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The effectiveness of an integrated science and mathematics programme: Science-centred mathematics-assisted integration

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Abstract

Recently, the interest in ensuring integration between science and mathematics has been increasing. Taking this interest into consideration, this paper investigates whether or not a programme integrating particular attainments of science and technology, and mathematics classes in Turkey is effective. The study was performed in the educational term of 2007-2008 with 8th grade students (aged 14 and 15) of a middle school in Ankara. The workgroup in the study consisted of 90 students in total from three classrooms; two of them were the experiment group (30+30 students) and one was the control group (30 students). The mixed method was utilized in the study. The quantitative data obtained from the measurements performed with the tests developed were compared using variance analysis (one-way ANOVA) and covariance analysis (ANCOVA). These findings were discussed by integrating the opinions of the teachers and the students and the qualitative findings obtained from the researcher's log. The outcomes of the study indicated that the programme, called by the researchers "Science-centred mathematics-assisted integration", increases the achievement of the students, if applied properly. Nonetheless, the outcomes also indicated that the teachers' lack of content knowledge and basic skills in science and mathematics has an adverse effect on the achievement of the students. It is believed that the outcomes of the study will make a contribution to the institutions educating science and mathematics teachers and to the institutions providing teachers with in-service training.

Keywords: Integration of science and mathematics; Transfer between science and mathematics; Educating science and mathematics teachers

1. Introduction

Curricula have traditionally been structured separately since the segmentation of natural philosophy into disciplines. Nonetheless, educators share the idea that if there is no field of

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application of knowledge, this knowledge should not be considered significant [1, 2]. In the traditional understanding of the disciplinary programme, students are expected to merge knowledge, which they learn separately, where required. It is assumed that students apprehend topics better in this way. In the course of time, it has been observed that this assumption and expectation is not valid. It has been found that when students learn a lesson in a manner isolated from other lessons, they have difficulties in transferring the knowledge to other situations. This approach emphasizes the importance of the connections among the disciplines in today's sense of education, where we cannot abandon the disciplines, and the importance of the transfer of knowledge and skills among the disciplines.

1. 1. Transfer of learning

Transfer can simply be defined as something learned in a situation that affects another situation or is used in another situation. In order to perform this transfer, learned knowledge is needed first. Although the previous learning increases the value of the transfer, inadequacies in the previous learning and incorrect learning may sometimes prevent the transfer [3]. If the initial knowledge is strictly connected to the context of learning, it prevents transfer of this knowledge to other situations [4-6]. On the contrary, if knowledge is learned to exceed the context of learning, it facilitates the transfer. Transfer may be divided into two, near and far [7]. Near transfer is the transfer performed between very similar contexts. Far transfer requires connection between very distant areas; for instance, using a tactic employed in chess to control a city or a war. Usually, looking through the window of learning, semi-automatic answers and behaviours emerge in the near transfer. Answers to many questions are given automatically, benefiting from previous experiences, without a need for high level thinking. In the far transfer, mental abstraction from the context and the application, a search for deep connections is required. Nevertheless, the transfer, either near or far, does not occur by itself. It always emerges as a result of the learner's efforts to establish a connection.

According to Dewey [8], similar qualities always build a bridge of transition in the mind from a previous experience to a new one. As well as shared qualities, utilization of representations in science and mathematics (formulas, equations etc.) may facilitate the transfer [9, 10]. Another factor facilitating the transfer can be suggested as the attention point during learning [11]. Brown and Palincsar listed the factors facilitating the transfer as follows. When the students (a) see how the problems are similar to each other (b) directly see the main reason behind the compared problem (c) become familiar with the problem domains (d) encounter samples accompanying the rules, especially the samples formulized by the students themselves (e) take place in the social context, the transfer is facilitated (cited [10]). Another factor affecting a better transfer is to hold more knowledge and to specialize in a domain. The experts put the knowledge, which is in a large chunk form, into an order and make connections with the contexts where the knowledge can be employed. They use and apply this knowledge where required. It is more difficult and takes more time for the novices to manage this [6]. Therefore, the experts solve problems better than the novices [12-21].

1. 2. Science and mathematics integration programme

Recently, an insistent emphasis has been placed on the requirement to establish connections among the disciplines present in the curricula [22-24]. Since science and mathematics are systems close to each other, the connections between these two disciplines are analysed under a special topic. Kren and Huntsberger referred to three possibilities for the integration of science and mathematics. These can be summarized as (a) teaching mathematical concepts and then applying them within science, (b) firstly ensuring familiarity with mathematical concepts within science and then presenting them within mathematics, (c) presenting scientific and mathematical concepts simultaneously [25]. Hurley [26], in his meta-analysis study, considered science and mathematics integration through the programme framework and specified five categories as (a) a sequenced programme, where science and mathematics are taught in sequence (b) a partial programme, where some parts of science and mathematics are integrally taught, some taught separately (c) an enhanced programme, where either science or mathematics is determined as the main discipline and the other is connected to this discipline (d) a total programme, where science and mathematics are taught together and have equal portions (e) a parallel programme, where science and mathematics are taught separately and simultaneously. The understanding of science and mathematics integration, adopted by Lonning DeFranco [27], Roebuck and Warden [28] and Huntly [29], can be shown in linear format as follows.

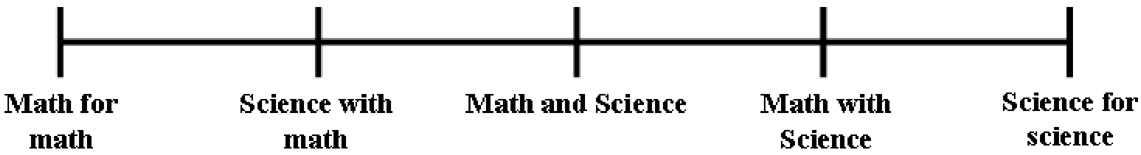

Fig. 1. Continuum included in the models.

The centre of the continuum is the point where science and mathematics are totally fused and hold equal standing; whereas both ends of the continuum are the points where science and mathematics exist without any connection to any other class. The points remaining between the centre and the ends can be identified as the points where science is at the centre and mathematics is utilized as a tool on the science side of the continuum; and where mathematics is at the centre and science is utilized as a tool on the mathematics side of the continuum. Another model, which takes the content knowledge to the centre in science and mathematics integration, as with the researchers above, was developed by Kiray [30]. This model consists of five dimensions; (a) content knowledge, (b) skills, (c) the processes of teaching and learning,(d) affective characteristics, and (e) measurement and assessment. The content is shown on a balance in this model. Content knowledge constitutes the centre of these stages. The model adopts understanding to constitute other stages with content knowledge. Since the model is content-centred, it is, in general, called the balance model.

1. 2. 1. Content knowledge

Content knowledge is described in the following seven categories in the balance model.

Mathematics: This is the class where only mathematics outcomes are taken into consideration. The integration in the programme dimension is limited to in-class association within the mathematics class.

Mathematics-centred science-assisted integration (MCSAI): This is a programme, which takes the mathematics outcomes as the basis and considers science as a discipline. The integration between science and mathematics can be realized by arranging the topics of science and mathematics in such a manner as allows the students to make transfers themselves (parallelism, primacy and recency association). The mathematics outcomes are supported by transferring content, present in the science programme, into the mathematics outcomes where appropriate. It is preferred that the transferred science content is present in the science programme. Nevertheless, even if it is not present in the science programme, various examples from nature and daily life can be included in the mathematics class.

Mathematics-intensive science-connected integration (MISCI): Outcomes of the mathematics programme are weighted. The mathematics class approaches the science class via connections between the content outcomes. In the transfers performed within the mathematics class, pre-learning of the science class, as well as that of the mathematics class, is taken into consideration. The outcomes to be learned simultaneously are determined. The classes are integrated simultaneously, if the outcomes are appropriate. Whether or not the mathematics outcomes to be acquired will provide pre-learning for the science outcomes in future is taken into consideration in the planning. Complete acquisition of the outcomes for the mathematics class at the end of the process is among the objectives of the class. Although the science content of the class is intense, having the students acquire all the outcomes of the science unit is not an objective of the class.

Total integration (TI): The objective is that mathematics and science have equal standing in total integration. There is no intention to have one of the classes at the centre. This class may be called science-maths or maths-science. Separate science or mathematics outcomes cannot be mentioned. An observer attending the class from outside cannot distinguish whether the class is mathematics or science. The aim is that all the outcomes of the topics belonging to the integrated science and mathematics field should be acquired by the students.

Science-intensive mathematics-connected integration (SIMCI): Outcomes of the science programme are weighted. The science class approaches the mathematics class via connections between the content outcomes. In the transfers performed within the science class, pre-learning of the mathematics class, as well as that of the science class, is taken into consideration. The outcomes to be learned simultaneously are determined. The classes are integrated simultaneously, if the outcomes are appropriate. Whether or not the science outcomes to be acquired will provide pre-learning for the mathematics outcomes in future is taken into consideration in the planning. Complete acquisition of the outcomes for the science class at the end of the process is among the objectives of the class. Although the mathematics content is intense, having the students acquire all the outcomes of the mathematics unit is not an objective of the class.

Science-centred mathematics-assisted integration (SCMAI): This is a programme which takes the science outcomes as the basis and considers mathematics as a discipline. The integration between science and mathematics can be realized by arranging the topics of science and mathematics in such a manner to allow the students to make transfers them (parallelism, primacy and regency association). The science outcomes are supported by transferring the mathematics content into the science outcomes where appropriate. It is preferred that the transferred mathematics content is present in the mathematics programme. Nevertheless, even if it is not present, various examples from nature and daily life can be included in the science class.

Science: This is the class, where only the science outcomes are taken into consideration. The integration in the programme dimension is limited to in-class association within the science class.

1. 2. 2. Skills

The skills are divided into two, the common skills that are regarded as primary and the common skills that are regarded as secondary, based on their frequency of use in the balance model. The common skills that are regarded as primary are making connections, problem solving, reasoning, reaching conclusions and interpreting, organizing the data and formulating models, comparison-classification, measurement, collecting information and data, estimation, making inference, prediction, recording the data, communication and observation. The common skills that are regarded as secondary include and extend beyond the primary common skills. They are observation, collecting information and data, making connections, making inference, comparison-classification, reasoning, organizing the data and formulating models, measurement, formulating hypotheses, identifying variables, recording the data, designing experiments, forming and experiment design, estimation, knowing and using experimental equipment and tools, prediction, functional definition, controlling and changing variables, reaching conclusion and interpreting, problem solving and communication. The primary common skills are recommended to be used in the model stages of science, mathematics, SCMAI and MCSAI. The secondary common skills are recommended to be used in the stages of SIMCI, MISCI and TI.

1. 2. 3. The processes of teaching and learning

The balance model suggests that the process of teaching and learning should be shaped according to the constructivist approach. It defends teaching and learning with inquiry-based teaching methods in all the stages.

1. 2. 4. Affective characteristics

According to the balance model, when a programme is applied, not only the affective variables belonging to science, but also the affective variables belonging to mathematics affect the success in science or the learning of science. The same is applicable for success in mathematics and the learning of mathematics. Whereas this cross-effect is dominantly seen in TI, it is felt less in the stages of SCMAI or MCSAI. It states that the implementers should be aware of the characteristics of the affective domain while applying the science and mathematics integration programme.

1. 2. 5. Measurement and assessment

The measurement and assessment process of the science and mathematics integration programme, which adopts the constructive approach, should bear similar characteristics. Therefore, the measurement and assessment understanding, which assesses not only the content knowledge but also the process, should be adopted. Depending on the preferred type of integration, science and mathematics teachers may decide to perform measurement and assessment jointly or separately. Whereas it is appropriate to prepare the measurement and assessment criteria jointly to cover science and mathematics when TI is applied, the criteria considered important for mathematics may be included in the criteria prepared for science in SCMAI.

Furner and Kumar [31] asked the question whether or not integration of the physics-related domains in science with mathematics would improve the teaching of science. The researchers have come to the conclusion that the integration of science and mathematics provides significant learning and increases student motivation. Bassok and Holyoak [32] examined the information transfer between mathematics and physics, the former considered abstract and the latter concrete in the historical process. The researchers have examined whether the transfer from mathematics to physics or from physics to mathematics is more effective. As a result of the studies, it has been concluded that the transfer from mathematics to physics is more effective. Kaminski, Sloutsky and Heckler [33] in their study explored whether the transfer from abstract to concrete or from concrete to abstract is more effective. The researchers, who associated mathematics with abstract and science with concrete, as a result of their study concluded that students managed the transfer only from mathematics to science, in other words, from abstract to concrete. Perkins and Solomon [34] emphasize the primacy and recency associations in the performance of the transfer. They state that the transfer rarely occurs simultaneously. Kren and Huntsberger explored the primacy, regency and concurrence associations of science and mathematics. As a result of their study, they came to the conclusion that the groups to which mathematics is presented before science, and those to which science and mathematics content are presented simultaneously, are more successful in problem solving [25].

Lehman [35], in his study, stated that 50% of middle school teachers have the pre-knowledge to integrate science and mathematics. Mason [36] stated that the content-specific and pedagogical content knowledge of teachers out of their own domains is limited and these teachers do not know how to integrate the programmes in cooperation. He stated that if the teachers suffer from lack of knowledge, it would be problematic to apply the inter-disciplinary programme. Huntly [29], working with a science teacher and a mathematics teacher, first suggested the theoretical model and had the teachers apply it. Huntly stated that although the integrated science and mathematics classes are more powerful than separate classes, the emergence of this power depends on the content knowledge of the teachers. Huntly stated that the teachers who have limited understanding of science and mathematics are also limited with regard to deep connections between science and mathematics. Basista and Mathews [37] expressed the view that the teachers need to fully understand the content of science and mathematics and the lack of domain knowledge causes low self-efficacy.

1. 3. Purpose

The purpose of this paper is to test the effectiveness of the SCMAI programme developed by Kiray [30].

2. Methodology

2. 1. The model of the study and the work group

The mixed method, where quantitative and qualitative data are analysed together, was adopted in this study. One of the methods of applying the mixed method is to collect and interpret quantitative and qualitative data together [38]. The quasi-experimental pattern with the experiment group and the control group was preferred in collecting the quantitative data of the study. The face-to-face interview method was preferred in collecting the qualitative data. The work group of the study consisted of 8^{th} grade students of a middle school in Cankaya District of Ankara Province. The experiment and the control groups were created according to the results of a cognitive entrance behaviour test applied to six classes. Three groups, statistically equivalent among these six classes, were randomly distributed to the experiment and the control groups and the codes Experiment1 (E1), Experiment2 (E2) and Control (C) were assigned to the groups after the drawing of lots. Ninety students in total, who attend school in the mornings, participated in the study, 30 students in each group.

2.2. Data Collection Tools

Cognitive entrance behaviour test(CEBT): A cognitive entrance behaviour test for the students to answer at the beginning of the semester was developed in the domains of learning under science and mathematics. The test, which includes pre-learning at 6th and 7th grades, consists of 45 questions. The KR-20 reliability coefficient of the test was found to be 0.9027. The test consists of multiple-choice questions, each with four choices.

Science-centred mathematics-assisted integration (SCMAI) Test: This test was developed in a manner to assess the outcomes of (a) the Science and Technology Class, the learning domain of Living Creatures and Life, the 8th grade unit titled Cell Division and Inheritance and (b) the Mathematics Class, the learning domain of Statistics and Probability, the units entitled Graphics, Determination of Probable Events, Types of Events and Types of Probabilities. The test consists of 30 multiple-choice questions, each with four choices. The KR-20 reliability coefficient of the multiple-choice section was found to be 0.859.

Teacher/Student interview forms: Two separate forms were developed in order to ascertain the opinions of the teachers and the students. Expert opinions were taken for validity of the forms, which consist of semi-structured interview questions.

2. 3. Application process

The programme developed by the researchers was applied in two separate classrooms. Whereas the programme was applied by one of the researchers (attending the classes in that classroom throughout the year) in one of the classrooms (E1), it was applied by the science and technology teacher (trained by the researchers) in the other classroom. In the control group, the classes were taught as prescribed in the textbook prepared by MEB. The classes were observed by the researchers and an assistant observer.

Prior to the application, the unit about the learning domain of "statistics and probability" in the mathematics class was given to all three groups. Upon completion of the mathematics unit, the experimental application was commenced in these three groups. The documents followed in the experiment group were reshaped to integrate the outcomes of (a) the Science and Technology Class, the learning domain of Living Creatures and Life, the 8th grade unit entitled Cell Division and Inheritance and (b) the Mathematics Class, the learning domain of Statistics and Probability, the units entitled Graphics, Determination of Probable Events, Types of Events and Types of Probabilities (to transfer the mathematics outcomes into science). In the experiment and the control groups the classes were taught according to the 5E learning model, which is one of the teaching methods prescribed by the constructive approach and which is also preferred by the MEB textbook,. In the experiment groups, the documents were structured in a manner to develop the mathematical skills as a result of association of the unit content with the mathematics outcomes. The SCMAI test, which was developed for the measurement and assessment dimension of the programme, was developed in a manner to include the criteria that are considered important for mathematics within the criteria prepared for science. The application was performed on the groups, decided by the school management to be the morning groups according to their success in the domains of science and mathematics two years previously and which were distributed randomly by the school management to ensure homogeneity in the classrooms. It was determined by the school counsellor that the students in these three classrooms were mainly interested in professions related to science and mathematics.

2. 4. Data analysis

The variance analysis (ANOVA) was preferred in a comparison of the groups according to the results of the cognitive entrance behaviour test and the pre-test, whereas the covariance analysis (ANCOVA) was preferred in a comparison of the post-test results according to the results of the pre-test and the cognitive entrance behaviour test. The qualitative findings of the study are presented upon integration with the qualitative data obtained from three different sources (teachers' opinions, students' opinions and the researchers' log).

3. Results and discussion

In this section, first of all, the quantitative findings of the study are presented. After that, in accordance with the mixed method employed in the study, the qualitative results are integrated and discussed with the quantitative findings. Measures of central tendency and expansion with regard to the results of the ANOVA test, which was utilized to determine equivalency of the three groups included in the study in accordance with the cognitive entrance behaviour test, are given in Table 1.

When Table 1 is examined, it is observed that the average scores of the groups obtained from the cognitive entrance behaviour test are 36.13 for group E1, 34.16 for group E2 and 35.50 for group C. The results of the ANOVA test, which was performed to test whether or not these values form a statistically significant difference, are given in Table 2.

Table 1. Measures of central tendency and expansion with regard to the results of the cognitive entrance behaviour test of the groups

Groups	N	Min	Max	Mean	Sd
E1	30	23	42	36.13	4.369
E2	30	21	43	34.17	5.453
C	30	29	44	35.50	4.200

Table 2. Comparison of the groups according to the results of the cognitive entrance behaviour test

Source	SS	df	MS	F	p
Between-Groups	60.467	2	30.233	1.365	0.261
Within-Groups	1927.133	87	22.151		
Total	1987.600	89			

$p > 0.05$.

When Table 2 is examined, it is observed that there is no statistically significant difference at a significance level of .05 between the average scores of the groups obtained from the cognitive entrance behaviour test. Depending on these findings, it can be stated that the three groups are equivalent to each other in terms of cognitive entrance behaviours. One-Way ANOVA was performed to determine whether the SCMAI pre-test results of the three groups, which were determined to be equivalent in accordance with the results of the cognitive entrance behaviour test, and the results are given in Table 3.

Table 3. Results of one-way ANOVA with regard to the SCMAI pre-test results of the students in the experiment groups and the control group

	Source	SS	df	MS	F	p
Sci/Maths	Between-Groups	6.668	2	3.334	1.113	0.333
	Within-Groups	257.692	86	2.996		
	Total	264.360	88			
Only Science	Between-Groups	2.843	2	1.422	0.223	0.801
	Within-Groups	548.775	86	6.381		
	Total	551.618	88			
Overall	Between-Groups	17.470	2	8.735	0.756	0.473
	Within-Groups	993.474	86	11.552		
	Total	1010.944	88			

In Table 3, it is observed that according to the SCMAI pre-test results of the students in the Experiment1 (E1), Experiment2 (E2) and Control (C) groups, there is no statistically significant difference in the questions in which science and mathematics are integrated, ($F(2\text{-}86) = 1.113$; $p > 0.05$), only in science questions ($F(2\text{-}86) = 0.223$; $p > 0.05$) and in overall scores ($F(2\text{-}86) = 0.756$; $p > 0.05$).

Before the ANCOVA analysis, the descriptive statistical results of the pre-test and post-test results of the groups were considered. The results are given in Table 4, after omitting from the study the data of a student in group E2 who did not answer the post-test.

When Table 4 is examined, it can be observed that the average scores (3.133 over 11) of the students in group E1 increased from 28% to 73% in the science/maths questions, from 29% to 74% in only science questions, from 29% to 74% overall. It can be observed that the average scores of the students in group E2 increased from 25% to 50% in the science/maths questions, from 29% to 72% in only science questions, from 30% to 64% overall. It can also be observed that the average scores of the students in the control group increased from 22% to 53% in the science/maths questions, from 27% to 71% in only science questions and from 25% to 65% overall.

Table 4. Measures of central tendency and expansion with regard to the SCMAI Pre-test and post-test results of the students in the experiment groups and the control group

			N	Mean	Sd	Min	Max
Science/Maths (Number of Questions:11)	E1	Pre-Test	30	3.13	1.871	0	7
		Post-Test	30	8.13	1.737	4	10
	E2	Pre-Test	29	2.79	1.567	0	6
		Post-Test	29	5.55	1.824	3	9
	C	Pre-Test	30	2.47	1.737	0	8
		Post-Test	30	5.87	2.097	2	10
Science Only (Number of Questions: 19)	E1	Pre-Test	30	5.57	2.096	2	9
		Post-Test	30	14.13	3.148	8	19
	E2	Pre-Test	29	5.52	2.400	1	10
		Post-Test	29	13.86	3.259	7	19
	C	Pre-Test	30	5.17	2.995	0	11
		Post-Test	30	13.63	2.580	8	17
Overall (Number of Questions: 30)	E1	Pre-Test	30	8.70	3.120	2	14
		Post-Test	30	22.27	4.250	15	29
	E2	Pre-Test	29	8.31	2.792	2	14
		Post-Test	29	19.41	4.476	11	28
	C	Pre-Test	30	7.63	4.123	0	17
		Post-Test	30	19.50	3.821	13	27

Descriptive statistics of the post-test scores, which are obtained by comparison of the experiment and the control groups using the ANOVA analysis, according to the pre-test and the CEBT scores are given in Table 5.

Table 5. Descriptive statistics of the post-test scores according to the pre-test and the CEBT scores

	Group	N	Mean	Adjusted Mean
Sci/Maths	E1	30	8.13	8.201
	E2	29	5.55	5.507
	C	30	5.87	5.842
Only Science	E1	30	14.13	14.070
	E2	29	13.86	13.894
	C	30	13.63	13.666
Overall	E1	30	22.27	22.379
	E2	29	19.41	19.338
	C	30	19.50	19.620

In Table 5, it is observed that the highest average in science/maths questions belongs to group E1, followed by group C, with the lowest average belonging to group E2. According to the post-test scores obtained in only science questions of the adjusted SCMAI test, the highest average belongs to group E1, followed by group E2, with the lowest average belonging to group C.

In Table 5, according to the post-test scores of overall questions in the adjusted SCMAI test, it is observed that the highest average belongs to group E1, followed by group C, with the lowest average belonging to group E2. The results of the ANCOVA analysis performed to determine whether the difference observed among the adjusted pre-test average scores of the groups are given in Table 6.

According to the ANCOVA results, it was found that there is a significant difference among the average scores of the students in different groups for the science/maths and overall questions in accordance with the SCMAI test: $F(2.84) = 17.202$, $p < 0 .05$ for the science/maths questions and $F(2.84) = 4.170$, $p < 0.05$ for the overall questions. Correspondingly, in accordance with the results of the Benferroni test performed on the adjusted post-test scores of the groups, there is a significant difference between the achievement averages of groups E1 and E2 (in favour of E1) and groups E1 and C (in favour of E1) in the science/maths and overall questions. In only the science questions was no significant difference observed among the average scores of the students. This outcome of the study indicates that the difference among the groups arises from the science/maths questions.

Table 6. ANCOVA results of the adjusted SCMAI post-test scores according to the post test scores per group

	Source of Variance	Sum of Squares	df	Mean of Squares	F	P	η^2	Difference
Sci-Maths	Pre-test	.435	1	0 .435	0.121	0.729	0.001	E1-E2
	CEBT	6.301	1	6.301	1.756	0.189	0.020	and
	Group	123.443	2	61.722	17.202	0.000	0.291	E1-C
	Error	301.388	84	3.588				
	Total	426.180	88					
Only Science	Pre-test	4.372	1	4.372	0.479	0.491	0.006	None
	CEBT	5.066	1	5.066	0.555	0.458	0.007	
	Group	2.441	2	1.220	0.134	0.875	0.003	
	Error	766.762	84	9.128				
	Total	781.640	88					
Overall	Pre-test	1.701	1	1.701	0.95	0.759	0.001	E1-E2
	CEBT	.003	1	0.003	0.000	0.990	0.000	and
	Group	149.586	2	74.793	4.170	0.019	0.090	E1-C
	Error	1506.692	84	17.937				
	Total	1665.438	88					

The SCMAI stage of the balance model tested in the study can be considered through the perspective of transferring mathematics into science. Considered through this perspective, it can be stated that the difference between groups E1 and C is parallel to the studies of Kren and Huntsberger [25, 32, 33] suggesting that the transfer of mathematics into science is effective. In the study, learning the mathematics before the science may be one of the factors causing group E1 to be more successful. Another factor may be the effect of the integration of science and mathematics, which increases the success of the students in science, as suggested by Friend [39]. The students who have discovered the integration of mathematics with science in the class might have answered the test questions requiring transfer better. As stated by Ainsworth [9] and Terwel et al. [10], utilization of representations in the science class integrated with mathematics, especially the students' inquiry and relearning of the formulas employed in mathematics in the science class, might have facilitated the transfer of the mathematics content into science. As also stated by Anderson et al. [11], the focus on the previously learned mathematics during the class might have facilitated the transfer of the mathematics content into science.

Another factor may be that the students, who have a lack of learning in the mathematics class, have realized these deficiencies in the science and technology class and learned thoroughly by reinforcing the unit of mathematics in the science and technology class. The students, whose knowledge of mathematics is reinforced, might have been more successful in the questions requiring mathematics content. The following statements of students nos. 15 and 19, respectively, support this probability.

I found the chance to repeat the topics in two classes. It allowed me to reinforce. Especially association with probability in the reproduction unit attracted my attention and the classes were fun (Student 15).

We had employed factorial, permutation in DNA calculations…. I had known that topic from mathematics. I recalled it in science … (Student 19).

In the control group, the classes were taught according to the MEB textbook, which is prepared with a conceptual understanding of science, without too much mathematics content. Therefore, whereas the students in the control group encountered the need to transfer the mathematics knowledge into science for the first time while answering the test without any previous transfer process, familiarity of the students in the experiment group with the content of the problems might have allowed them to be more successful, as suggested by Brown and Palincsar [10]. The in-class integration experience of the students in the experiment group might have allowed them to specialize in solving integrated problems. As stated by Mestre [6], these specializing students might have been more successful than the students in the control group, who are novices in terms of integrated problems. The statement written by the researcher in his log during the intermediate interview made with the teacher of the control group supports these two probabilities.

The teacher of the control group gave a reaction as "I cannot answer some of these questions and I do not think the students can answer them too. Actually, I do not know how much they have learned in mathematics, but they cannot answer these questions based on the science class I teach. I do not know the mathematics content knowledge here. I haven't taught it, and it is not present in the book" when he examined the test on Cell Division and Inheritance (SCMAIT) as the post-test prior to the application (Teacher).

When the post-test average scores of the groups are examined, it is observed that group E1 has the highest average and group E2 has the lowest average in science/maths questions. Group C has a slightly higher average than group E2. This outcome of the study is parallel to the findings of Huntly [29] who taught the theoretical model to the teachers and observed their implementations, as we did in this study. In Huntly's study, the teachers could not fully implement the stages, which were described for the integration of science and mathematics, and remained too far away from the specified integration. Lehman [35] stated that the teachers did not have adequate pre-knowledge to integrate science and mathematics even at the middle school level. Mason [36] stated that the teachers had limited content-specific and pedagogical content knowledge from their own domains and therefore, it was problematic to implement the inter-disciplinary programmes. Similarly, it was observed in this study that the science and technology teacher had hard times in front of the students while implementing the ready-made class notes and had difficulty in answering questions out of the class notes and the opinions of the teachers and the students also supported this probability. The researcher made the following note in his log during the interview made at the break.

S2, the Science and Technology teacher, stated that she graduated from the biology department and did not receive a proper education in his years at the educational institute. The teacher S2 uttered that her knowledge on mathematics was inadequate and she still felt insufficient especially about this topic. S2 said he asked the mathematics teachers questions about permutation, probability and combination during the times I was not at the school, but he realized that the mathematics teachers also did not know this topic well (Observer).

One of the factors to cause group E2 to remain behind group C may be the lack of mathematics content knowledge of the mathematics teacher. In other words, the students, who have not been able to learn the mathematics content knowledge thoroughly in the mathematics class, might not have been able to transfer this mathematics knowledge while answering the questions in the test. As stated by Bransford, Brown and Cocking [3], the deficiencies and the mistakes in the pre-learning of the students might have prevented the transfer. Whereas the education given to group E1 has helped the students cover up their deficiencies in mathematics content knowledge, the students in group E1 might have been confused by the topic, as the science and technology teacher suffers from a lack of mathematics content knowledge. Due to the confusion of the students, the education might have had a reverse effect or remained ineffective. Shulman [40] emphasized the quality of content-specific knowledge, pedagogical content knowledge and basic skills for effective teaching. He stated that the observing researchers do not pay attention to the specialization of the teachers in content-specific knowledge in many cases. Although it is not statistically significant, one of the factors for the arithmetical average of group E2 remaining behind the control group in the science/maths and overall questions might be the teachers' lack of content-specific knowledge. As well as the lack of mathematics content knowledge of the mathematics teachers in the application, the science and technology teachers' lack of content-specific knowledge in their own domain and in the mathematics domain might be one of the factors for group E2 remaining behind. Studies of Lehman and McDonald [41], Mason [36], Huntly [29], Basista and Mathews [37] and Frykholm and Glasson [42], suggesting the teachers' lack of content-specific knowledge as one of the obstacles against the integration of science and mathematics, also support these probabilities.

4. Conclusions and implications

The outcomes of this study indicate that the integration understanding, which takes the transfer from mathematics to science as the basis, can increase the achievement of the students especially in answering integrated questions exceeding the scope of a class. Apart from this positive effect, the study also suggested that the failure to implement the programme in an ideal manner can leave the achievement of the students behind that of the programme providing education via traditional separate disciplines. It was determined that the most important obstacle against ideal implementation of the programme is the lack of content-specific knowledge of the teachers, who will implement the science and mathematics integration programme, in the domains of science and mathematics. As the transfer of mathematics content knowledge and skills into science is required within the SCMAI programme, the deficiencies of the science teachers in their mathematics content knowledge and the failure of the mathematics teachers to teach the transferred mathematics content to their students thoroughly and significantly have resulted in failure in the portion of the programme implemented by the science teacher. It was determined that the students' lack of pre-learning has a negative effect on the performance of the transfer.

There are several studies suggesting that quality improvement in the education of science and mathematics is possible with various methods and techniques of teaching [74-80]. Nevertheless, this study revealed the importance of program design and teacher characteristics for quality improvement in education. According to these outcomes, it may be recommended that the teachers to implement the science and mathematics integration program should be trained with pre-service and in-service programs in a manner to develop their content-specific knowledge and basic skills in both classes. Furthermore, it can also be recommended that the program designers of science and mathematics classes should consider joint and separate portions of these classes, arrange the program flow accordingly and emphasize integration of the two classes in the programs in order to generalize the science and mathematics integration programs, which produce positive outcomes if implemented properly.

References

[1] Bransford J, Sherwood R, Hasselbring T, Kinzer C, Williams S. Anchored instruction: Why we need it and how technology can help. In D. Nix & R. Spiro (Eds.), Cognition, education, & multimedia: Exploring ideas in high technology, Erlbaum, Hillsdale, NJ, pp 163-205, 1990.
[2] Wicklein RC, Schell JW. Case studies of multidisciplinary approaches to ıntegrating mathematics, science and technology education. J Technol Educ 1995;6:59–76.
[3] Bransford J, Brown A, Cocking R. How people learn: brain, mind, experience, and school. National Academy Press, National Research Council, Washington, DC, 1999.
[4] Carraher TN. From drawings to buildings: mathematical scales at work. Int J Behav Develop 1986;9:527–544.
[5] Eich E. Context, memory, and integrated item/context imagery. J Exp Psych Learn Mem Cogn 1985;11:764–770.
[6] Mestre JP. Probing adults' conceptual understanding and transfer of learning via problem posing. Appl Devel Psych 2002;23:9–50.
[7] Perkins DN, Salomon G. Transfer of Learning. International Encyclopedia of Education. Pergamon Pres, Oxford, 1992.
[8] Dewey J. How We Think. Heath and Company, Boston, 1933.
[9] Ainsworth S. DeFT: A conceptual framework for considering learning with multiple representations. Learn Instr 2006;16:183–198.
[10] Terwel J, Oers B, Dijk I, Eeden P. Are representations to be provided or generated in primary mathematics education? Effects on transfer. Educ Res Eval 2009;15:25–44.
[11] Anderson JR, Reder LM, Simon HA. Situated learning and education. Educ Res 1996;25:5–11.
[12] Simon DP, Simon HA. Individual differencies in solving physics problems. In R. S. Siegler (Ed.),

Children's Thinking: What Develops? Lawrence Erlbaum. Hillsdale, NJ, pp 325-348, 1978.
[13] Larkin JH. Reif F. Understanding and teaching problem solving in physics. Europan J Sci Edu 1979;1:191–203.
[14] Larkin JH. Processing information for effective problem solving. Eng Educ 1979;70:285–288.
[15] Larkin JH. Skilled problem solving in physics: A hierarchical planning model. J Struct Learn 1980;1:271–297.
[16] Larkin J H. The Role of Problem Representation in Physics. In D. Gentner & A. L. Stevens (Eds.), Mental Models. Lawrence Erlbaum, Hillsdale, NJ, pp 75-98 1983.
[17] Anzai Y, Yokoyoma T. Internal models in physics problem solving. Cogn Instr 1984;1:397–450.
[18] Finegold M, Mass R. Differences in the process of solving physics problems between good physics problem solvers and poor physics problem solvers. Res Sci Tecnol Edu 1985;3:59–67.
[19] Mc Millan C, Swadener M. Novice use of qualitative versus quantative problem solving in electrostatics. J Res Sci Teach 1991;28:661–670.
[20] Kiray SA. Ilkogretim 7. Siniflarda Fen Bilgisi Dersinde Uygulanan Problem Cozme Stratejisinin Ogrencilerin Kavramlari Anlama ve Problem Cozme Performanslari Uzerine Etkisi. Master Thesis, Selcuk University, Konya, Turkey, 2003. [in Turkish].
[21] Kiray SA, Ilik A. Polya'nın problem cozme yonteminin fen bilgisi ogretiminde kullanilmasina yonelik bir calisma: Kanit temelli uygulamaya dogru. SU Ahmet Kelesoglu Egit Fak Derg 2011;31:183–202 [in Turkish].
[22] Rutherford FJ, Ahlgren A. Science for All Americans. New York: Oxford University Press. American Association for the Advancement of Science. 1990.
[23] NCTM. Principles and Standards for School Mathematics. NCTM, Reston, VA, 2000.
[24] Erdogan A. Preservice mathematics teachers' conceptions of and approaches to learning: A phenomenographic study. Energy Educ Sci Technol Part B 2012;4:21–30.
[25] McBride JW, Silverman FL. Integrating elementary/middle school science and mathematics. School Sci Maths 1991;91:285–92.
[26] Hurly MM. Reviewing ıntegrated science and mathematics: The search for evidence and definitions from new perspectives. School Sci Maths, 2001;101:259–268.
[27] Lonning RA, DeFranco TC. Integration of science and mathematics: A theoretical model. School Sci Maths 1997;97:212–215.
[28] Roebuck KI, Warden MA. Searching for the center on the mathematics science continuum. School Sci Maths 1998;98:328–333.
[29] Huntly MA. Theoretical and empirical investigations of integrated mathematics and science education in the middle grades with implications for teacher education. J Teacher Educ 1999;50:57–67.
[30] Kiray SA. İlköğretim ikinci kademede uygulanan fen ve matematik entegrasyonunun etkililiği. PhD., Hacettepe University, Ankara, Turkey, 2010 [in Turkish].
[31] Furner JM, Kumar DD. The Mathematics and Science Integration Argument: A Stand for Teacher Education. Eurasia J Maths, Sci Technol Edu 2007;3(3), 185–189.
[32] Bassok M, Holyoak KJ. Interdomain transfer between ısomorphic topics in algebra and physics. J Exp Psych Learn Mem Cogn 1989;15:153–166.
[33] Kaminski JA, Sloutsky VM, Heckler AF. Transfer of learning between isomorphic artificial domains: Advantage for the abstract. In K. Forbus, D. Gentner, & T. Regier (Eds.), Proceedings of the XXVI Annual Conference of the Cognitive Science Society, Erlbaum, Mahwah, NJ, pp 642-647, 2004.
[34] Perkins D, Salomon G. Are cognitive skills context-bound? Educ Res 1989;18:16–25.
[35] Lehman J. Integrating science and mathematics: Perceptions of preservice and practicing elementary teachers. School Sci Maths, 1994;94:58–64.
[36] Mason TC. Integrated Curricula: Potential and Problems. J Teacher Edu 1996;47(4):263-270.
[37] Basista B, Mathews S. Integrated science and mathematics Professional development programs. School Sci Maths 2002;102:359–370.
[38] Buyukozturk S, Kilic Cakmak E, Akgün OE, Karadeniz S, Demirel F. Bilimsel Arastirma Yontemleri. Pegem Academy Publications, Ankara, Turkey, 2011 [in Turkish].

[39] Friend H. The effect of science and mathematics ıntegration on selected seventh grade students' attitudes toward and achievement in science. School Sci Maths, 1985;85:453–461.
[40] Shulman LS. Knowledge and teaching: Foundations of the new reform. Harvard Educ Rev 1987;57:1–22.
[41] Lehman JR, Mc Donald JL. Teachers' perceptions of the ıntegration of mathematics and science. School Sci Maths, 1988;88:642–649.
[42] Frykholm J, Glasson G. Connecting science and mathematics ınstruction: Pedegogical context knowlege for teachers. School Sci Maths 2005;105:127–141.
[43] Dikmenli M, Cardak O, Yener D. Science student teachers' metaphors for scientists. Energy Educ Sci Technol Part B 2012;4:51–66.
[44] Karamustafaoglu S. Chemistry teachers' levels of using teaching materials. Energy Educ Sci Technol Part B 2010;2:255–268.
[45] Sahin C, Calik M, Cepni S. Using different conceptual change methods embedded within 5E model: A sample teaching of liquid pressure. Energy Educ Sci Technol Part B 2009;1:115–125.
[46] Cardak O. The determination of the knowledge level of science students on energy flow through a word association test. Energy Educ Sci Technol Part B 2009;1:139–155.
[47] Dikmenli M. Biology students' conceptual structures regarding global warming. Energy Educ Sci Technol Part B 2010;2:21–38.
[48] Yigit N. Developing presentation skills of student teachers through micro-teaching method. Energy Educ Sci Technol Part B 2010;2:55–74.
[49] Calik M. How did creating a constructivist learning environment influence my graduate students' views? Energy Educ Sci Technol Part B 2011;3:1–13.
[50] Ay M. University students' comprehension difficulties in accounting subjects and their reasons. Energy Educ Sci Technol Part B 2012;4:323–330.
[51] Kubiatko M, Vaculova I. Project-based learning: characteristic and the experiences with application in the science subjects. Energy Educ Sci Technol Part B 2011;3:65–74.
[52] Aydın S, Yel M. The effect of brain based learning biology education upon the academic success and attitude. Energy Educ Sci Technol Part B 2011;3:87–98.
[53] Metin M, Coskun K, Birisci S, Kaleli Yilmaz G. Opinions of prospective teachers about utilizing the 5E instructional model. Energy Educ Sci Technol Part B 2011;3:411–422.
[54] Tas E, Apaydin Z, Çetinkaya M. Research of efficacy of web supported science and technology material developed with respect to constructivist approach. Energy Educ Sci Technol Part B 2011;3:455–468.
[55] Erdogan A. Preservice mathematics teachers' conceptions of and approaches to learning: A phenomenographic study. Energy Educ Sci Technol Part B 2012;4:21–30.
[56] Ozyurt O. Analysis of asynchronous dialogues to reveal the effect of discussions on learning programming languages by candidates of computer programmers. Energy Educ Sci Technol Part B 2011;3:739-750.
[57] Tatli ZH. Computer based education: Online learning and teaching facilities. Energy Educ Sci Technol Part B 2009;1:171–181.
[58] Turhan K, Kurt B. Computer based medicine education: Improved skin segmentation using YCbCr color space. Energy Educ Sci Technol Part B 2010;2:1–20.
[59] Yesilyurt M. Meta-analysis of the computer assisted studies in physics: A sample of Turkey. Energy Educ Sci Technol Part B 2011;3:173–182.
[60] Koray O. The effectiveness of problem-based learning supported with computer simulations on academic performance about buoyancy. Energy Educ Sci Technol Part B 2011;3:293–304.
[61] Kaplan A, Ozturk M. The effect of computer based instruction method to resolve misconceptions on ratio-proportion subject. Energy Educ Sci Technol Part B 2012;4:271–282.
[62] Demirbas A. Energy issues in energy education. Energy Educ Sci Technol Part A 2011;27:209–220.
[63] Demirbas C. Innovative preschool education. Energy Educ Sci Technol Part B 2011;3:647–652.