowledge after the course were measured using questionnaires.

Data was analysed by looking at the data collected from the observations, followed by analysis of the questionnaires. A traditional approach based on Strauss's (1987) "coding from the data" method was adopted where we analysed the data as we collected it during the project. We explored what was more significant based upon our knowledge and understanding of the topic as we found that having three experts from different backgrounds was very useful for this process. Quotes from the interviews with the students were used to give an insight into the student's experiences. The data collected was analysed using the constant comparative method to conceptualize the overall data and establish the links to the research question (Glaser and Strauss, 1967).

The children and parents were informed about this project and that the outcome of the investigation would be published both on the Internet and also presented in conferences. A generic permission letter that had been prepared by the school, regarding studying the children's work to improve standards in school was signed by all of the parents. The children were also reminded that they may withdraw from the activity at any time they liked.

3. Implementation of Talking Cells project

As our discussion in the previous section demonstrated; teaching science, technology, engineering and mathematics concepts through art-based learning can improve students understanding and problem-solving abilities. At this point we need to remind ourselves what the core elements of the STEM approach are. Jolly (2014) has listed the characteristics of STEM as:

- *lessons focus on real-world issues and problems.*
- *lessons are guided by the engineering design process*
- *lessons immerse students in hands-on inquiry and open-ended exploration.*
- *lessons involve students in productive teamwork.*
- *lessons apply rigorous maths and science content for students to learn.*

- *lessons allow for multiple right answers and reframe failure as a necessary part of learning.*

We developed our Talking Cells project with these core elements of STEAM learning in mind. The students were given a real-life problem and asked to formulate solutions through planning, design, testing and evaluation. The students were taken on an open-ended exploration where they worked as part of a team. The project focused on developing concepts in different subject domains.

The project was based on a story which had a main character called ATP. The story tells how ATP decided to go to his dad's science lab without his permission and used his new invention, which shrinks the size of the objects.

ATP shrinks himself by accident to the size of an atom, then falls onto the floor inside a petri dish and sinks into an animal cell. This is the beginning of his adventure with organelles. ATP has to follow the nucleus commands in order to get out of the cell safely. During this project, the students were asked to act as ATP and visit organelles in order to prepare themselves for following the commands of the nucleus.

The implementation of the project involved several steps:

Real Life Problem and Restrictions (1 hour)

The story describing ATP's cell adventure (Appendix 1) and project notebooks (Appendix 2) were distributed to students. At the beginning, the story was read by the teacher, using an Interactive White Board to display the visuals related to the story. At the end of the story, the teacher asked the students the following questions;

- What do you think that the interesting machine in the science lab did to ATP?
- Where did ATP find himself after the effects of the machine?
- What do you think the round shapes were that ATP saw when he fell into the water drop?
- What should ATP look for when navigating inside the cell?
- If you were ATP what would you do to get out of the cell?

Acquiring Information (2 hours)

- The students filled in the first part of the" Recruitment Form" in the project books.
- The teacher asked the students to use the subject materials (iPad, science textbook, etc.) in science to study the topic, "Cell" which is included in the unit "Systems in Our Body"
- The teacher distributed capsules in which the names of the organelles are written to the students. Individually, the students conducted research about Molecular Biology and Genetic Engineering in the computer laboratory about the organelles that were written in the capsules.
- The students filled in the second part of the" Recruitment Form" in the project books.
- Based on the results of their research, they described the organelles using their characteristics. One example of this can be illustrated through Child A's description.

Vacuoles is my name. I have five siblings. The nucleus is my boss, but he's always late with my *salary. I'm found in all eukaryotic cells, but I still may not be present in some cells. Mostly big in plants, but less, in animals I'm small, but I'm too many.*

Child B described Lysosome:

Hello my name is Obur(Greedy) Necmettin. I'm a lysosome. I'm in the plant cell. I am very oburu. That's why I can digest within the cell. Bring everything to me, but don't bring it cooked food. I'd like to introduce you to five fingers. When you're talking, give me the amoeba between bread!

Idea Development (2 hours)

- Students decided on the voice that they wished to use for their presentation.
- After giving the presentation of the study to the science teachers in the classroom, they filled in the second part of the adventure of ATP with their friends. They received feedback on their ideas.
- Students filled in the "First Days" section of the project books.

Product Development: (Total 3 hours)

- The science teacher prepared A3 sized models and shared the models covered with PVC with the students (Appendix 4, Animal Cell Model)
- Students filled in the "Product Analysis" section of the project books.

Visual Arts Course (1 hour)

- The students start to make 3D models.
- They improved their design by looking at real 3D organelle images that are shown on the IWB board.
- At the end of the course, the science teacher checked the designs that the students had made and directed the students to the information technology class.

Information Technologies and Software (2 course hours)

- Throughout the study, the students took on their professional roles by selecting one of the professions in the project books.
- 3D Modeling Professionals paste 50x70 dried models onto canvas (Figure 1).

Figure 1: Models of organelles

- Computer Engineers encoded the audio files that they collected in accordance with the use of the Makey Makey and Scratch program. (Note for the teacher: Each organelle will be associated with a letter from Makey Makey.)
- Electrical Electronics Engineers, in cooperation with the Modeling Professionals, installed Makey Makey by creating their system with electronic cables.
- Public Relations Specialists prepared presentations for the marketing of the product.

Testing

The three different branch teachers created and completed the rubric jointly based on their observations whilst the children were creating their models and when they presented their product to whole class. The students had opportunities to evaluate their own project throughout the sessions.

Sharing and Mirroring (Total of 2 courses)

- The students presented their project to the teachers of the three courses and their peers. (1 lesson hour)
- The students took an exam in science. (1 lesson hour)
- Self-evaluation forms were distributed to the students to be completed.

The detailed list of skill and knowledge set that this project aims to cover can be found in Appendix 1 and all the necessary materials for delivering the sessions can be found in Appendices 2-5.

4. Discussion of findings and conclusion

The data from the observations showed that when evaluating their own learning, the students gave full marks to themselves in working as part of a team, research, application, presentation and comprehension skills. This shows, that not only were they able to assess their own learning, but also had high self-esteem.

The students were able to recall the concepts that they had learned and to use the skills that they had developed after the project in other sessions. This shows that they were able to retain the information and skills. We could link this to both Piaget (1970) who highlighted the importance of learning through doing and also Vygotsky who emphasised the role of social interactions in children's learning (1978).

Both the observations and student's exam results showed that there was a significant increase in children's understanding of concepts and processes in many subject domains. For example, in science, the results showed that the children were able to use scientific inquiry and technology to implement their solutions. This also involved coding skills as they used the Scratch application to program their organelles. They were able to create a 3D representation of cells where they learned to work using a wide range of materials.

In terms of mathematics when drawing cells, they learned to calculate the diameter-radius of the model and draw the circle using compasses. They also used the measurement techniques to create 3D models of organelles on the canvas. This also requires the skill of imagination, creativity, visualization, which can highlight the role of art in design and making processes. From an engineering perspective, the students documented the stages of their production using an engineering notebook and systematically identified issues and modified their design accordingly.

One other interesting finding of this classroom investigation was how children that normally showed anxiety when learning mathematics or science, did not display any negative emotions during this project. One reason for this might be that they perceived this project as a problem-solving activity rather than learning in any specific subject.

In conclusion we can suggest that designing learning opportunities for children using a STEAM approach can support their learning of concepts in different disciplines in a meaningful way as long as real-life problems are used for the project. It is also important to have experts from different disciplines involved in the design, teaching and evaluation of the project as this would bring in the expertise of professionals from different fields, increasing the validity and reliability of the project.

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Appendices

Appendix 1: The knowledge and skill set covered

Cognitive Process Attainments

1.1. Attainment related to the main discipline:

Science

6.1.1.1. Compares animal and plant cells with their basic structure and their objectives.

a. As for the basic structure of cells, cell membrane, cytoplasm and nucleus are given.

b. Only the surface information about organelles such as names and objectives are mentioned.

1.2. Attainments related to other disciplines of STEAM:

IT and Software programming

6.1.3.5. Develops a strategy for storing files and accessing files. Customizing the working environment for storing files is highlighted.

6.4.2.2. Uses software that can edit audio and video files. Open source or free access audio and video editing programs are preferred.

6.5.1.5. Develops an algorithm to solve the problem.

6.5.2.15. Creates an original project with all programming structures

Mathematics

6.3.3.1. Recognizes the center, radius and diameter by drawing a circle.

Visual Arts and Design

6.1.2. Uses different materials and techniques to create visual art work.

6.1.4. Reflects his / her ideas on visual art work according to the selected theme and subject.

Liberal arts

6.5.6. Investigate the personality traits, skills and training process required by the profession.

Turkish

6.2.1. Makes a prepared speech.

6.3.4. Uses reading strategies.

1.3. Social Product Achievements:

He communicates effectively with his group mates and shares his ideas and actively participates in group work. The student presents the designed product clearly. Develops skills in front of the public, having empathy, and being open minded about the opinions of their friends.

Appendix 2: Adventures of ATP / Story Book

https://drive.google.com/open?id=1WU8kEdsxmQTTZe-W9RZMWHWHc_Sk-A5N

Appendix 3: Project Notebook

https://drive.google.com/open?id=1uMw_i43_0Qgc1BGAm5H2UOd-GI5121hC

Appendix 4: Voice Record

https://drive.google.com/open?id=10Fcjlt2Vu52EsKfv7FZlgEewxblWxHcH

Appendix 5: Cell picture

https://drive.google.com/open?id=1wQ1BXcP3FJgy8W4nw-netS0NR6MuuYhX

The Role of School Leadership in the Implementation of Programming and Stem Concepts into Classroom Practice

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Abstract

This short practitioner report discussed the role of the school leadership in the implementation of programming, and STEM concepts into classroom practice in an educational institution in Izmir, Turkey. The study investigated the process of how the school's leadership team including the ICT coordinator made it possible to integrate these relatively new concepts into the school's curriculum by effectively managing the change process. 50 teachers from different fields including early years, primary, history, science, mathematics, computing, visual arts and English, were active participants in the implementation program and were asked to regularly reflect on their experiences. The data from teacher's reflective journals showed that both programming and STEM concepts were seamlessly integrated into the schools' curricula and classroom practice. The teachers reported that by receiving training about these concepts and the tools that are necessary for teaching them, was beneficial for supporting the student's development of 21st century learning skills such as collaboration, communication and problem solving. They also explained how the supportive attitude of the leadership team which provided time, resources and training opportunities for teachers, had an impact on the teachers attitude towards the change process.

Key Words: Education Technology, STEM, coding, robotics, ICT, teacher training, leadership

1. Introduction

Until recently, the focus of technology integration in schools were on Information and Communication technologies. The increased interest in teaching children coding and STEM skills, especially the shift from ICT to computer science, has encouraged schools in many countries to consider ways of integrating these concepts into their school curricula. The difficulty is that this implementation process requires both financial and training support for schools which is only possible if the leadership team sees the value in including these concepts in their school' curricula. In a way this explains the difference in schools' responses to technological innovations. MacNeil and Delafield argue that in order to implement technology programs effectively 'School principals must understand the importance of technology for improving school management as well as its implications for improved instruction' (1998, p. 296). Stegall (1998) also supports this and suggests that school principals should model technology use by taking part in service-training, visiting example schools, attending conferences and bringing in experts who would be able to support this process, in other words they should plan in advance how they intend to integrate the new technology into their school.

Fullan (1992) notes that the change process should be planned in advance and address the key aspects that are important for the implementation of the new technology in classrooms. He lists innovation, commitment and support, professional development and leadership as the main aspects that should be considered when planning for the change process. He also notes that, leaders can influence an organisation by creating a shared vision and understanding of the change process, which could contribute to motivating others (Fullan, 2002). Wilmore and Betz (2000) compares the approaches to change management by Fullan (1994) and NSW QA School Review, which highlights the crucial role of the school leadership in this process. Table 1 displays the change management comparison.

Table 1. Change Management (adapted Des Wilmore, & Muhammad Betz. (2000)

Fullan	**NSW QA School Review**
1. You can't mandate or force change	Provide time, resources and opportunities
2. Change is a journey, not a blueprint	Articulate the purpose
3. Problems are our friends	Organize relevant training and development, establish supporting structures for change
4. Vision and strategic planning come later	Shape and reshape the schools vision
5. Individualism and collectivism have equal power	Nurture the use of innovative and creative solutions
6. Neither centralization nor decentralization work by themselves	Build teams
7. Connections with the wider environment is critical for success	Influence the direction of others
8. Every person is a change agent	Model, advocate and support continuous learning

If we are to apply the main concepts from Table 1 into the implementation of ICT including programming and STEM concepts into the classroom, it is clear that this change process is not about specific tools or software, but equipping teachers with the necessary pedagogical and subject knowledge for engaging their students with their learning (Yuen et al, 2003). This table shows that the change cannot be forced upon teachers, rather they should be encouraged to articulate the purpose of the change and play an active role in the design and implementation of the change process. Furthermore, as Weiss (1994) reports, school leaders should be prepared to provide teachers with continuous teacher training in the focused field. This study will provide an example of how the school's leadership can impact on the attitudes of teachers by planning an appropriate change process to facilitate the implementation of STEM and programming concepts into school's curricula.

2. Method

A qualitative approach was adopted whereby teacher's reflections during and at the end of the implementation period were evaluated to understand the impact of the leadership and their approach to implementing the programming and STEM concepts into the school's curriculum. At the beginning of each month, 50 teachers from different subject fields including early years, primary, history, science, mathematics, computing, visual arts and English, were invited to a training session where they participated in collaborative learning activities. They were then supported to apply their new learnt knowledge by designing and teaching activities to their class. They were asked to reflect on their journey in a free flow format, especially after each session they taught.

This project took place in a school in Izmir, Turkey. The school has students from diverse socio-economic backgrounds. At the beginning of each month, the monthly training sessions were announced, and teachers were invited to attend these sessions on a voluntary basis. Although the attendance at these sessions was low in the first month, the numbers increased dramatically in the second and third months training sessions. The administrative team members and the leadership team also attended to the CPD sessions with the class teachers. At the end of three months, 80% of teachers (Kindergarten to high school) were trained in 18 different skills set. The teachers were introduced to tools such as Lego robotics, Arduino, Dash board, 3D printer, green screen technology that was planned to use for teaching programming and STEM concepts.

3. Data analysis and Findings

The data from the 50 teacher's reflections were analysed to make sense of their attitudes to the change process and how the leadership team managed it. A thematic analysis approach was used "for identifying, analyzing and reporting patterns within data." (Braun and Clarke, 2006, p. 79). The emerging themes were listed under two categories; positive aspects and barriers. Many teachers mentioned that effective change management practices by the leadership team was the main reason for the successful integration of programming and STEM concepts. Some of the comments that were included by teachers in their reflective journals:

- Having a positive attitude to change
- Being inspired by other teachers and trainers
- Effective modelling by the CPD trainers
- Leaders acting as part of the team
- Leaders adapting mentoring/ coaching approach rather than acting as an instructor
- Being allowed to involve in the design of the CPD sessions
- Opportunities for sharing good practice
- Celebrating success through social media
- Voluntary participation rather than compulsory ones

Under barriers; issues related to environment, funding and number of skilled people were mentioned. Many teachers reported that new technology is expensive, therefore it might be difficult to have all the tools that would make their teaching more engaging. This view started to change when the leadership team explained that it is possible to persuade the school governors to purchase a new technology if it can be proved that it will have an impact on children's learning. The leadership team also highlighted the importance of focusing on pedagogy rather than a tool itself. They encouraged teachers to think creatively when designing activities so that they could make use of what is already available in the school.

One issue that was noted by many teachers was that there are many resources in school but only a few people have the necessary skills to use them. They suggested that more people should be trained to use the new technology to establish consistency in teaching and learning across the school.

4. Discussion and Conclusion

Our study found that the integration of programming and STEM concepts into school's curricula is a complex process, and it was effective because of the active role that leadership team played and the way teachers were prepared for the change. This was supported by other studies who highlighted the role of the school leadership and the readiness of the teaching staff in technology integration (Dimmock et al. 2013; Thurlings et al. 2014).

Ruis and Parés (1997) suggested that reflection in CPD settings can provide a context for the development of shared practices and values. The findings from the data analysis showed that the teachers enjoyed spending quality time with their colleagues in an informal learning environment. This also strengthened the schools' community spirit where the teachers constantly wanted to share photographs and clips from their training sessions. Some teachers took this further and presented their classroom activities in national and international conferences. In the long term these practices have contributed to the construction of the school's shared values and practices in regard to innovation and change.

Minott (2010) noted that reflection on action, is a key tool for professional development, especially for developing practice through shared experiences. The teachers in this study also found the reflection process to be very useful and continued to reflect on their teaching and the impact of this on children's learning after the project. This has encouraged teachers to think creatively when designing activities to teach STEM and programming concepts and work collaboratively with their colleagues.

The teachers expressed how they felt that they were part of the school community because they were included in the design of the training sessions. This was also useful for meeting the needs of all of the staff. The project also found that the leadership team acted as a coach /mentor during the change process and established a positive relationship with each teacher, valuing their reflections and suggestions. They also used the teacher's reflection points to inform their future actions.

In conclusion we can suggest that the approach of the leadership team to innovations including integration of programming and STEM concepts into a school's curricula has a very strong impact on how it has been perceived by teachers and students. Furthermore, the way that the school leaders manage the change process, will shape the outcome of the integration process. Therefore, the school leaders should develop themselves in both management skills and domain specific subject knowledge such as learning to code in order to make sense of the innovations and to be part of the change process.

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Cross Curricular Use of Technology for Solving Mathematical Problems: Exploring Angel Falls Interdisciplinary Plan

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Abstract

This short practitioner report presents information for the planning, teaching and evaluation cycle of a cross curricular Computing, Geography and Mathematics lessons in a 5th grade classroom. The study focused on both mathematical thinking and Geographical knowledge. The objective of the lesson was to teach children measurement and prediction skills through exploring the Angel Falls, located inside of the Canaima National Park in Venezuela, using the Google expedition application. For the purpose of this study, action research was chosen whereby the findings of this study were used to inform future planning and improve learning. The study found that the students were able to use their logical reasoning to predict the length of many objects including the Angel Falls. The project also found that providing children with real-life learning contexts motivated them to learn and made learning more meaningful. The children were able to transfer and apply their prediction skills during their coding sessions, which highlights the link between mathematical and computational thinking.

Keywords: Real-life experiences, logical reasoning, computational thinking, mathematical thinking, predictions, cross-curricular learning, integrated learning

1. Introduction

In this short practitioner report I will be discussing how I planned and taught a series of lessons to provide learning experiences for students in a real-life context using technology as a tool. The students were taught about the Angel Falls found in the Canaima National Park, Venezuela, using Google Expeditions application. Within the lesson I focused on providing students with a real-life problem whereby they can develop and apply their mathematical, technological and geographical knowledge and understanding. The main reason for this is that teaching mathematics through experiences and contexts that students are interested in can make learning more meaningful and relevant to students (Turner & Strawhun, 2007). It also been suggested that the knowledge and experiences that students bring from their everyday lives can serve as resources for the teaching and learning of mathematics (Civil 2002, 2007). Furthermore, there is evident that when concepts and skills are connected to real life contexts and situations, student learning is enhanced (Boaler, 2008).

From the aspect of computational concepts, during this project, the students had to use their logical reasoning to make predictions for solving problems which can be seen as part of computational thinking (CAS Barefoot Computing, 2014; Voogt et al., 2015). Making predictions is an important aspect of computational thinking as children constantly use their prediction skills to predict the behaviour of simple programs that they have written. In this scenario, prediction helps the students to plan and evaluate their solutions. This skill is used by children in many subjects, for example in this study the children had to use their logical reasoning to make predictions about the height of the Angel Falls. This also highlights the close link between mathematical thinking and computational thinking (Wing, 2016, 2011).

2. Literature review

A number of studies have suggested that integrating traditional learning materials with technology tools can be beneficial for learners (Gray, 1991; Wirt, 1991). One reason for this might be that technology has the power to provide learners with real-life situations from outside of the classroom. This was also supported by The National Council of Teachers of Mathematics (NCTM) who stated in their standards that students should be able to confidently use their mathematics skills to explain applications in the outside world and to analyze situations that arise in the real world (NCTM, 2014).

The review of the literature also suggest that technology can enhance students' understanding of mathematical concepts (Clements & Battista, 1994; Graham & Thomas, 2000) and improve their achievement (Hembree & Dessart, 1992; Kaput, 1992; Quesada & Maxwell, 1994). Furthermore, the implementation of technology for learning in other curricular subjects can improve classroom experiences for students (Guerrero, Walker, & Dugdale, 2004).

In addition to this a cross-curricular teaching and learning approach provides students with active and experiential learning experiences. When cross-curricular learning happens, it can positively impact on the learning process in two ways; "First, young people are encouraged to integrate learning experiences into their schemes of meaning so as to broaden and deepen their understanding of themselves and their world. Second, they are engaged in seeking, acquiring, and using knowledge in an organic – not an artificial – way" (Beane, 1995, p.616). My aim was to provide my students with an organic learning experience that would engage them to deepen their thinking and understanding of measurement and prediction skills.

3. Methodology and Procedure

An action research approach was adopted, whereby observations were used to study the student's attitudes to learning in a technology supported learning environment. The reason for selecting this method was because my aim was to improve my practice through reflections (Elliott, 1991). My research started with a practical question from everyday educational work (Altrichter et al., 2005): Can a cross-curricular use of technology for teaching problem solving in mathematics improve students' attitudes to learning? The study took place in an independent primary school in Istanbul and included 75 students in total.

The lessons were taught in a combined approach during social studies and mathematics sessions. Firstly, the social studies teacher introduced and modelled the use of the Google Earth Program by explaining how to locate Venezuela. Then the students were asked to explore the other continents, countries and characteristics of the land. They were then asked to complete an online research questionnaire about the Angel Falls and Canaima National Park. They were then asked specific questions about the Canaima National Park and to use different websites to answer them.

During their mathematics sessions the students were told that they would be predicting and measuring the height of the Angel Falls. They knew that the Angel Falls are the world's highest uninterrupted waterfall, however, they had not investigated its height yet. The students were asked questions about measuring length in-link to including real life context. I think that this made the students more excited about the topic and motivated them with their learning.

The main questions that were asked:

- How can sailors measure latitude and longitude whilst at sea?
- How can scientists measure the magnitude of a tsunami?
- Which materials can we use for measuring length?
- Do you remember the basic unit for measuring length?
- Share the ways / methods that you know for measuring the length of any object?

The last question was, 'Which common word did you hear in all these questions?". Through peer and class discussions the students were able to recall their prior knowledge in measuring length and making predictions. I modelled the use of a metre ruler and then discussed how we could use this to measure the length of the Angel Falls. They visualized the Angel Falls and then made predictions to estimate its height. This involves both mathematical and computational thinking.

During the teaching sessions the children's learning was scaffolded through open-ended questions that aim to deepen their thinking. Some of these were:

- Can you give an example of our natural resources in Turkey?
- How many waterfalls are there in our country? Do you know which is the highest one?
- Where is the World's highest waterfall? Can you estimate the height of that waterfall?

After these questions, the students started to use cardboards to explore the Angel Falls by using the Google expedition application. At the same time, I provided them with information about some geographical features of the Angel Falls that involve numerical data such as tepui's height on the fall, which can reach 2,500 metres. At the end of this session the students applied their knowledge and understanding to solve word problems about measuring length.

4. Findings and discussion

This short classroom investigation study found that prior knowledge plays an important role in children's construction of new knowledge, making learning meaningful. This also shows that teachers should be aware of children's prior knowledge, in order to plan and teach according to their needs.

It was very clear from the observational data that the children were able to recall not just what they had learned in this session but from other mathematics and also in other subject lessons such as geography, art and physical education. This shows that they were able to retain their knowledge and understanding of measuring skills.

Another interesting finding of this study was that the students were able to solve paper-based problems which were again based in a real-world context. This was also supported by Boaler (1998), who noted that the students who learn through meaningful real-world experiences are able to apply their mathematical knowledge and skills to different learning contexts (Boaler, 1998).

The project also found that the children's attitude to mathematics learning in this cross curricular context was more positive than their general mathematics sessions. They were engaged and always stayed on task. They asked many questions and were very interested in finding out about this place and its characteristics. I think that because this was a real location, it made learning about it more interesting for them.

In terms of measuring skills, at the beginning the children found it very hard to estimate the height of the Angel Fall correctly. After this session, they were able to estimate the length of the many objects correctly. This shows that their understanding of length and making predictions using logical reasoning had improved. Another interesting finding was that they were able to use their prediction skills more accurately during other activities such as coding when making games using Scratch, which was again focusing on real life topics. This suggests that the students' use of prediction skills is facilitated through providing them with real life problems. This motion of providing students with learning experiences in a real life context was also supported by Businskas (2008), who argued that real world connections motivate learners and enable them to transfer their mathematics skills to solve problem in new contexts.

Exploring the Angel Falls with Cardboards and Google Expeditions program I was able to transform an abstract learning into a concrete experience which is very important when working with young children. The children were able to see the 360-degree photos of Angel Falls which was taken from different perspectives.

5. Conclusion

In conclusion, this study can suggest that integrating technology as a tool for learning into a classroom environment can increase the motivation of the students and change their attitudes towards the lesson. It makes the concept less complicated and abstract for children.

Through this cross-curricular & integrated approach, the children were able to connect the concepts that they had learned in different subjects and use this to construct their new knowledge. This experience provided the children with a space to develop crucial skills and they were then able to apply this to their learning in geography, history and computing. The link between mathematics and geography was also emphasised by Guido (2017) who argued that studying any topic related to geography requires the tools of mathematics.

During these integrated geography and mathematics sessions the children had many opportunities for developing and using their prediction skills. They were later able to apply this in another learning context, which is coding. They were able to predict the behaviour of their script and describe the action that a code would make happen. This shows that this integrated teaching approach helped learners to retain their knowledge and understanding and then use it to achieve a goal in different lesson context.

This was a small-scale study focused on one technology tool, further studies where more classes from different ages should be included and other technology tools should be used for teaching and learning to investigate the impact of cross curricular use of technology on children's learning.

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