An Investigation of the Views on the Integration of Science Technology and Mathematics in a Mathematics Teacher Education Program[1]

Ali Delice, Emin Aydın, Gökhan Derin and Ömer Yaşın

Abstract

STEM is a new concept for Turkey. Interest is increasing in the academic community of the related fields and especially in the field of education of science and mathematics. At the practical level there are sparse individual efforts of practice in high schools by teachers of science and mathematics. Therefore our primary aim is to understand how this idea is reflected in the minds of teacher candidates of the related fields in a non-integrated mathematics-science program. We also analyzed the curricula followed in the above programs. Our sample consisted of 349 teacher candidates from the departments of mathematics, science and computer education and instructional technologies education who were in their final years. For this inquiry we use a mixed methods strategy. We use both quantitative and qualitative data. Quantitative data comes from the scale developed by the researchers "The integration of STEM" and also from a questionnaire for the demographics of the sample. Qualitative data comes from the programs used in the departments. Document analysis method and descriptive & inferential statistics techniques, are used to analyze data from the scale and from the questionnaire. Findings of the study suggest positive attitudes towards STEM integration. Findings also indicate similar and different attitudes with respect to the department. Reasons for these were discussed with regard to the current literature and to the curricula of the departments under study.

Key words: STEM integration, Teacher education, Attitudes towards STEM

Introduction

Connections among the fields of science, technology, engineering, and mathematics (STEM) to improve student attitudes and performances in these subject areas have been taken more seriously in recent years in the USA (National Council of Teachers of Mathematics (NCTM), 2000; National Research Council (NRC), 1996), Europe (e.g. McKinsey & Company Report, 2007). Although STEM is a new concept for Turkey, there are signs of awareness in the governmental and academic levels. There also are efforts to introduce the issue to the attention of teachers (e.g. http://fetemm.tstem.com)

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and to the Turkish research community in the area of teaching and learning (e.g., Corlu, Capraro, & Capraro, 2014; Çorlu, Capraro, & Çorlu, 2015, Çorlu & Aydın, 2016).

STEM education includes the knowledge, skills, and beliefs that are collaboratively constructed at the intersection of more than one STEM subject area (Corlu, Capraro, & Capraro, 2014). Curriculum integration models exist within the continuum with two extremes: too general approaches which lack rigor in domain-specific knowledge and radical approaches in the school curriculum through interdisciplinary approaches (Hartzler, 2000). In the Turkish case the initial efforts is more close to the left end of this continuum. There have been very cautious initial attempts at the planning level: Recent changes in the curricula of the STEM subjects signal a change towards more integration between STEM and some non-STEM subjects (Ministry of National Education (MoNe, 2013). In fact, there is encouragement in the lower and upper secondary school teachers of mathematics and science curriculum to collaborate and use an integrated approach (MoNE, 2009a, 2009b, 2013). There are references in the program document for the upper secondary school mathematics, to the ideas of mathematical modeling and real life applications of mathematics (MoNe, 2013).

This attempt at the level of intended curriculum did not reflect in the implemented level because of the attitude of "sorting out things with a radical reform" without paying attention to the difficulties at the practical level (Yağcı, 2010). The pressures resulting from external examinations hinder this attempt even before the start of the professional teaching experience. Using the idea of the inseparability of beliefs and knowledge[3] (Leatham, 2002; Wilson & Cooney, 2002) we can say that teachers "know" the importance of the idea of integration but does not "believe" they are able to apply.

Aim of the Study

At the practical level there are rare individual efforts of practice in high schools by teachers of science and mathematics. There has been efforts to understand as to in what degree this idea is reflected in the curricula of the teacher training programs of science, mathematics and technology education (Çorlu, 2014). Therefore our primary aim is to understand how this idea is reflected currently in the minds of teacher candidates of the related fields without using a treatment strategy of any kind by focusing on a teacher training program using a non-integrated mathematics and science program. We also analyzed the curricula followed in the above programs. Our points of interest, as a result, are written as four research questions:

[3] Leatham (2002) stated "those things we "more than believe" we refer to as *knowledge* and those things we "just believe" we refer to as beliefs" (p. 92). This is compatible with Schefller (1965)'s argument such that " a claim to knowledge must satisfy a truth condition, whereas beliefs are independent of their validity" (cited in Thompson, 1992, p. 129).

- RQ1. What are the attitudes and perceptions related to integration of prospective mathematics, science, and technology teacher candidates in general and based upon certification area?
- RQ2. Are there statistically significant differences in attitudes in regard to the certification area?
- RQ3. Are there statistically significant attitudinal differences in towards integration and in towards feasibility?
- RQ4. What are the specific features of the curricula followed in the mathematics, science, and technology education programs?

Method

For this inquiry we use a mixed methods strategy. We use both quantitative and qualitative data. Quantitative data comes from the scale developed by the researchers "The integration of STEM" and also from a questionnaire for the demographics of the sample. Qualitative data are the curricula and program objectives of the science, mathematics and technology education programs which are stated in the web pages. Document analysis was the method of analysis. Quantitative data analysis methods, descriptive and inferential statistics, are used to analyze data from the scale and from the questionnaire. Graphics and tables are used to summarize the data visually.

Participants

Our target population is teacher candidates enrolled in the teacher education programs in lower and upper secondary education areas: mathematics (lower and upper secondary mathematics teaching), lower secondary integrated science, upper secondary science (biology, physics and mathematics teaching).

In the sample we use, nevertheless, does not contain candidates from some areas listed above for practical constrains such as time and budget. Hence the sample comprised of a total of 349 teacher candidates from mathematics, physics, biology, chemistry and computer education and instructional technologies (CEIT) departments. The demographic characteristics of the sample are summarized in Table 1.

Table 1: Demographic characteristics of the sample

Gender	N	%	**Faculty**	N	%
Male	108	30,9	Science	85	24,4
Female	241	69,1	Education	264	75,6
Total	349	100,0	Total	349	100,0
Certification area			**Year**		
Mathematics	97	27,8	2	74	21,2
Physics	76	21,8	3	40	11,5
Biology	78	22,3	4	38	10,9
Chemistry	49	14,0	5	111	31,8

CEIT	49	14,0	Graduate	86	24,6
Total	349	100,0	Total	349	100,0

Data collection instruments

The instrument we used for obtaining data about teachers attitudes towards integration of STEM areas is "Integration of Mathematics, Science, & Technology Education" (IMSTE) scale (see table 2 for sample items) (Aydın, Delice, Derin, & Yaşin, 2016) This is a scale comprised of two subscales ("value of integration" and "feasibility of integration") having 32 Osgood type semantic differential items. The instrument is extensively based on the instrument developed by Berlin & White (2012) which has 20 items in total, 17 of which is in the value and three of which is in the feasibility sub-dimensions. The reliability of the scale item statistics and alpha correlations were 0.917 for the first, 0.835 for the second dimensions. Alpha for the whole scale was 0.771.

Table 2. Sample of the items of the IMSTE

Item no	Dimension	Item
02	Value	passive-active
05	Value	deep-shallow
13	Value	productive-unproductive
15	Feasibility	simple-complicated
17	Feasibility	discrete-integrated
24	Value	practicable-impracticable
30	Feasibility	constructivist-behaviorist
31	Feasibility	dynamic-constant

Qualitative data are the curricula and program objectives of the science, mathematics and technology education programs. We used the official web site of the mathematics, physics, biology, chemistry and CEIT departments under study as the data source. These program objectives were examined in terms of the STEM characteristics by using the content analysis approach.

Findings

We will present the findings in the order of the research questions. In order to answer the first research question, we calculated means and standard deviations from the two subscales for each of the areas. According to the comparison of the mean scores presented in Table 3, it is observed that the attitudes in general are high and that teachers generally have more positive attitudes for value of STEM integration than its feasibility dimension and that physics and mathematics teacher candidates have the most positive attitudes in the value dimension, whereas, no meaningful differences can be observed in between the areas in the feasibility dimension.

Table 3: Means and Standard deviations of attitude scores of teacher candidates from different certification areas

	Mathematics		Physics		Biology		Chemistry		Computer		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Value	3,81	0,42	3,96	0,48	3,59	0,46	3,60	0,56	3,45	0,53	3,71	0,48
Feasibility	3,54	0,52	3,35	0,71	3,57	0,46	3,49	0,60	3,55	0,40	3,49	0.54

To investigate if there are statistically significant differences in attitudes in regard to the certification area (RQ2) a one way ANOVA was conducted Results of the analysis showed a statistically significant difference in the value dimension (are presented in Table 4). Consequently, the Scheffe Test was conducted (see Table 5) to what pair this difference can be attribute to? Results indicated that there are statistically significant differences between teacher candidates of physics & biology and physics & CEIT.

Table 4: One way ANOVA to test for differences in attitudes and based upon teacher candidates' certification area.

		Sum of Squares	df	Mean Square	F	p
Value	Between Groups	10,748	4	2,687	5,651	0,000
	Within Groups	163,554	344	0,475		
	Total	174,302	348			
Feasibility	Between Groups	2,395	4	0,599	1,102	0,355
	Within Groups	186,859	344	0,543		
	Total	189,255	348			
IMSTE	Between Groups	2,017	4	0,504	2,926	0,021
	Within Groups	59,264	344	0,172		
	Total	61,281	348			

Table 5: Scheffe Test for the reason for differences in attitudes and based upon teacher candidates' certification area (IMSTE).

CE (I)	CE (J)	Mean Difference (I-J)	Std. Error	p
Mathematics	Physics	-0,156	0,1056	0,704
	Biology	0,218	0,1049	0,366
	Chemistry	0,210	0,1208	0,558
	CEIT	0,353	0,1208	0,076
Physics	Biology	0,374	0,1111	0,025 (*)
	Chemistry	0,365	0,1263	0,082
	CEIT	0,509	0,1263	0,003 (*)
Biology	Chemistry	-0,008	0,1257	1,000
	CEIT	0,135	0,1257	0,884
Chemistry	CEIT	0,144	0,1393	0,899

Consequently, T test for paired samples was conducted to understand whether or not teacher candidates have different attitudes in regard to the value of STEM integration and its feasibility (RQ3). The results revealed a significant difference in favor of the value dimension (Table 6).

Table 6. Paired T test to test the difference between teacher candidates' responses to the value & feasibility dimensions.

	Paired Differences						
	Mean	SD	Std. Error Mean	t	df	p	Effect Size Cohen's d

Value	vs.	Feasibility	.614	1,364	.156	3.923	75	.000	0.390
$\bar{X}$=3.81 ,SD=.65 - $\bar{X}$=3.54 ,SD=.72									

As a factor influencing teacher candidates' attitudes, we wished to investigate the specific features of the curricula followed in the mathematics, science, and technology education programs?" previous research questions are answered using quantitative analyses: means, standard deviations, t test (independent and paired samples) and one-way ANOVA. Our final research question, on the other hand necessitates the use of a qualitative analysis technique. In order to answer that research question we have chosen the document analysis technique. In doing so, we analyzed the program objectives of each of the department under study which are present in the official web pages. In Table 7, we presented results of this analysis.

Table 7. Number and percentage values of STEM related program objective statements

	Total number of objectives	Number of objectives related to STEM	Percentage of objectives related to STEM
Mathematics	15	6	40
Physics	15	9	53
Biology	15	4	27
Chemistry	15	2	13
Computer	15	2	13

According to the results of the analysis, physics teaching department has the highest percentage (53%), followed by the mathematics teaching (40%) and biology (27%) teaching departments, the least percentage of STEM related program objectives are stated in CEIT and chemistry teaching departments (13%). In analyzing the program objectives statements in terms of STEM relation, we checked the statements that mention a direct or indirect necessity for making a connection to another discipline. We did not start the analysis with initial themes in a deductive way. The emerging themes were the use of real life applications, problem solving, applying theory to practice, inter-disciplinary connections and use of technology, use of the scientific process and unforeseen complex problems (Table 8).

Table 8. Program objectives related to STEM integration.

MATHEMATICS TEACHING

1. Students will acquire, apply and communicate a broad knowledge of mathematical concepts throughout their coursework.
2. Students will be able to demonstrate an appreciation of science as an integral part of society and everyday life.
3. Students will be able to organize and critically evaluate information that involves mathematics and they will be able to present it clearly in written and oral form.
4. Students will be able to demonstrate the ability to effectively use information and communication technologies and implement them in teaching / learning environments.
5. Demonstrate the problem solving, analytical and communication skills that provide the foundation for lifelong learning and career development.
6. Students will be able to take on responsibilities as an individual or team member to solve unforeseen

complex problems that might be encountered in practice.

PHYSICS TEACHING

1. Students will be able to demonstrate the ability to inform non-specialist or specialist audiences on physics and physics education and to transfer problems and solutions in verbal and written forms.
2. Students will be able to demonstrate the ability to carry out independently advanced studies and critical thinking.
3. Students will be able to take on responsibilities as an individual or team member to solve unforeseen complex problems that might be encountered in practice.
4. Students will be able to plan and manage professional developmental activities for employees under their responsibility.
5. Students will be able to demonstrate the ability to effectively use information and communication technologies and implement them in teaching / learning environments.
6. Students will attain knowledge and skills in Physics and Physics Educations supported by application tools and equipment and will have an understanding of basic concepts in the field.
7. Students will be able to effectively define, collect and use the necessary data for solving problems as defined in the Physics and Physics Education.
8. The students will demonstrate the ability to identify problems that have occurred due to unforeseen situations in Physics and Physics Education and find solutions.
9. Students will be able to evaluate concepts, ideas and data with scientific methods, to identify and analyze complex problems, to make arguments and to develop recommendations based on evidence and research.

BIOLOGY TEACHING

	1. Students will be able to acquire, apply and communicate a broad range knowledge in biological concepts to specific problems in coursework. 2. Students will be able to demonstrate an appreciation of science as an integral part of society and everyday life. 3. Students will be able to demonstrate an ability to use information and communication technologies and effectively implement them in teaching/learning environments. 4. Students will be able to demonstrate problem solving, analytical, and communication skills that will provide the foundation for lifelong learning and career development.
CEIT	
	1. Students will be able to design and develop technology supported learning materials based on learners' needs. 2. Students will be able to find out the technologic necessities of companies, set up these technologies.

Discussion and Conclusion

A review of teacher education literature reveals that several methods courses designed to connect or integrate science and mathematics have been developed (Austin, Converse, Sass, & Tomlins, 1992; Foss & Pinchback, 1998; Berlin & White, 2012). Current educational practices are far from being adaptive to a model that integrates STEM areas. Within the limitations set forth by the pressures resulting from external testing, classroom culture per se, student attitudes, teaching quality, school management styles, and unequal opportunities due to differences (e.g. regional, school type) influence the current classroom practices. Hence transition from the departmentalized model of teaching to an integrated teaching model (Furner & Kumar, 2007) is farfetched as a global aim for the Turkish education. However far reaching that might be, teacher training programs still need to be designed to equip the prospective teachers with the skills of 21st century (Çorlu & Aydin, 2015).

Science teachers use mathematics as a tool or an inscription device (Roth, 1993; Roth & Bowen, 1994). Mathematics is already embedded in the physics curriculum. For physics teacher candidates, the integration with mathematics already exists, though in a covert way. It can be considered normal, if the level of enthusiasm for a physics teacher candidate is not high. On the other hand, the only way that mathematics teachers can use science is as an application (Aydin & Delice, 2007; Delice & Kertil, 2015; Kertil & Gürel, 2016). Otherwise, mathematics becomes extensively algebra oriented, which actually was the case in Turkey before (Delice & Roper, 2006) and after the curriculum reform (Ayas, Aydin & Corlu, 2013).

The Turkish curriculum after the reform is still not constructivist oriented. For teachers and teacher candidates every new concept introduced in academic circles is considered inapplicable. From that perspective, "attitudes towards STEM" can as well be read as "attitudes to reform in education". In the minds of a teacher candidate STEM is some theory which is in some way related to (or more specifically, is a result of) the constructivist theory. The 2013 reform with its evident emphasis on the importance of the mathematical modeling has closer connections to the idea of STEM integration (MoNE, 2013). It seems that the 2005 and 2013 curriculum reforms in science and mathematics education reflects a theoretical position (which is 'valuable' as an idea) but do not have a chance in practice. Hence it is inevitable that STEM integration will be considered "valuable" but not "feasible". We believe that one of the patterns that can be derived from these results is existence of two concepts which we prefer to call "awareness of the theory-practice duality" and "fear of practice".

We analyzed the program outputs to have an idea about the awareness of the departments on the idea of STEM integration. Results of the RQ4 seem to corroborate the results from the quantitative statistics: Goals of mathematics and physics teaching departments have more in terms of quantity and more up to the point in terms of quality than those of chemistry, biology and CEIT teaching departments. Data from the study may provide feedback for the design and improvement of preservice teacher education programs and the improvement of teaching and learning of students in STEM classrooms in Turkey.

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Matematik Öğretmenliği Programında Fen Bilimleri, Teknoloji ve Matematiğin Entegrasyonu Üzerine Görüşlerin İncelenmesi

Özet

FeTeMM Türkiye için yeni bir kavramdır. Bu konuya akademik çevrelerden özellikle de fen ve matematik eğitimi alanlarından olan ilgi gün geçtikçe artmaktadır. Uygulama seviyesinde nadir bireysel ve kurumsal çabalardan söz edilebilir. Bu çalışmada bizim amacımız bulunan bu fikrin bütünleştirilmemiş bir program yürüten bir üniversitede matematik, fen ve bilgisayar eğitimi alanlarındaki öğretmen adaylarının tutumlarını zihninde oluşan çağrışımlar yoluyla araştırmaktır. Aynı zamanda bu alandaki öğretim programlarını da mercek altına aldık. Çalışma grubumuz adı geçen bölümlerde son sınıfta bulunan 349 öğretmen adayıdır. Yöntem olarak nitel ve nicel verileri bir arada kullanma imkanı veren bir karma yöntem araştırma tasarımı benimsenmiştir. Nicel veri araştırmacılarca geliştirilen bir ölçekten, nitel veri ise bu bölümlerde uygulanan program kazanımlarından oluşmaktadır. Belge analizi ile betimsel ve yordayıcı istatistik teknikleri verileri analiz etmek için kullnılmıştır. Çalışmanın bulguları FeTeMM bütünleştirilmesine yönelik olumlu tutumlara *işaret etmektedir. Bölümlere göre benzer ve farklı tutumlar da kaydedilmiştir. Bu bulguların sebepleri mevcut alanyazın ve bölümlerde uygulanan öğretim programları açısından tartışılmıştır.*

Anahtar kelimeler: Bütünleşik FeTeMM, Öğretmen eğitimi, FeTeMM' e yönelik tutum