E-ISSN: 1305-8223

EURASIA

Journal of Mathematics, Science & Technology Education

FEBRUARY 2009

Volume 5, Issue Number 1

www.ejmste.com

EURASIA Journal of Mathematics, Science & Technology Education

www.ejmste.com

The Eurasia Journal of Mathematics, Science and Technology Education (EJMSTE) is an academic journal devoted to the publication and dissemination of research and position articles on all aspects of mathematics, science and technology education. All articles are reviewed by the members of the editorial board which consists of internationally respected science and mathematics educators, researchers, and practitioners.

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Eurasia Journal of Mathematics, Science and Technology Education (EURASIA) is a **quarterly** journal published online four times annually in **February**, **May**, **August**, and **November**.

EJMSTE is indexed and/or abstracted in Asian Education Index, Cabell's Directory Index, DOAJ, EBSCO, EdNA Online Database, Education Research Index, Higher Education Teaching and Learning Journals, Higher Education Research Data Collection, Index Copernicus, JournalSeek, MathDi, PsycInfo, SCOPUS, TOC Premier Database, Ulrich's Periodicals Directory, and Zeitschriftendatenbank (ZDB).

Journal Owner:

Dr. Esma USAK

Mailing Address:

Mareşal Cakmak Mh. Göktug sk. No: 23/4
Sincan, Ankara – TURKEY
E – mail: ejmste@ejmste.com

Editorial Office:
Mehmet Fatih Taşar (**Editor**)
Gazi Universitesi, Gazi Eğitim Fakültesi,
İlköğretim Bölümü,
K Blok 210, 06500, Teknikokullar,
Ankara – TURKEY

E-ISSN 1305 - 8223

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EDITORIAL

M. Fatih Taşar, Editor
Gazi Üniversitesi, Ankara, TURKEY

Dear all,

I am gladly serving as the editor of this fine journal for the past two years. It has been a lot of hard work but it was worth every moment of it. I would like to thank all of our contributors as paper authors, reviewers, and editorial board members who with their invaluable suggestions help develop and grow the journal.

With the current issue we are entering the fifth year of the EURASIA Journal. So far, the EURASIA Journal has been accepted by 15 major indexes in our field (please see the inside of the front cover for a list of the indexes). We are hoping to bring more good news in the new future.

This journal, just like any other one, would not grow without the continuing support of its readers, authors, and reviewers. We sincerely thank all the people who have got involved in contributing the EURASIA Journal at some stage in some way.

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E-ISSN: 1305-8223

Eurasia Journal of Mathematics, Science & Technology Education, 2009, **5**(1), 3-14

Student Generated Recommendations for Enhancing Success in Secondary Science and Mathematics

Joseph E. Conboy and Jesuína M. B. Fonseca
University of Lisbon, Lisbon, PORTUGAL

Received 23 February 2008; accepted 10 September 2008

One frequently overlooked approach to improving academic success is the simple technique of listening to the students. Students are uniquely positioned to understand the nature of school problems, and their perceptions can be useful in forming solutions to problems of academic failure and school leaving. In this study, science-tracked secondary school students in Portugal (*N*=346) responded to open-response questions regarding what schools and teachers can do to improve success in the 10th grade in general, and specifically in Mathematics and Physics/Chemistry. Content analysis revealed specific dimensions of student recommendations including (a) teacher strategies, (b) teacher affect and (c) curriculum. Student recommendations emphasized diversifying teaching methods, permitting greater student input, making clear connections between class material and real-life applications. Students indicated the importance of developing a positive classroom environment and urged more time for the learning of complex concepts. While their implementation may not be appropriate in all cases, student suggestions can be useful in identifying problem areas, and in some instances may offer sound advice to teachers and educational leaders. We discuss these suggestions, including just what it means to teach with a "real-life" orientation. We propose a distinction between authentic events that are learning relevant and those that are goal relevant.

Keywords: Academic Success, School Organization, Science Education; Student Perceptions, Teacher Behavior.

INTRODUCTION

Abundant empirical studies demonstrate that many students do not understand some concepts essential to science and mathematics, that they have difficulty in applying basic knowledge, and that they lack proficiency in decision making and in resolving real-life problems (GAVE-Gabinete de Avaliação Educacional, 2001, 2003, 2004; OECD-Organization for Economic and Cultural Development, 2003a, 2003b, 2004, 2006, 2007). Researchers around the world have targeted this general problem and given it high priority from an institutional and educational perspective (Abd-El-Khalick et al., 2004; American Association for the Advancement of Science, 1990; Colucci-Gray, Camino, Barbiero & Gray, 2006; Fischer, Klemm, Leutner, Sumfleth, Tiemann & Wirth, 2005; Hofstein & Lunetta, 2004; National Research Council, 1996; Roth & Désautels, 2002; Roth & Lee, 2004). Attempts at reform take place in a context of increased governmental emphasis on the importance of science and technology in modern societies (Gago, 2007).

In Portugal, student achievement, levels of understanding and application of science concepts are

Correspondence to: Joseph Conboy, PhD in Educational Pshycology, Centro de Investigação em Educação Faculdade de Ciências da Universidade de Lisboa, Campo Grande, C6, Piso1, Sala 6.1.18, 1749-016 Lisboa, PORTUGAL
E-mail: jeconboy@fc.ul.pt

E-ISSN: 1305-8223

consistently described as below the average of other OECD countries (Farinheira, Fonseca & Conboy, 2005; GAVE, 2001, 2003; OECD, 2004, 2007; Pinto-Ferreira, Serrão & Padinha, 2007). At the secondary level, failure rates in science and math are especially high, most notably in the 10^{th} grade (Carreira & André, 2000). School leaving, or dropping out, is commonplace (Aguiar, 2007; Ministério da Educação, 2008).

Many organizations, researchers and educational leaders have begun to call for systemic reforms that attack the problem of academic failure on all possible fronts, from school organization, climate and conditions, teacher training, supervision and accountability, to curriculum development (American Association for the Advancement of Science, 1990; Anderson, Brown, & Lopez-Ferrão, 2003; Fonseca, 2003; Hewson, Kahle, Scantlebury, & Davies, 2001; National Research Council, 1996; Supovitz, & Taylor, 2005). Contributions from science educators and other educational leaders have resulted in the implementation of curricular reform in Portugal (Decreto-Lei nº 74/2004 of 26 March; Miguéns, 2004).

However, whether we talk about the Portuguese approach to the problem or the global effort, seldom have the students themselves been consulted about what they see as the important changes necessary to improve academic success in science and mathematics. When student views are incorporated in research designs, strident criticisms of the teaching of science frequently emerge (Osborne & Collins, 2001; Haussler & Hoffman, 2000).

A better understanding of student perceptions can provide science educators and other educational leaders with additional information about how to increase academic success and reduce the dropout rate. As primary actors, clients and beneficiaries of the education process, students are uniquely positioned to understand the nature of school problems. It is therefore fundamentally important to understand what the students themselves perceive as the causes of school failure and to take under advisement their suggestions for action by schools and teachers.

In a previous study (Fonseca & Conboy, 2006), Portuguese secondary-school students rated a series of predefined, literature-based factors with regards to their perceived importance in academic failure in science disciplines in the 10th grade. The students highlighted poor teaching and inadequate previous academic preparation as the most important factors of failure. As part of the same project, the present study reports student-generated, open-response suggestions as to how to improve success in the sciences, both in terms of actions that should be taken by schools as well as by individual teachers.

The study of student perceptions of success and failure and student recommendations for educational reform has been limited, but promising. One approach has been to measure discrepancy between what occurs in school and what students think should occur--the perceived difference between reality and an ideal. The resulting real-ideal deficit can be useful in gauging student perceptions of pedagogical strategies that may require teacher, or school-wide, attention. Angell, Guttersrud, Henriksen and Isnes (2004) used this method in a study involving more than 2000 randomly selected Norwegian science students in grades 12 and 13. The largest discrepancies they observed between what is done and what is desired by students were the factors they termed "qualitative" and "pupil-centered" teaching methods. Students indicated they would prefer greater use of practical description for the presentation of new concepts (as opposed to mathematical presentation), and more group discussion and demonstrations to illustrate concepts. Other areas that showed a real-ideal deficit included (a) using pupils' suggestions in the lessons, (b) letting pupils choose both the problem and the method in experiments, (c) problem-solving in groups, (d) project work and (e) the use of additional literature besides the textbook. According to students, the method of the teacher presenting new material at the blackboard is used frequently in the sciences. Students indicate that they would prefer less "chalk and talk" and more class discussion as a means of making difficult subject matter more understandable.

The work of Seidel and Prenzel (2002) also supports the notion of a student preference for an expanded repertoire of teaching strategies. They studied 13 introductory physics class groups (grades 7 and 8) over the course of one school year. Students reported that, for most classes, teaching consisted mainly of transmission of concepts and demonstrative experiments. Some classes were more student centered (with periods of individual or small group work as opposed to lecture and teacher-centered questioning). When working in this context, students reported more intensive cognitive activity and more intrinsic motivation. In classes with longer periods of individual or group work, students reported more positive perceptions of teachers' support and interest, quality of instruction, learning conditions, relevance of class content, as well as social relatedness.

Angell et al. (2004) also found that students adapt--swiftly and submissively-- to the teaching they actually do receive. The authors suggest that it is sometimes difficult for the students to imagine alternatives to the teaching they receive—since they view the subject matter as fixed and the instruction methods as largely determined by the nature of the subject matter. In this Norwegian study, students acknowledged their responsibility in learning, asserting that success depended largely on their own enthusiasm and engagement. Fonseca and Conboy (2006) on the other hand, in a sample of Portuguese 10th-grade students, found that the students overwhelmingly attributed failure to factors that were essentially external to them and uncontrollable, such as teaching quality.

Many studies have pointed to the fundamental influence of the teacher on students' attitudes toward the subject matter and teaching (Corbett & Wilson, 2002; Nollen, 2003; Osborne & Collins, 2001; Sadler & Tai, 2001). But do students have preferences about teaching?

Stokking (2000) found that high school physics students, in a representative sample of schools in the Netherlands, wanted physics teaching to have a stronger orientation toward everyday life and to use methods that encouraged their active participation in class. But what is the meaning of an "everyday life orientation", and what are its consequences? Such student attitudes about an "orientation toward everyday life" have been instrumental in effecting curriculum change in some cases. Just such an approach was described by Carlone (2003) and demonstrates the pendulum effect frequently observed in curricular reforms.

Carlone describes the implementation of a reform-based curriculum (*Active Physics*), implemented in an upper-middle-class high school in the United States. The curriculum was described as activity-based, group-oriented and aimed at student interests. Its scope was considered wider than the typical, academic-oriented physics courses and was designed to appeal to a broad range of students. The curriculum placed emphasis on interesting, relevant, real-world themes and on students' involvement, participation and sharing of ideas. While analysis revealed no differences in achievement between the *Active Physics* group and traditional physics students, attitudes toward physics were considerably more positive among the *Active Physics* students. The following year the number of students who registered for the *Active Physics* course increased greatly (Carlone, 2003).

In the following years, Carlone observed two tendencies: First, the students perceived the course as "easy" physics, "fun" physics, even "blow-up" physics; second, the school community responded by pressuring for a more rigorous "real physics" course. Over a five-year span, the reform-based curriculum gradually reverted to its more traditional format. She concluded that the shaping of innovative science practice will always be influenced by contexts, and attempts to broaden the meaning of physics, and physics teaching, give rise to hidden complexities (Carlone, 2003).

In contrast with Carlone's findings and reflections, others have suggested that students' emphasis on the importance of "everyday life" aspects can be interpreted not only as "student interests" but also as an appeal to the social and cultural implications of physics. From this perspective, the teaching of physics should include, or perhaps center on, these social and cultural dimensions beyond the personal and purely scientific and mathematical. Teaching could, for instance, emphasize the role of pure physics in the associated sciences (environmental physics, biomedical physics, and so on). Other science fields have felt the same pull to the practical: Schwartz-Bloom (2003) argued that student performance in high school biology and chemistry classes will improve if interesting and relevant topics (such as pharmacology) are integrated. Ölme (2000) highlighted this same recommendation from the European Physical Society: Motivation for the study of physics emerges from the understanding that physics provides key knowledge for solving present and future problems in such areas as the environment, medicine and biology.

Specific contexts may also influence student perceptions. We consider here three studies that investigated student preferences and attitudes in (a) a low income area, (b) an alternative residential program, and (c) a predominantly African-American school.

Corbett and Wilson (2002) interviewed nearly 400 low-income, middle and high school adolescents in inner city schools in the USA undergoing district-wide educational reform. These students identified their teachers as the main factor determining how much they learn. Students characterized good teachers as the ones who (a) make sure students did their work; (b) controlled the classroom; (c) were willing to help students whenever and however the students wanted help; (d) explained assignments and content clearly; (e) varied the classroom routine; and (f) took the time to get to know students and their circumstances. It is interesting that students did not confuse teachers' personal qualities with their professional behavior. If the teacher had the six "good teacher" qualities identified, then demeanor, sense of humor, charisma, and other personal characteristics were unimportant. Furthermore, students equate good teaching with more learning. The students in this study based their evaluation of the reform efforts on the effects these reforms had on teacher behavior and the increase in the number of good teachers. Corbett and Wilson (2002) concluded that schools should guarantee that teachers act in ways that demonstrate how much they care about students and their learning.

A study in an alternative, tuition-free, residential high school in the United States reported student perceptions of learning needs and behavioral problems. The students involved came from diverse regions of the USA and previously had endured compound social problems: academic failure, substance abuse, expulsion, gang membership and so on. Easton (2002) describes how students identified specific areas of need--areas where deficiency is perceived as interfering with learning. Students referred to emotional needs, such as the need for self-esteem and personal accountability, and they talked about the need for teachers who care and use teaching methods that promote active and personalized learning. They further mentioned the need for high expectations on the part of the school (Easton, 2002).

Tucker, Herman, Pedersen, Vogel and Reinke (2000) analyzed student-generated recommendations for improving the academic success among African-American students. The responses suggest that parent and teacher encouragement, expectations and praise may improve student schoolwork and class participation; such improved preparation and participation may in turn enhance achievement. The authors also recognize the important role of peer interaction and how this can influence (for better or worse) academic behavior even prior to the onset of adolescence. The responses also showed, according to Tucker et al., that the students often lack self-management techniques and that these students could be empowered by the teaching of such techniques.

Students, then, recognize many different causes of failure in high school (and particularly in the sciences) and many different ways of improving achievement. Some common strategies can be identified in the international literature as to how to improve student success. It is important, however, to extend this body of data to other contexts and conditions. A better understanding of such student perceptions can provide educators, school managers and leaders another decision-making tool for defining and selecting policies for enhancing academic success and reducing the dropout rate. This study, therefore, sought to identify unprompted suggestions and recommendations provided by 10th-grade, science-tracked students in the south of Portugal both in terms of actions that should be taken by schools and by teachers.

METHOD

Participants

The participants in the study were 346 10th-grade, science-tracked students, from eight public schools in the Algarve region of southern Portugal. With a median age of 16, the sample included 214 girls (61.8%); 301 (87%) were Portuguese nationals. Two class groups from each school were selected. School curriculum for science-tracked students included five disciplines in the sciences: Physics-Chemistry, Biology-Geology, Mathematics, and two science laboratory techniques courses. While the sample is not probabilistic, relevant parameters are fairly typical of the Algarve. Slightly more than 11% of the sample had previously failed the 10th grade at least one time. Average evaluation of achievement (based on a 20-point scale where 10 is passing) was 12.5 in Physics-Chemistry, 11.5 in Mathematics, and 13.4 in Biology-Geology. About one quarter of the sample indicated they were currently failing Physics-Chemistry, about one third, Mathematics, and one tenth, Biology-Geology. Nearly all reported that they felt it was important to finish high school.

Material

A questionnaire was prepared based on the literature review. Four open response questions were posed asking for suggestions as to how to improve success in general and in the sciences. The questions solicited responses in terms of actions that should be taken both by schools and by teachers: (a) What can Physics-Chemistry teachers do to improve success in the discipline in 10th grade? (b) What can Mathematics teachers do to improve success in the discipline in 10th grade? (c) What can the School do to improve student success in 10th grade in general? (d) What can the School do to improve student success in Physics-Chemistry and Mathematics in the 10th grade?

Students were asked to give three suggestions for each of the questions.

Procedure

Prior to the field phase of the study, the data collection instrument and procedures were piloted in two other secondary schools in the same region. Data collectors (eight teachers, one in each school) presented the questionnaires to the students, asking for their collaboration, and remained in the room for the time necessary for students to complete the answers.

Questions of semantics will always be a challenge in this type of study. In order to tap the general, unprompted student responses, we could not specifically operationalize response terms (e.g. "creative") in the data collection phase. The meanings of such terms, as used in this study, flow from social interactions and the interpretation of those interactions. *Personal* meanings and understandings evolve but as Cobb and colleagues have pointed out, *normative* understandings also develop. Cobb has used the term "taken-as-shared" to refer to such meanings (e.g. Cobb, Wood, Yackel & McNeal, 1992). It is this kind of normative meaning that the coding procedure attempted to measure, without necessarily exposing specific operationalizations.

In order to identify a preliminary set of categories, the responses to each question were read, then re-read several times. Interpretations were adjusted in order to present the best account possible of student meanings. Although the students were asked to propose three suggestions for each question, some students gave only one or two, while others presented four suggestions. All the answers were coded. When in one suggestion the student repeats an idea, the answer was counted once only (for example, "be more patient in presenting the subject matter; cover the program at a slower pace"). Some of the answers were rather general and others were quite specific (for example, "math teachers should, while writing formulas on the blackboard, write one formula at a time, and discuss it and apply it, and only then should they write other formulas"). Some of the suggestions were complex, including several codable responses, and so were classified in more than one category. As an example we have this student response about mathematics teaching:

There are students who lack good background preparation, and so teachers have to understand that, and should explain in a more understandable manner and help students as much as necessary.

This response was coded in three response categories: "teachers are concerned", "explain better", and "help students".

Content analysis permitted the coding of suggestions regarding teacher actions into 12 variables (plus one additional category for other and uncodable responses). These were grouped into nine general constructs and analyzed both in terms of improving success in Physics/Chemistry as well as Mathematics. The answers to the two questions concerning recommendations to schools were organized into five constructs: (a) school organization and management; (b) teachers in school; (c) interactions in the classroom; (d) curriculum; and (e) equipment and other conditions.

RESULTS

Teachers

Physics-Chemistry. The first question asked what teachers can do to improve success in Physics-Chemistry in the 10th grade. Of the 346 students, 308 (89%) provided at least one response. A total of 714 suggestions were coded in the 12 substantive categories. One additional category included seldom-mentioned "other" responses. Some of these categories were then further reduced to form coherent practical suggestions.

Table 1 shows the frequencies and relative frequencies of each coded response. Categories derived from the data included the following student-generated suggestions:

1. Teachers should motivate students, and develop their self-confidence through creative teaching (112 responses). "Creative teaching" was frequently operationalized by students as the use of diverse and innovative methods involving greater student participation (93 responses). Thus 205 of 714 responses (28.7%) fell into this general suggestion category.
2. A second category appealed to the use of experimentation, practical exercises and a robust connection between classroom activities and real-world relevance (104 responses; 14.6%).
3. Teacher motivation was addressed in a third category (158 responses; 22.1%). Students suggested that teachers be more engaged in their teaching, that they should enjoy teaching and show the kind of concern for students learning that creates good classroom environment (97 responses). They further suggested that teachers be available for group and individual remediation (61 responses).
4. Teachers should prepare and present their classes with language appropriate for their students--it should be clear and understandable (62 responses; 8.7%). (The perception of "unclear language" in the classroom may be associated with the perception of a lack of adequate previous preparation. Students without adequate preparation would surely sense that the language used by teachers lacked clarity and understandability).
5. Teachers should have students resolve more application exercises (34 responses) and worksheets (16 responses). This category, with 50 responses (7%), could conceivably be combined with category 2, above. We chose to maintain it as a separate student suggestion due to its emphasis on classroom exercises and *formative evaluation* as opposed to actual *teaching* that is emphasized in category 2.
6. Students also suggested that teachers should use diverse forms of assessment and not limit evaluation to the use of highly demanding tests (39 answers; 5.5%).
7. In this category, 29 responses (4.1%) focused on questions of curriculum, saying that the official program of the Physics-Chemistry discipline (defined by the Ministry of Education) should be reduced, and more time should be allowed for the learning of concepts.

Improvement of school conditions was mentioned in 13 responses (1.8%) and 19 responses (2.7%) indicated that Physics-Chemistry teachers "do their best" and therefore the responding students provided no further suggestions for improvement. Still a few responses (f=6; 0.8%) mentioned that teachers should verify student preparation when they enter 10th grade and do revisions of 9th grade topics before advancing to new material.

Mathematics. The same question was asked regarding Mathematics teachers. Table 1 shows the suggestions provided by 300 (86.7%) of the students who offered 669 responses. The suggestion categories used were the same as those used for Physics-Chemistry and, in general, the proportion of responses was similar for both disciplines. The proportion of total responses was higher for Mathematics teachers in categories (a)

Table 1. What can Teachers do to Improve Success in Physics-Chemistry and Mathematics?

		Physics/ Chemistry		Math	
		f	%	f	%
	a. Teachers should motivate students, develop their self-esteem, self-confidence and self-purpose, by teaching in a more interesting and creative manner	112	15.7	123	18.4
1	b. Teachers should use diverse, innovative methods involving greater student participation, in ways that make difficult subject matter more understandable	93	13.0	96	14.3
2	c. Teachers should have classes in which students perform experiments and other practical activities; practical, real-life, activities	104	14.6	35	5.2
	d. Teachers should be highly engaged in their teaching, empathic, patient, just and fair, should enjoy teaching and be concerned with student comprehension of subject-matter, and with creating a good class environment	97	13.6	82	12.3
3	e. Teachers should help students individually, in remediation classes or extra-class time, above all the students with more difficulties	61	8.5	79	11.8
4	f. Teachers should explain in understandable and clear language	62	8.7	65	9.7
5	g. Teachers should have students resolve more application exercises	34	4.8	44	6.6
	h. Teachers should provide more worksheets	16	2.2	16	2.4
6	i. Teachers should use diverse forms of evaluation and not limit evaluation to the use of highly demanding tests	39	5.5	43	6.4
7	j. Curriculum issues: the official program should be shorter and allow more time for learning concepts	29	4.1	32	4.8
8	k. School conditions should be improved	13	1.8	12	1.8
9	l. Teachers do their best (no suggestions for improvement)	19	2.7	11	1.6
	m. Other answers (8 different categories)	35	4.9	31	4.6
	Total Responses	714	100.0	669	100.0

"Teachers should motivate students, develop their self-esteem, self-confidence and self-purpose, by teaching in a more interesting and creative manner" (18.4 % versus 15.7 %); (b) "use diverse, innovative methods involving greater student participation, in ways that make difficult subject matter more understandable" (14.3 % versus 13.0 %); (e) "help students individually, in remediation classes or extra-class time, above all the students with more difficulties" (11.8 % versus 8.5 %); and (f) "Teachers should explain in understandable and clear language" (9.7 % versus 8.7 %).

The relative frequency of responses was also higher for Mathematics in categories involving types of evaluation (6.4 % versus 5.5 %) and the use of application exercises/worksheets (9.0 % versus 7.0 %).

School

Academic Success in General. To the question about what schools can do improve academic success in general, 325 students (93.9 %) provided at least one suggestion and 811 responses were coded. The recommendations about possible school actions were organized into five categories: (a) School Organization and Management; (b) Teachers in School, (c) Classroom Interactions; (d) Curriculum; and (e) Equipment and other Conditions. Table 2 shows the frequencies and relative frequencies within these coding categories.

Of a total of 811 responses to the question regarding academic success in general, 357 (44.0%) were coded in the category of School Organization and Management. The largest proportion of these responses dealt with early identification of student learning problems and the furnishing of institutional remedial support such as tutoring (90 of 357 responses; 25.2%). A second group of responses focused on institutional promotion of future student objectives and good study methods (61 answers). The organization of extracurricular activities (clubs, contests, debates, visits, fairs, real-life projects) was mentioned in 57 suggestions. Concerns about scheduling issues (for example, reducing the number of in-class hours) appeared 49 times. Less frequently

Table2. What Can the School do to Improve Academic Success?

	Category	Success in Sciences and Math?		Success in General	
		f	%	*f*	%
1	School Organization and Management	207	29.3	357	44.0
2	Teachers in School	220	31.1	179	22.1
3	Classroom interaction	94	13.3	72	8.9
4	Curriculum	96	13.6	74	9.1
5	Equipment and other Conditions	90	12.7	129	15.9
	Totals	**707**	**100.0**	**811**	**100.0**

mentioned responses included: Schools should better train and evaluate teachers; they should listen to students concerns, recognize student achievement (though prizes, honor roll, merit scholarships); they should invest in career education. Eight responses indicated that the school already does the best it can.

Student responses revealed numerous recommendations related to teachers (179 of 811; 22.1%). These suggestions were often associated with the school's presumed power to hire, supervise and direct teachers, for instance: (a) contract qualified and competent teachers (48 responses); (b) hire teachers that show concern for students and that provide them with motivation and support (43 responses); (c) ensure that teachers use diverse, interactive teaching, with practical activities based on student needs (31 responses); (d) have teachers that are committed to teaching, enjoy teaching and are empathic and patient (28 answers).

A total of 72 recommendations were coded concerning classroom interactions: (a) 29 suggestions mentioned that the school should support practical activities, and dynamic, non-lecture classes; (b) 20 mentioned specifically that classes should be "fun"; (c) 20 mentioned a need for better class environment and better communication (both teacher-student and student-student communication).

Recommendations regarding Curriculum were voiced 74 times and included such comments as: (a) Eliminate from the official program everything that is irrelevant, out-of-date, uninteresting or difficult; the official programs should be shorter, the current program attempts to cover too much in the time available ($f = 28$); (b) tests should be easier, other forms of evaluation should be used and evaluation should be consistent with what is being taught ($f = 21$); (c) difficulty of the 10th grade should be decreased ($f = 20$). While some of the recommendations in this category include a hedonic component (the appeal for less challenging material and easier evaluation), we chose to leave them as the students reported them.

Insufficient school conditions and equipment were noted in 129 of the 811 suggestions about what schools can do to improve academic success in general. Within this category, we noted the following often mentioned recommendations: (a) school should have better installations (including tutoring rooms, labs, quiet study rooms, libraries); better equipment (Information and Communication Technology); and better conditions (environmental heating and cooling) (75 responses); (b) more and better didactical material (computer hardware and software; laboratory material) (41 responses); and (c) smaller classes (13 responses).

Success in Physics-Chemistry and Mathematics. The 707 responses to the question, "What can the school do to improve the success of students in Physics-Chemistry and Mathematics in the 10th grade?" were organized into the same five categories as for improving success in general. Although the categories are the same, the emphasis in each category, based on proportion of responses, is somewhat different for success in the 10th grade in general and for success in Physics-Chemistry and Mathematics. Table 2 shows the results, based on the responses of 314 students (90.7%) who provided at least one suggestion.

The proportion of responses regarding success in Physics-Chemistry and Mathematics was greater than that of success in general in three categories: Teachers in School (31.1% versus 22.1% for success in general); Classroom Interaction (13.3% versus 8.9%); and Curriculum (13.6% versus 9.1%). Success in science and mathematics was associated principally with responses related to the action of teachers; success in general was associated more with school organization and management.

The 207 responses classified as School Organization and Management (29.3% of 707) included: (a) provide tutoring support including the early identification of student needs (f=70); (b) motivate students to study sciences/develop in students good study methods (43 answers); (c) organize extra-curricula pedagogical activities (clubs, contests, debates, visits, fairs, real-life projects--39 answers). Other responses focused on teacher selection, hiring, evaluation and development (19 answers).

Slightly less than one third of the responses ($f = 220$) referred to how the school should influence teacher actions. In this category, two sub-categories appeared that were not mentioned in relation to success in general: (a) require teachers to assign more exercises and homework and to teach extra classes; and (b) require teachers to show the applications and importance of subject material and make learning fun.

The 94 recommendations (13.3%) classified as Classroom Interaction included the frequent suggestion that schools should encourage practice-oriented classroom interaction, specifically more experimental work. The frequency of suggestions regarding better classroom communication was inferior to that regarding success in general.

Responses in the category of Curriculum ($f= 96$; 13.6%) emphasized the need to eliminate from the official curriculum irrelevant, out-of-date material. Some students proposed reducing subject-matter difficulty; some indicated that other forms of evaluation, consistent with what is taught, should be used.

The responses that emphasized the importance of Equipment and Other Conditions ($f= 90$; 12.7%) included (a) more and better didactical material, namely computer and lab material; (b) better installations (classrooms to be used as tutoring rooms, labs, quiet spaces for studying).

DISCUSSION

Suggestions from students emphasize the importance of both teacher actions and school policies on reducing levels of academic failure in 10^{th} grade secondary schools in Portugal. Without attempting to suggest any hierarchy, we can summarize some of the unprompted, student-generated recommendations. First, with regard to teachers and teaching, three areas emerge: (a) strategies, (b) affect and (c) curriculum.

Teaching strategies recommended by students focused on how teachers can motivate students through the use of diverse methods, varying the routine of classroom activities. They also recommended that teachers permit students a greater input in defining and implementing practical, experimental, real-life activities, and that there be more application exercises including homework and in-class exercises. They further urged teachers to provide remedial assistance to those students who require it.

In the affective domain, students indicated that greater achievement could be attained by teachers who enjoy teaching, who are patient and fair, and concerned with student understanding of subject matter. In short, they recommend that teachers zealously create a positive classroom environment. The students indicate their belief that this will help develop self-esteem and self-confidence as well as assist the construction of long-term life goals. In this, our results are most in accord with those of Easton (2002). Unlike Easton's results, the unprompted student responses in the current study did not mention a need for high teacher expectations. While this factor may not receive emphasis on the part of the students, previous evidence from Portuguese high school students suggests a positive correlation between perceived expectations and achievement (Fonseca & Conboy, 2006).

Students may not comprehend the policies and politics surrounding curriculum issues, but some do recognize the difficulty of covering all the material in the official program in the time allotted. Though they may appreciate that the teacher's prerogative is limited in this area, they nonetheless recommend that the program should be shorter and allow more time for the learning of complex concepts.

The general pattern of responses was similar whether the students were referring to Physics/Chemistry or to Mathematics. This could be a function of the question format, an artifact of the qualitative coding process or it could reflect that student concerns are indeed generally similar across disciplines. In some cases, predictable differences were observed between areas. When students recommend greater emphasis on experiments in Physics/Chemistry compared to Mathematics (where instead they refer to practical activities), the responses lend some credence to the validity of area-specific concerns within general categories. However we cannot rule out the possibility that response categories may be an artifact of question formats or encoding procedures.

With regard to student-generated recommendations aimed at schools, five general areas emerged: (a) school organization and management; (b) teachers in school; (c) interactions in the classroom; (d) curriculum; and (e) equipment and other conditions. (It is interesting to note that the middle three--teachers, interactions and curriculum-- recapitulate the recommendations aimed at teachers. Students appear to know what they want done, but do not necessarily appreciate administrative mechanisms and hierarchies). Within these categories, different patterns of response surfaced when the students referred to academic success in general and when they referred to success in science and mathematics. School organization and management received the highest proportion (nearly half) of suggestions from students regarding how to improve academic success in general, followed by the importance of teachers. In science and mathematics these two categories of recommendations each comprise about the 30% of the coded responses. The relative equality of these two constructs (based on proportion of responses) may be explained by student perceptions of the school's role in hiring and supervising teachers, a perception that, in the Portuguese system, is mistaken. At present, these processes are largely centralized and a school's power to reward good teaching practice, and remedy or remove teachers for poor practice is strictly limited.

Of the six student-identified characteristics of good teaching/factors of success identified by Corbett and Wilson (2002), four were also reported in our study. Students suggested that teachers should vary the classroom routine, be willing to provide remedial assistance, explain assignments and content clearly, and take the time to get to know students and their circumstances. Controlling the classroom was mentioned by a very small number of students (five with respect to math teachers and three with respect to physics/chemistry teachers).

The results are also generally consistent with those of Angell et al. (2004), though the terms used may vary. When Angell et al. refer to a student preference for more "pupil-centered" and "qualitative" teaching methods, perhaps their meaning is similar to what we have called "varying the classroom routine" and using real-life content (as opposed to mathematical presentation of concepts). This expanded repertoire of teaching strategies is also supported by Seidel and Prenzel (2002). Our data also agree with regards to greater use of experimentation, practical exercises, project work and more student participation. Students in our study did not, however, make reference to the use of additional literature besides the textbook as in Angell et al. (2004), nor did the Norwegian students voice affective concerns that emerged in our data about teachers being "engaged", "concerned with student learning", and "creating a good classroom environment". Norwegian students also seem less preoccupied with remediation and extra tutoring classes.

The student-generated suggestions and recommendations we observed are, moreover, in general agreement with those of educational leaders who advise systemic reform (AAAS, 1990; Anderson, et al., 2003; Fonseca, 2003; NRC, 1996; Supovitz & Taylor, 2005). Students did not, however, report any recommendations regarding school-community relations or school-parent relations; nor did they relate suggestions pertaining to science enterprise and research, generally emphasized as important factors by experts. This is not surprising for two reasons: first because questions of enterprise are beyond most students' experience and secondly, since these factors are often disregarded even by many responsible educators when re-conceptualizing, and restructuring science and mathematics practice.

In the current study, using a method of unprompted, open-response questions, the students' prior academic preparation was not mentioned among recommendations for reducing failure. This factor was, however, salient among "failure factors" reported by Portuguese secondary-school students to Fonseca and Conboy (2006). That research, however, used a literature-based, predefined list of factors for the students to rate. Perhaps students interpreted the questions in the current study as having a personal, future orientation ("What can be done in the *future* to improve *your own* success…?") as opposed to a general reform orientation ("What can be done *now* to avoid a continuation of past problems experienced by *many* students?"). Both the differences in response owing to item presentation (open- or closed-format) as well as the possible interpretations (including scope of response and temporal interpretations) should be addressed in future research in order to clarify possible ambiguities.

The sample in this study, though non-probabalistic, was a fairly representative group of grade 10, science-tracked students in southern Portugal. As such the data are a useful contribution to the international literature on student perceptions; we feel they describe the Portuguese reality. They should not, however, be generalized beyond this population owing to specific cultural and organizational contexts.

One area of methodological concern may be the question of the consequences of using the *response* as the unit of analysis as opposed to the *student*. The choice of this method means that the number of units analyzed (codable responses) is greater than the number of units actually included in the study (students). It creates a response bias in which students who provide more responses have greater impact on the results than those who provide fewer responses. These questions are primarily of concern in statistical and inferential studies where an inflated value of N could increase the probability of encountering statistical significance. However, their importance in a descriptive study such as this is quite limited. Since no response was coded twice in the same category (i.e. repetitions of the same idea by a given student were tallied only once), we are confident that the student responses are fairly representative of unprompted student concerns.

The suggestion of Angell et al. (2004) that it can be difficult for students to imagine alternatives to the teaching they receive garners little support from our data. This may involve cultural differences between the Norwegian and Portuguese populations studied, or it may reflect organizational differences between the two systems. In our sample, very few students responded saying that schools, or teachers, "do their best"; most students had no difficulty in voicing critiques and recommendations. The number of students providing at least one codable response to each question was always superior to 85%. The proportion of responding students was lowest when these were asked to make recommendations to teachers regarding how to improve success in mathematics. This lower proportion of suggestions may indeed reflect a perception of instruction methods in mathematics as more determined by the nature of the subject matter. Since there is little basis for comparison of methods in mathematics with other areas, students may have greater difficulty in imagining alternative methods.

The literature suggests a cultural mechanism by which these two student populations differentially perceive causes of academic success and failure. The Norwegian students acknowledged their responsibility in learning, asserting that success depended largely on their own enthusiasm and engagement (Angell et al., 2004). But Fonseca and Conboy (2006) found that Portuguese students attributed failure to factors that were essentially external to them and uncontrollable, such as teaching quality. The present study did not shed light on this important question. It is a question of some significance: if cultural differences emerge in patterns of how students attribute causes for failure, this could suggest specific avenues of intervention for different societies. In Portugal, it might inform teacher education in encouraging failure attributions to internal and controllable factors (e.g. the student should increase personal effort, and improve efficiency of study habits). Future studies of this type should therefore consider including questions of the nature, "What can the students themselves do to improve success in mathematics and physics/chemistry?" Unprompted, student-generated responses to this kind of question could help us understand if students consider their own actions as important, or if they consider themselves as pawns in an education game.

While the students did appeal for stronger connections between class content and "everyday, real-life events", the results fail to shed light on the question of just what it means to incorporate "everyday, real-life events" in the teaching of science and mathematics. Future studies should attempt to better operationalize this colloquial term, determine its social representations (from both teacher and student perspectives) and verify consequences of implementing competing definitions for teaching practice. As a first attempt at operationalizing the dichotomy suggested by the work of Carlone (2003) and by Schwartz-Bloom (2003), we suggest that there is pedagogical value in incorporating *learning-relevant* real-life events in teaching practice while there is motivational value in incorporating *goal-relevant* real-life information in teaching practice. In the first case, students can be encouraged to make connections between the new content being learned and prior knowledge from personal experience. In the second case, teachers can motivate learners by linking new content to real-world problems that may be beyond personal experience, but are within the realm of interests, aspirations and future professions.

We hesitate to adopt the students' recommendation of making science and mathematics courses easier, with simplistic evaluation. Many theories and empirical results point to the importance of challenging, but attainable, goals in maximizing student motivation. On the other hand, the not infrequent student recommendation to shorten the program and allow more time to consolidate knowledge and understanding should not be dismissed as merely a self-serving, hedonic appeal by students. Casual observation demonstrates that many science and mathematics teachers in Portugal would agree with the students' assessment of the excessive nature of the programs. Such concerns can only be addressed at the national, ministerial, level, but the data to evaluate the appropriateness, or excessive nature of the programs, must originate at the grass-roots school level (including input from students, teachers and parents).

While the implementation of student suggestions may not be appropriate in all cases, their study can be useful in identifying problem areas, and in some instances may offer sound advice to teachers and educational leaders.

Acknowledgements

This research was supported by the Gulbenkian Foundation, Lisbon, Portugal; the Center for Educational Research of the Faculty of Sciences of the University of Lisbon and the Center for Educational Sciences and Training, Loulé, Portugal. We are grateful for the comments of an anonymous reviewer.

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Eurasia Journal of Mathematics, Science & Technology Education, 2009, **5**(1), 15-26

Components of Environmental Literacy in Elementary Science Education Curriculum in Bulgaria and Turkey

Mehmet Erdoğan
University of Akdeniz, Antalya, TURKIYE

Zdravka Kostova
Kliment Ohridski University, Sofia, BULGARIA

Thomas Marcinkowski
Florida Institute of Technology, Melbourne, FL, USA

Received 05 December 2007; accepted 17August 2008

The purpose of this study was to analyze the extent to which science education objectives in elementary schools addressed to the six basic components of environmental literacy (EL), and how this attention differed from Bulgaria to Turkey. The main method in the study involved comparative content analysis of these objectives. The courses sampled for Bulgaria include "The Human Being and Nature", "Biology and Health Education", "Chemistry and Environmental Protection" and "Physics and Astronomy". The course sampled for Turkey is "Science and Technology Education". Content analysis of these objectives reveals that all components of environmental literacy did not receive the same attention. For example in both countries most attention was given to knowledge, less to skills and attitudes, and little to environmentally responsible behavior (ERB).

Keywords: Bulgaria, Turkey, Environmental Literacy, Environmental Education, Science Education Objectives

INTRODUCTIION

One of the priorities of the European Union is to ensure the sustainability of the environment by taking the necessary precautions and raising public awareness (UNECE Strategy, 2005). Efforts to overcome continuous environmental degradation and establish sustainable development around Europe and other continents can be advanced by providing citizens of all ages with opportunities to become more environmentally informed, committed and active, and thus more environmentally literate. Implementation of environmental education in elementary school depends on both school curricula and teachers` environmental competencies. It can be argued that the foundations of consistent environmental literacy are emphasized in elementary schools mainly through science education.

Correspondence to: Mehmet Erdoğan,
PhD in Curriculum & Instruction,
Akdeniz Üniversitesi, Eğitim Fakültesi, 07058
Antalya, TURKEY
E-mail: mehmederdogan@yahoo.com

E-ISSN: 1305-8223

Components of Environmental Literacy (EL)

Environmental literacy (EL) is an evolving concept in the developing world literature. Even though this concept was dealt with by many scholars (e.g. Hungerford, Volk, Tomera, Marcinkowski, McBeth, and Simmons) in the area of environmental education (EE), this concept still has been conceived as wrong by some others and needs to be conceptualized and even contextualized. This concept and its components are apparent in definitions and frameworks (Stapp et al., 1969; Harvey, 1977; Schmeider, 1977; Disinger, 1983; Hungerford & Volk, 1990; Simmons, 1995), sets of goals and objectives (Unesco, 1977, 1978; Hungerford, Peyton, & Wilke, 1980; United Nations, 1992), other reviews of the professional literature (Hart, 1981), and collections and reviews of research (Iozzi, 1981, 1984; Hines, Hungerford, & Tomera, 1986/87; Marcinkowski & Mrazek, 1996; Volk & McBeth, 1997; Hart & Nolan, 1999; Erdogan & Marcinkowski, 2007a, 2007b). Some authors think EL marginal in EE (Staples & Bishop, 2001) and discuss it as functional, cultural and critical (Stables, 1998), others regard it as a predictor to environmentally responsible behavior (ERB) (Hsu & Roth, 1998). Still others think its implementation in primary school problematic because of inadequate EL of teachers (Makenzie & Smith, 2003). Recent publications show a great interest in EL and EE. Some authors point out their inseparable relations with environmental ethics (Lundmark, 2007) and stress the importance of action competence (Lundegard & Wickman, 2007), or a personal sense of competence and a sense of collective competence (Chawla & Cushing, 2007). Others notice the growing interest of children in exploring alternative futures and see the need for a future perspective in education (Hicks & Holden, 2007) or engaging students emotionally in non-captive wildlife tourism and suggestions for future research (Ballontyne et al., 2007). The brief analysis shows that EL is at the center of environmental education research and that it can be used in assessing school curricula.

Some of the difficulties in the analysis are due to the different terms and understandings about one and the same thing in EE. The term EL is seldom used in Bulgaria and other East European countries where scientists prefer to use the concepts of environmental education and environmental culture, consciousness and behavior as its outcomes (Kostova, 1978, 2003; Kutov & Kostova, 1984). Likewise, this term was not used in Turkish professional literature until recent days. Instead, EE, environmental consciousness, behavior, knowledge and attitudes were preferred. Parallel to growing EE and EL literature in USA and also in Europe, the concept of EL has appeared recently in some research studies (e.g. Erdogan & Erentay, 2007; Erdogan & Marcinkowski, 2007a, 2007b) done in the context of Turkey.

Literacy means basic knowledge in a given area (Andreichin, 1976), ability to read and write (The Concise Oxford Dictionary, 1964, p. 709), having the necessary knowledge and information in a certain field or any deeds, fulfilled without mistakes (Ojegov, 1981, p.128). Consequently, EL is defined as "basic functional education for all people, which provides them with the elementary knowledge, skills and motives to cope with environmental needs and contribute to sustainable development. Environmental literacy is conceived as "functional literacy" (UNESCO, 1989). Roth (1992) believed that EL is beyond the certain cognitive skills and the basic definition of literacy – ability to read and write. He claimed that "*Environmental literacy builds on an ecological paradigm. Environmental literacy is the capacity to perceive and interpret the relative health of environmental systems and to take appropriate action to maintain, restore, or improve the health of those systems* (p. 17)". EL in its totality seems to comprise the same elements as environmental culture, consciousness and behavior taken together.

Based upon an evolving understanding of EL, we assume that EL includes six main components; *namely*, Ecological knowledge, Socio-Political knowledge, Knowledge of environmental issues, Affect, Cognitive skills and Environmentally responsible behaviors (Simmons, 1995; Volk & McBeth, 1997). On the bases of these authors` contributions the components of EL can be described as following:

Ecological knowledge refers to the knowledge and understanding of major ecological concepts, principles and theories as well as knowledge and understanding of how natural systems work and how they interact with social systems.

Socio-Political knowledge includes an understanding of the relationship between beliefs, political systems, and environmental values of various cultures. Socio-political knowledge also includes an understanding of how human cultural activities (e.g. religious, economic, political, social and other) influence the environment from an ecological perspective. Also included within this category is knowledge related to citizen participation in issue resolution. It is often referred to as cultural literacy comprising knowledge of environmental action strategies.

Knowledge of environmental issues includes an understanding of environmental problems/issues caused as a result of human interaction with the environment. Also included within this category is knowledge and understanding, related to alternative solutions to issues and to major sources of environmental information.

Affect refers to factors within individuals which allow them to reflect on the environmental problems/issues at the interpersonal level and to act on them if they judge the issue/problem warrants action. It is expressed in the intention to act.

Additional determinants of environmentally responsible behavior include locus of control and the assumption of personal responsibility.

Cognitive skills are those abilities required to analyze, synthesize and evaluate information about environmental problems/issues and to evaluate a selected problem/issue on the basis of evidence and personal values. This category also includes those abilities necessary for selecting appropriate environmental action strategies, and for creating, evaluating and implementing an action plan. It is the action competence as a major constituent of functional EL.

Environmentally responsible behaviors include active and considered participation aimed at solving problems and resolving issues. Categories of environmentally responsible actions are persuasion, economic and consumer action, eco-management, political and legal action (Volk & McBeth, 1997, pp. 8-9) accompanied by strong conviction of personal commitment and responsibility.

For the purpose of this analysis, we broke these six components into forty sub-components (Babulski, Gannett, Myers, Peppel, & Williams, 1999; Erdogan & Marcinkowski, 2007a, 2007b) which were used as criteria in the analysis of the status of EL in the elementary schools of Bulgaria and Turkey.

Bulgarian Context / Case

Environmental Literacy (as an outcome of EE) was introduced into the science education curriculum and textbooks for the 9th grade of the Secondary school in Bulgaria in 1967 through a new topic "The organism and its environment," and since then it has always been a part of the compulsory education (Kostova, 1995). Ecological and nature conservation concepts were introduced in the school subjects "Knowledge of the Fatherland" (1st to 3rd grade) and "Nature study" (4th grade) in 1972. EE topics are present in the programs and science textbooks from 1st to 12th grades nowadays. One key goal in the grades from 5th to 8th is "to develop attitudes towards the living place, the role and the responsibility of everyone towards society, nature and its protection" (Revised school programs, 2003). From 1972 to 1992 the development of theory and practice of EE, including curricula, textbooks and teachers' guides, was under the guidance of a specialized research team. At present with the development of State Educational Standards and the implementation of new curricula, the EL is receiving a greater attention in the so called Cultural educational area (KOO in Bulgarian) "Natural sciences and ecology" from 3rd to 12th grades of the Secondary education.

Turkish Context / Case

Environmental Literacy, which is assumed to be the major outcome of environmental education (Stapp et al., 1969; Harvey, 1977), seems to have been somehow neglected in Turkey for several years. Environmental and nature-related concepts were not sufficiently incorporated in the natural studies, agriculture, and life sciences until 1960s. In line with the trends and developments in the USA and Europe, topics pertaining to environmental education were more introduced into school curricula. For example, elementary school science curricula that paid much greater emphases on environmental related concepts/topics were developed in 1992 and 2000 respectively. It merits due recognition and appreciation that this has been receiving greater attention with the initiation of a new Science and Technology Curriculum for elementary schools in 2004-2005 academic year. This curriculum is different from the previous ones in that the dimensions of technology and environment have been added to and integrated with the science dimension. One of the key goals of this curriculum is to develop environmental awareness and consciousness (Erdogan, 2007), and increase scientific process skills of students (Ozgelen & Yilmaz-Tuzun, 2007).

Rationale and Purpose of the Study

Bulgaria has just become a member of the European Union (EU). One of the hot topic and requirements of EU is to develop understanding for sustainable development as well as to develop responsible citizens for the quality of the environment. The main topic of environment is like an umbrella covering other related topics such as sustainable development, environmental education, environmental literacy and … so on. On the other hand, Turkey is a candidate country for EU and still in the adaptation process to EU. Considering this priority of EU, both countries have been undertaking protection measures and steps to take care of this broad concept. This can be observed in national policy, school curricula, and vision of NGOs in both countries. This study only focuses on one part of this umbrella; *environmental literacy and its components and how they are represented in the implemented school curricula from 4th to 8th grades.* In this study, only science education curriculum was considered, because it was believed that the subjects of the science curriculum give much more scientific bases of EL than the other curriculum (e.g. social sciences, math…etc).

The purpose of this study was to analyze the extent to which science education objectives in elementary schools include attention to the six basic components of environmental literacy (EL) in both Bulgaria and Turkey, to compare how this level of attention may differ from Bulgaria to Turkey and how the results can be used in improving the contemporary situation.

METHOD

The design of study was content analysis, one of the common methods of qualitative research. This study covers the comparative analysis of four curriculum

Table 1. Text books selected from both countries for the study and their characteristics

Country	Name of the courses selected	Characteristics of the selected curriculum / textbooks
Bulgaria	The Human Being and Nature 3^{rd} to 6^{th} grade.	Up to now the course is developed and introduced in 3^{rd} to 6^{th} grades. Three different versions of textbooks for each grade were approved and implemented in schools by the Ministry of Education and science. 6^{th} grade textbooks are under first year trial.
	Biology and Health Education 7^{th} to 8^{th} grade	The program is ready, but the textbooks (three versions) are under preparation and will be introduced successively in the next two school years. The current textbooks are named biology.
	Chemistry and Environmental Protection 7^{th} to 8^{th} grade	The program is ready, but the textbooks (also three versions) are under preparation and will be introduced the next two school years. The current textbooks use the name chemistry.
	Physics and Astronomy 7^{th} to 8^{th} grade	The program is ready, but the textbooks (three versions) are under preparation and will be introduced the next two school years. The current textbooks are physics.
Turkey	Science and Technology Education 4^{th} to 8^{th}	The program was developed and piloted with elementary schools in 2004, disseminated in following years gradually. It is for the students who are in 4^{th} to 8^{th} grade. The name of this course was science education before 2004. Three different versions of textbooks for each grade were approved and implemented in schools by the Ministry of Education. The name of the text books are Science and Technology – 4, - 5, - 6, - 7 and - 8.

guide books for 3^{rd} to 8^{th} grade in Bulgaria and one curriculum guide book for 4^{th} to 8^{th} grade in Turkey.

Selected Textbooks

Five curriculum guide-books used in obligatory science courses in elementary schools in both countries were selected for this analysis. Of these, four were from Bulgarian elementary schools, integrated in the Cultural Education Area (CEA) "Natural Sciences and Ecology" and the other one was from Turkish elementary schools. In Turkey, there are some others course in which EL components are implicitly stated, such as life science course for 1^{st} to 3^{rd} grade, social science course for 4^{th} to 8^{th} grades, and agriculture course (elective course), although only a science education course was selected because of its meeting the purpose of the study. The name and characteristics of the selected books are illustrated in table 1.

Whereas the courses selected from Bulgaria cover 3^{rd} to 8^{th} grades, the course from Turkey covers 4^{th} to 8^{th} grades. Lower level courses were not considered because of their irrelevance to the study.

In Bulgaria, the course "*The Human Being and Nature*" is only introduced to 3^{rd} and 6^{th} grade students and comprises three parts: 1^{st} part Physical phenomena, 2^{nd} part Substances and their properties and 3^{rd} part Structure and life processes of organisms. The other three science-related courses (biology, chemistry and physics) are introduced from 7^{th} to 8^{th} grades. The new curriculum guide books and the corresponding textbooks from 3^{rd} to 6^{th} grades are already prepared and introduced, but from 7^{th} to 8^{th} grades students use old textbooks and guides introduced in 1998-2000 school years. On the other hand, there is only one obligatory course related to science education in elementary level in Turkey. The course titled "*Science and Technology Education*" was designed in 2004, piloted in 120 elementary schools in 2004-2005 academic year and then disseminated to all Turkish schools in following years (Erdogan, 2007). The course for 4^{th} to 8^{th} grades includes several topics pertaining to chemistry, biology, physics and the natural environment. The units in this course are categorized under four learning domains; (1) Living Organism and Life, (2) Matter and Change, (3) Physical Events and (4) Earth and Universe.

Content Analysis of the Textbooks

The selected curriculum guide books were subjected to content analysis. First, the objectives, which are called attainments in 2004 Turkish elementary school curriculum, and standards and expected results in the Bulgarian curriculum, were retrieved from the selected guides. A table including six components of EL (affect and additional determinants of ERB were combined for this analysis since their nature seems to be similar) and forty sub-components of EL was constructed for comparative analysis.

Table 2. Environmental Related Concepts – Topics in Selected Courses in *Bulgaria*

Grade	Name of the Course	Grade	Name of the Courses		
	The Human being and Nature		**Biology and Health Education**	**Chemistry and Environmental Protection**	**Physics and Astronomy**
4th grade	Substances (properties), bodies and organisms, movement and energy, earth (natural resources, soil, ores, minerals, fuels) , moon, sun, solar energy, natural phenomena and processes, life processes of plants and animals, adaptation, biodiversity, health, hygiene, contagious diseases, harmful substances, environmental damage and protection (air, water and soil protection from pollution)	**7th grade**	Biodiversity, classification and protection of organisms (e.g. prokaryota, protoktista, plants, fungi and invertebrate animals), extinct and threatened species from each taxa, the relationship among organisms, environment and human beings and their activity.	Classification, structure, properties and application of substances, chemical processes in nature, everyday life and in production (technology), useful and harmful chemical processes for man and nature, solving pollution problems, security in the chemical laboratory, harmful effects of chlorus, acids, freons, thermal effect, corrosion.	Electrical energy, light, sound, noise pollution and its negative effects, movement and forces, from the atom to the Cosmos, biological effects of ionizing radiation, cognitive interest, environmental consciousness.
5th grade	Energy, classification of substances, purification of water, purifying stations, clean and polluted air, chemical processes, structure, living processes and classification of organisms, cellular structure, biodiversity, nutrition, respiration and excretion in plants and animals comparatively and in the human being, interdependence and hygiene of those three processes.	**8th grade**	Classification of organisms continues with vertebrate animals, extinct and threatened species from the different taxa, structure and functions of the human body, health and hygiene, interaction of organism and environment, unity of organisms and environment, the human being in nature	Structure, properties and application of substances, organic and inorganic substances, chemical elements, water purification, first aid, sources of acid rains and its effects, environmental problems, pollution with gaseous emissions, heavy metals, fuels, acid rains, fertilizers etc.; recycling, decomposition, environmentally friendly technology	Movement and forces, mechanical movement, work and energy, equilibrium, energy, heat energy and movement, heat equilibrium, heat pollution of the environment. Safety rules in the laboratory and in working with electrical appliances, apparatus and different substances.
6th grade	Movement of solar bodies, research in Cosmos, temperature and heat, heat pollution, chemical and physical properties of substances, chemical reactions and substances in nature, and in practice, conservation of environment, reproduction, growth and development, movement and irritability of plants and animals, same processes in human beings, health and hygiene, human and environment relationships	Notes: Topics, connected with Earth and Universe (Earth, evolution of the Earth and life on it, natural resources, continents and oceans, ocean, land and soil pollution, technologies, population, depletion of resources, anthropogenic influence on Earth, environmental problems of Europe, Balkan peninsula and Bulgaria) are dealt with in geography and economics from 5th to 8th grades.			

Table 3. Environmental related concepts – topics in Science and Technology Course in *Turkey*

Grade	Name of the Learning Domains in Science and Technology Curriculum			
	Living Organism and Life	**Matter and Change**	**Physical Events**	**Earth and Universe**
4th grade	Human health, Ecosystems, environmental pollutions, and environmental protection, environmental responsibility,	Matter, status of matter (liquid, solid and gas), types of matter (natural, artificial and processed), natural events (snow, wind, rain…etc)	Noise pollution, hearing and eyes health, energy Disposal of the battery	Layers of the earth, a-biotic factors (stone, soil, water, air…etc), universe, underground recourses (minerals), pollution
5th grade	Human health, balanced diet, ecosystems, food chain, environmental problems, prey-predator relationship, biodiversity [plants, animals, fungus]	Energy [sun], Matter, Water cycle	Noise pollution, lunar eclipse, solar eclipse	Universe, earth, moon, sun
6th grade	Organic agriculture, pesticide usage	Matter, status of matter (liquid, solid and gas),	__	Natural monuments, soil, erosion, fossils, water, underground and surface-water, mine, types of rock
7th grade	Ecosystem, environmental protection, a-biotic factors (humidity, light, and temperature), biodiversity, environmental problems in local and global area (forest fire, avalanche, landslide, flooding,)	__	__	Universe, earth, sun and moon, natural satellite, sun system, universe pollution
8th grade	Adaptation, evolution, biodiversity, energy flow, food chain, matter cycle, recycling, energy sources (renewable and un-renewable), photosynthesis, respiration	Matter, types of matter, Water purification, acid rains, water, air and soil pollution	Noise pollution	Earthquake, air humidity, air temperature, climate, air pressure, meteorology, mountain, continent, volcanoes, ocean, seasons

This table included one column for Turkey and one column for Bulgaria across to grade level (4th grade to 8th grade). The objectives in the selected guides were analyzed against the forty sub-components of EL selected for use in this study.

Charting of the Results

For the comparative analysis, three different, but related tables were developed. These visualize the results emerged from the content analysis of the guide-books and make the results more comparable. The concepts associated with EE from analyzed books were included in the first two tables (table 2 for Bulgaria and table 3 for Turkey). The concepts in Bulgarian guide-books were categorized under selected courses and grade levels. On the other hand, the concepts in Turkish guide-books were grouped under four main learning domains. The last table (Table 4) was designed for comparative analysis of the objectives according to country and forty sub-components of EL.

RESULTS AND DISCUSSIONS

The comparative analysis of the objectives and content of the selected science education guide books indicated that environmental education in both countries is not considered as a separate subject, but is

Table 4.Comparative Analysis of Environmental Literacy in Selected Science Education Curricula in *Bulgaria* and *Turkey*

	Components and Sub-Components of EL	Country: Bulgaria	Country: Turkey
KNOWLEDGE	1. *Knowledge of Natural History and Ecology* 1.1. Species & Population 1.2. Environments & Habitats 1.3. Communities & Interactions 1.4. Abiotics & Material Cycles 1.5. Ecosystem & Biomes 1.6. Natural & Social System 1.7. Physical & Biological History	(1) The sub-components of 1.2 and 1.4 are relatively more emphasized in all grades. (2) The sub-components of 1.1, 1.3, 1.5, 1.6 receive less attention (3) The sub-component of 1.7. is not adequately considered	(1) All sub-components are emphasized in the curriculum. (2) The sub-component of 1.3 in 4th to 6th grades is ignored. (3) The sub-component of 1.7 is not very much emphasized.
	2. *Knowledge of environmental issues and problems* 2.1. Risk, Toxicology and Human health 2.2. Bio-Physical Problems 2.3. Causes of Problems 2.4. Socio-Political Issues 2.5. Causes of Issues 2.6. Effects of Problems and Issues 2.7. Natural Disasters 2.8. Alternative Solutions and Actions	(1) Almost all the sub-components in all grades are emphasized. (2) Not enough attention is paid to 2.4, 2.7 and 2.8	(1) Almost all the sub-components in all grades are emphasized. (2) The sub-components pertaining to the socio-political issues, cause and effects of the issues in all grades except 7th grade, and the sub-component of natural disaster in all grades except 8th grade are somewhat ignored
	3. *Socio-Political-Economic knowledge* 3.1.Caltural Values & Activities 3.2. Economic Values & Activities 3.3. Societies & Social Systems 3.4. Government & Political System 3.5. Geographic Patterns 3.6. Citizenship Participation	(1) All the sub-components are emphasized in all grades to certain extend. (2) Exceptionally, the sub-components of 3.2, 3.3, 3.4, and 3.5 are dealt with in social subjects not in science courses (3) Component 3.6 is not apparent.	(1) This component is not dominantly stated (note: this is more dominant in social sciences course) (2) Except 3.5 and 3.6, none of the components is very much considered.
SKILL	4. *Cognitive skills* 4.1. Problem and Issue Identification Skills 4.2. Issue Analysis Skills 4.3. Variable and Research Question Skills 4.4. Data Collection Skills 4.5. Data Analysis Skills 4.6. Action Skills	(1) Almost all of the sub-components are well integrated (2) Not enough emphasis is exhibit to 4.3, 4.4 and 4.5. These are recommended for development in project work which is more or less not obligatory yet.	(1) Almost all of the sub-components are relatively well integrated
AFFECTIVE	5. *Affect and Additional determinants of ERB* 5.1.Environmental Appreciation and Sensitivity 5.2. Environmental Attitudes 5.3. Environmental Values 5.4. Ethical & Moral Reasoning 5.5. Efficacy / Locus of Control 5.6. Personal Responsibility 5.7. Willingness/ Motivation / Intention to Act	(1) Almost all the sub-components are integrated. (2) The sub-component of 5.5 is not observed. It is essential in class work and in implementation of action environ-mental strategies. The explanation notes of the curricula stress the point of skills for team work, good communication and tolerance in all grades.	(1) This component is not dominantly observed (2) Only the objectives pertaining to environmental appreciation and sensitivity are more apparent.
ACTION	6. *Environmentally responsible behaviors (ERB)* 6.1. Conservation and Eco-management 6.2. Consumer and Economic Action 6.3. Interpersonal and Public Persuasion 6.4. Governmental and Political Action 6.5. Legal Action and Law Enforcement 6.6. Other Forms of Citizen Participation	(1) The implications of action strategies pertaining to conservation and eco-management behaviors are well observed. (2) Sub-components 6.4 and 6.5 are mentioned, but 6.2, 6.3 and 6.6 are more or less ignored.	(1) The sub-components of 6.1 is observed in 4th, 7th and 8th grades (2) The sub-component of 6.2 is apparent in 5th and 8th grades and of 6.3 and 6.6 are observed in only 5th grade.

mainly infused in the science education curricula. Different numbers of courses for science education are used in both countries. In Bulgaria, environmental education (EE) is realized mainly in science courses, united in the cultural educational area (CEA) "Natural sciences and ecology", but some subjects (e.g. Geography and economics) from the CEA "Social sciences, civics and religion" are also involved. The topics associated with EE are more observable in four courses selected for the study. The concepts and topics emerged from these selected guide books are summarized in table 2. This table was designed according to grade (4^{th} to 8^{th}) in the column and selected courses in the row. It is clear to say that these all courses are complementary to each other and designed by considering the understanding of spiral curriculum. Advanced topics are introduced to the students based on the fundamental topics. There is a vertical connection among the courses as well as a horizontal connection (especially for 7^{th} and 8^{th} grade courses). Secondary school curriculum in Bulgarian is split into many subjects, and many textbooks make the comparison very difficult.

On the other hand, in Turkey, EE is realized under the curriculum of Science and Technology Course. The several concepts related to EE are emerged from this curriculum. These concepts are illustrated in table 3. Same as selected guide books from Bulgaria, vertical and horizontal connection among the learning domains and among the courses (e.g. with social sciences, interdisciplinary topics…etc) are also apparent in Science and Technology curriculum in Turkey.

The fundamental scientific concepts, needed for EL, are dealt with in the science curricula of both countries. Basic ecological and nature conservation concepts are accordingly developed. These all topics are for developing students' understanding of ecological processes in nature, the relationships among living organisms, non-living matter, human and natural environment, physical, biological and chemical aspects of the environment (nature). Furthermore, the topics related to causes and effects of and solutions to environmental problems, hygiene and health are also introduced to the students in both countries in various grades. Knowledge is a fundamental predictor of EL, especially of ERB and is perfectly dealt with in textbooks, though Bulgarian textbooks seem to be overburden with it.

Table 4 presents the results of the comparative analysis. These results indicated that all components of environmental literacy do not receive the same attention. For example, greater attention was paid to the environmental knowledge, relatively little attention to skill, and little attention to affective and behavior sub-components in Turkey. On the other hand, within Bulgaria, much greater attention was given to knowledge sub-components, less attention to skill and affective sub-components, and little attention to behavior.

Components of EL

Knowledge of Natural History and Ecology

This component of EL includes seven sub-components. Compared to the other components, it is apparent that this component is highly emphasized and incorporated in selected courses in both countries. In Bulgaria, the sub-components of Environments & Habitats and Abiotics & Material Cycles are relatively more introduced. However, the sub-components of Physical and Biological History (natural history) are not adequately considered. The reasons for that are several; (1) These subcomponents are mainly dealt with in geography, which is not analyzed. (2) They are thoroughly exhausted in higher grades from 9^{th} to 12^{th}. (3) Children may not possess the necessary background for understanding them. (4) The development of the biological scientific knowledge in 7^{th} and 8^{th} grades obeys the evolutionary process from simple unicellular organism to complex multicellular ones. On the other hand, all sub-components are very much observable in Science and Technology Course in Turkey. However, the sub-components of Communities & Interaction and Physical & Biological History (natural history) are somehow overlooked. The latter sub-component is still the only one which is rather less emphasized in both countries. Same as Bulgarian guide books, this sub-component seems to be more observable in Social Studies curriculum.

Knowledge of Environmental Issues and Problems

This component includes eight sub-components each pertaining to environmental problems and issues, their causes and effects, alternative solutions, natural disasters (earthquake…etc) and risk, toxicology, and human health. In Bulgaria, almost all of these sub-components are well integrated into the selected courses. But, socio-political issues, and causes of issues, natural disasters and alternative solutions and actions are underestimated and in some grades (e.g. 6^{th} grade) merely not apparent. It is not necessary to prove their importance as environmental situation in both countries speaks for itself. Those topics in Bulgaria are included in civics. Knowledge of environmental action strategies is somewhat vague and marginal. Besides behavior of business corporations set a very bad example of environmental treatment. On the other hand, even though this component and its sub-components are well observable in Turkish science curriculum, the concepts associated with socio-political issues and causes of these issues are not integrated in 4th, 5th, 6th and 8th grade. Likewise, the concepts related to natural disaster are not observable in 4th to 7th grades, except 8th grade curriculum.

Socio-Political-Economic Knowledge

This component consists of six sub-components. This component puts more emphasis on socio-political and economic aspects of the environment. Since this dimension is more related to social sciences, it is expected to observe this component more in Social Studies. Surprisingly, in Bulgaria, all the sub-components are well integrated in science curriculum. However, economic values and activities, societies and social systems, government and political system, and geographic pattern are not apparent in 4th grade. Those are more observable in Social Studies Curriculum in Turkey.

Cognitive Skills

This component includes six sub-components, each regarding as problem investigation and problem solving abilities. Considering the theoretical structure of this dimension, it is clear to say that these skills are in line with science process skills. In Bulgaria, almost all components are well integrated into the science curriculum, but not enough attention is given to variables and research question skills, data collection and data analysis skills. They are dealt with merely verbally but not as action skills. One reason for that is that school laboratories in Bulgaria are in a poor state because of the low economic development. No financial resources are allocated to school equipment. The overburden with information textbooks do not allow enough school periods for experiments. Therefore EL in respect to action skills is problematic and doomed to experience limited success. That in its turn narrows the boundaries of functional EL. Action skills are left for development as homework, teamwork in class or individual and group development of projects. Because of their ultimate importance, it is not surprising that authors put strong emphasis on this component (Stables, 1998) and suggest the use of zoos and aquariums in promoting conservation learning, values and skills development (Ballontyne, 2007). In Turkey, one of the most important innovations in new developed curriculum is the integration of science process skills. This is an evidence to say that cognitive skills are integrated into the curriculum in Turkey. Cognitive skills involve interest in environmental knowledge, which is best developed by solving real environmental problems. aspects are priority to geography, technology and civics curricula and text-books. This situation in Bulgarian Science curriculum is not as much observed as in Turkey's. That may be due to the more integrated subject in Turkey. Sub-components are not very much observable in the science curriculum. Only, the topics related to geographic patterns and citizenship participation is relatively well integrated in all grades (4th to 8th) in Turkish science curriculum. These components

Affect

Included seven sub-components, this component is a combination of two other main components of EL – Affect and Additional Determinants of Environmentally Responsible Behavior. In Bulgaria, except the sub-component of efficacy/locus of control, almost all the sub-components are integrated in all grades. Additional determinants (loci of control) are hard to apply to school curricula and that may be the cause for the obtained results. The explanation notes of the curricula stress the necessity of skills for team work, good communication and tolerance in all grades. The discussion of environmental problems and issues is done using reasons from within society and from within nature, i. e. natural and social causes. Externals (extroverts) deal with objective world and are more comfortable by being with others, while internals (introverts) deal with the subjective world and are more comfortable by being alone. Internals attribute their outcomes to ability, but externals to chance. The curricula give priority to social causes of environmental education but put less emphasis on greediness of people for material wealth. The value orientations and environmental ethics, though very insufficient, receive their attention through emphasis on the need of caring about nature. That is why ethical issues and moral reasoning are not observable in 4th and 5th grade science curriculum or sound very artificially. Ethical position on human-nature relationships shows signs of anthropocentrism and misses the crucial elements of the contemporary environmental ethics debate. Affect is simply overlooked. No criteria are developed for measurement of the outcomes. Nevertheless affect can be seen in the intention to act in order to solve environmental problems, in the desire to develop environmental skills and make the school environment cozy and clean. Besides, to overlook knowledge for the sake of affect is equally inadequate (Makenzie, 2003)

Comparing to the other components of EL, affect component is relatively less integrated into science curriculum in Turkey. Only the objectives pertaining to environmental appreciation and sensitivity are apparent in all grades. "Environmental attitudes", "personal responsibility" and "willingness to act" are rather less observable in the curriculum. Other sub-components are somehow ignored and never considered.

Environmentally Responsible Behavior

This component includes six sub-components. Comparing to the other main components, this component and its sub-components receive very little attention in science education curriculum in both countries. Conservation and eco-management behaviors sub-component, so-called physical actions, is relatively more observable in both curricula. Government and political action, Legal action and law enforcement are left for social sciences and mentioned very occasionally in science curriculum. The implications of physical action strategies are more dominant in 4th, 7th and 8th grades in Turkey. In Bulgaria, other types of behavior are extremely rarely apparent in the studied grades. On the other hand, only very few attainments in Turkish science curriculum pertains to "Consumer and Economic Action" in 5th and 8th grades and "Interpersonal and Public Persuasion" in 5th grade.

Little attention is given to action competence, involving the ability to take into consideration human conflicts of interest, which lies behind sustainable development and preserving the quality of the environment. Action is not very much concerned with future perspective and if it does it, the accent is on negative outcomes and dark predictions. Bad future perspective is despairing. The science school curricula raise questions that can be investigated by students in their out of school activities when making projects, using observations and experiments and analyzing the results as well as taking part in environmental organizations. These activities are not compulsory and teachers may decide not to organize them. They are more or less personal choices of teachers. At least that is the case in Bulgaria.

The six components of EL can be used as criteria for critical evaluation of the local, national and global environmental education (Singh, 1998). They help researchers and teachers to obtain more reliable results.

CONCLUSION

The comparative analysis of five science education textbooks taken from Bulgaria (n=4) and Turkey (n=1) with regard to components of environmental literacy revealed that all the components are not considered equally in both countries. While the components pertaining to environmental knowledge are highly emphasized, the other components are paid partially less attention both countries.

For example, even though relatively little attention is given to skills, this component is well integrated. But, the components of affect and behavior (action) receive little attention in new Science and Technology curriculum in Turkey. However, in Bulgaria, it was found that skill and affective sub-components are relatively well integrated, although the component of behavior is somewhat ignored and not well integrated in the obligatory curriculum.

In both countries, participation of students in nature conservation activities is limited in textbooks and, from all appearances, in school practices. Such kinds of activities are mainly voluntary in non-formal education (Revised school programs, 2003). This may be one of the primary reasons for low levels of responsible behavior of students to their surrounding environment (Kostova, 2003, p. 207 – 234). Another reason may be the bad example set by adults, expressed in their consumerism and other forms of irresponsible environmental behavior.

Considering that one of the important aims of environmental education in schools is to help students develop the abilities and capacities needed for civic participation, service, and action (Hungerford & Volk, 1984, 1990), it is clear to say that in both countries, this aim of EE may not be easily realized because the action component of EL is given little attention and some of its sub-components are even ignored in these textbooks. Fortunately, we have still a chance to integrate this component of EL because in Turkey science education curriculum is being under development and in Bulgaria the new textbooks are in the process of being prepared (considered the revisions returned back from the piloted schools and findings of the research studies). For that reason, the findings of this study serve as an in-depth source of information for (these) national curriculum revisions, particularly on the integration of all the components of EL. The value and action components require a new approach to teaching incorporating inquiry methods and field studies, ensuring the integration of knowledge, emotion and action, i.e., "heads, hearts and hands". This means that revision of curricula and text-books is not enough. Teachers` guides and teachers` qualification should also be updated in order to create stimulating learning environments.

Curricula are not the only predictors of environmentally responsible behavior and other factors should also be investigated, such as:

1. The state of environmental literacy as a possession of schoolchildren at the end of each grade.
2. The diversification of learning environments and the efficacy of their use.
3. Teachers` professional competencies to involve students in successful environmental learning.

Acknowledgement

The authors thank to PhD candidate Murat Aydemir at METU for his initial revision of the article.

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Eurasia Journal of Mathematics, Science & Technology Education, 2009, **5**(1), 27-34

Determining the Influence of a Science Exhibition Center Training Program on Elementary Pupils' Interest and Achievement in Science

Aykut Emre Bozdoğan
Giresun Üniversitesi, Giresun, TURKIYE

Necati Yalçın
Gazi Üniversitesi, Ankara, TURKIYE

Received 07 July 2007; accepted 16 September 2008

This research aimed to examine the effects of visiting exhibitions and participating in the activities offered by science centers on raising the interest of second level students of primary education in science and improving their academic achievements. Thirty one 8th grade students chosen randomly from primary schools participated in the research carried out in the Feza Gursey Science Center (FGBM) in Ankara in November 2005. The "Single Group Pre Test-Post Test Model" was used in the research. The data was obtained through an "interest scale" and an "academic achievement test" prepared by the researcher. Descriptive statistics, One-Way ANOVA, and Simple Linear Regression Analysis were utilized in data analysis. Study results showed that the exhibitions and activities carried out in FGBM brought about a permanent increase in the 8th grade students' interest in science and thus improved their academic achievement. In terms of predicting the interest scores of the students in the experimental group, the relationship between the interest scores and academic achievement scores was examined and it was observed that there was not a meaningful relationship between academic achievement and the interest scores of the students. Within this context, it is very important to develop museum training programs associated with the primary education curriculum and taking learning theories and teaching methods into consideration. Furthermore, it is necessary to repeat planned visits at sufficient intervals on a regular basis.

Keywords: Literacy, Religion, Science, Sociocultural, Superstition

SCIENCE AND SCIENTIFIC LITERACY

Science has been spectacularly successful, with things like international air travel, space flight, and curing of medical illness now routine. The impact of enabling technologies like micro-computers which now dominate much of everyday life, have become available to the general population only as recently as the 1980s. High speed computing and huge increases in cheap, small, memory storage devices is likely to further increase scientific and technological advances.

In order to help increasing number of people to easily and enjoyably acquire and understand new information obtained through the rapid developments in science and technology, it is necessary to support

*Correspondence to: Aykut Emre Bozdoğan, Assist. Prof., Giresun Üniversitesi, Egitim Fakultesi, Ilkoğretim Bölümü, Fen Bilgisi Eğitimi AD,
Giresun, TURKIYE
E-mail: aykutemre@gazi.edu.tr*

E-ISSN: 1305-8223

formal education in schools with informal learning environments.

Though formal education and informal education are interlocked and complementary with each other, they have totally different features. While formal education is obligatory, pre-planned, class and institution-based, structured, has specific aims, requires less social interaction and is costly; informal education is voluntary, is not class or institution-based, is unplanned and less structured, involves more social interaction and is less costly (Wellington, 1990).

Informal education is generally considered to be a kind of learning which continues in every part and phase of an individual's life and usually occurs outside a formal educational establishment. Educators in informal education focus on empirical learning which enables people to discover different experiences and learn from experience (Best, 2007). It is also described as the learning process taking place out of classroom environment such learning can occur through an educational television program, during a travel or a visit to a museum, art gallery, historic site or zoo. Informal environments encourage learning in various ways which usually do not exist in traditional classroom environments. Informal environments can meet the needs of students by offering different learning styles and allow each student to learn at their own speed (Melber and Abraham, 1999).

Informal learning environments give students the opportunity to make an individual relationship with real objects and by this way improve the comprehension and retention of the information gained by providing new perspectives, attitudes and values. There are numerous examples of informal learning environments such as television, radio, newspapers, magazines, internet; sport centers, science centers, science and technology museums, natural history museums, zoos, botanic parks, timberlands, libraries, aquariums, outdoor laboratories, natural centers (caves, lakes, rivers, coastal areas etc.), camps and houses (Davies, 1997; Hannu, 1993; Kelly, 2000; Martin, 2004; Pedretti, 2004).

Among the above-listed learning environments, probably the most important one is the science center since it is one of those unique institutions offering a combination of science, technology and training. Today developments in science and technology are increasing rapidly and young people need to gain both understanding and practical skills in order to become the workforce of tomorrow. Science centers contribute to science education and vocational training by building a bridge between science and education and technology and education.

In this context, it is very important to raise awareness of authorized bodies, institutions and science teachers on this issue and to light the way for the efforts to establish new science and technology museums by proving the positive effects of the science centers on students' interest in science and on their academic achievement.

AIM OF THE RESEARCH

This study was carried out in order to answer the question, "Does visiting the exhibitions and participating in the activities carried out in Feza Gürsey Science Center (FGBM) in Ankara affect the interest of the second level students of primary education in science and their academic achievements?" In this context, the sub- problems of the research are as follows;

a) Do the exhibitions and activities carried out in science centers affect the 8th grade students' interest in science?

b) Do the exhibitions and activities carried out in science centers affect the 8th grade students' academic achievement?

c) Is there a significant relation between interest levels for science and academic achievement of the 8th grade students who visit science centers?

METHODOLOGY

Research Model

The "Single Group Preliminary Test- Final Test Model" was used in the research. Both pre-test (preliminary test) and post-test (final test) measurements are made in this model (Karasar, 2000). A control group was not formed because the independent variable is "the visits to the science centers" and that the academic achievement tests and interest scales which were prepared in order to examine the effects of the independent variable on the dependent variables (interest and academic achievement) are limited to the exhibitions and activities in FGBM.

Participants

Thirty one 8th grade students who were chosen randomly from primary schools participated in the research carried out in FGBM in November 2005. 2 guides, 3 teachers and 1 researcher accompanied the participant students.

Learning Environment

After Ankara Major City Municipality signed an agreement with authorities of Ontario Science Centre (OSC) in 1992 construction of the first science center of Turkey begun. A total of 48 experiment packs worth of US$ 2,300,000 were purchased. The selection of experiments and exhibition units was done according to the Turkish curriculum in cooperation with universities and the museum during the process of establishment of the science center. The recommendation of the Ministry of Education about the science center to the primary school and secondary school students on 25th January 1995 shows that how the selection fits.

The name of foremost physicist of Turkey and the world, Feza Gursey, who died in 1992, was given to the science center. Feza Gursey Science Center was put into service on 23rd April 1993 with the assistance of Ankara Major City Municipality.

More than 1.2 million people visited the science center between 1994 and 2005. In this center which has 1000 m^2 experimental area and 2000 m^2 total area, 7 personnel and 10 to 20 (it changes) guide works. The guides working in the science center whether part time or full time are young people graduated from the university or under graduation in the physics, chemistry, biology, science teaching, astronomy, mathematics, computer and geology departments of the universities. The science center working with appointment system gives free service to the students of Ankara city center and districts. Ankara Major City Municipality also provides free transportation to the schools that come to science center.

FGSC serves for the aim of introducing, pleasing and comprehending the basic principles of science by doing experiments and especially in an entertaining environment helping students to understand and apply what they learn theoretically in science lessons. Because of this, each unit designed in an appropriate form to let visitors do the experiment and observe individually.

Data Collection

The "Interest scale" and "Academic achievement test" which were prepared within the framework of the exhibitions and the test mechanisms selected from FGBM were used in order to determine to the extent which "visiting science centers" affect the primary education second- level students' interest in science and their academic achievement.

Interest Scale

The interest scale covering the exhibitions and test mechanisms in FGBM included expressions to determine the students' levels of interest in science, thus, it was considered to be acceptable for this research

Items on the scale consisted of a total of 20 elements, 12 of which are positive and 8 are negative on a 5-point Likert Type scale. In the validity study of the interest scale which was prepared within the framework of the exhibitions and the test mechanisms in FGBM and which was given to 112 students, the scope and structural validity of the interest scale was examined. There were 10 titles under the scale: Static Electricity, Generator and Dynamo, Characteristics and Use of Liquid Nitrogen, Circulatory System and the Effect of Smoking on the Lungs, Pressure, Characteristics of Materials, Characteristics of Sound, Movement, Microscopes, and Other (X rays, reflex etc.). It was observed that for all the items on the scale the item-total correlations ranged between 0.30 and 0.49 and the t values were significant. Regarding the reliability of the scale, Cronbach Alfa reliability coefficient was found to be 0.83 (α = 0.83). The Kaiser-Mayer-Olkin (KMO) value and Barlett value of the interest scale was found to be 0.763 and 604.192, respectively; and the common factor variances of the items of the scale was found to range between 0.370 and 0.694. When the analysis results of the main components of the items on the scale were examined, it was concluded that the factor-load values gathered on the first factor and the factor-load values of 20 scale items was minimum 0.402 (Bozdoğan, 2007). Some of the scale items was;

Attending conference about the importance of electricity in our lives is boring.
I am not interested in documentaries on how the big passenger carrying balloons can fly.
I want to see the plasma state of an object etc.

Academic Success Test

An ample number of questions were determined which covered the same subjects with the exhibitions and test mechanisms offered by FGBM; the appropriateness of these questions for the level of students was decided after taking the opinions of the experts and the museum authorities. The pre-application of those questions was given to 111 primary school students not in the experimental group. As a consequence of the statistical analysis, the average differentiation capacity of the items of the preliminary test and the final test was found to be ($D_{(avr)}$) 0.437 and 0.416, and difficulty levels of these tests were ($P_{(avr)}$) 0.409 and 0.447, respectively. KR- 20 the reliability coefficient was 0.78 and 0.75, respectively. As the preliminary and final academic achievement tests -which were prepared in relation to the materials in FGBM-were different from each other, the Pearson Correlation technique was used to identify the relationship between those tests. A high level positive and significant relationship was found between the preliminary and final tests of academic achievement (r = 740, p< .01) (Bozdoğan, 2007). Some of the questions items was;

1. Why does the metal rod held with bare hands which was rubbed with wool cloth not attract small pieces of paper?
a) The fact that it was not charged with electricity by rubbing
b) The fact that an electric charge was not maintained
c) The fact that it did not interact with the wool cloth

Table 1. Central Tendency and Diffusion Measurements of the 8th Grade Primary Students' Total Scores of Preliminary and Final Interest Test, and Retention Test.

Interest Scale	N	$\overline{X}$	S
Preliminary test	31	69.48	12.23
Final test	31	83.32	10.73
Retentiveness Test	31	75.03	14.92

Table 2. Single-Factor ANNOVA Results for the Reiterative Measurements Related to the Interest preliminary Test, Final Test and Permanence Test Total Scores of the 8th Grade Students of Experimental Group.

Source of the Variance	Total of the Squares (KT)	Sd	Average of the Squares (KO)	F	P	Significant Difference
Between Subjects	10668.731	30	355.624			
Measurement	3007.247	2	1503.624	22.778	.000	2-1, 3-1
Error	3960.753	60	66.013			
Total	17636.731	92				

1. Preliminary Test
2. Final Test
3. Retentiveness test

d) The fact that the paper and metal rod have the same charge (polarity)

2. Which of the following statements accurately describes the association between heating the air in a balloon and the ascent or descent of the balloon?
a) The density of heated air within the balloon is lower than the density of the surrounding air
b) The density of heated air is higher than the density of the surrounding air
c) The density of heated air is equal to the density of the surrounding air
d) Heating leads to a reduction in the volume of the balloon
3. Which of the following are the structures that swallow objects in space in an irreversible manner?
a) Black hole b) Supernova
c) White dwarf d) Black dwarf

One feature of the incredible and seemingly ever increasing advance of science and technology is a sense of unease amongst some of the general population about sciences potential to change our lives, in sometimes unpredictable and alarming ways. Public understanding of science and ability to engage in debates about science is part of what is referred to as 'scientific literacy', which according to much recent literature, is of increasing concern worldwide (Carson, 1998; Laugksch, 2000). The term 'scientific literacy' actually represents a diversity of views, but a common theme in the literature is that of being 'learned' or knowledgeable about some science content, and being able to critique scientific debates. According to Laugksch (2000) a scientifically literate person does not accept opinion about a contentious scientific matter uncritically. Rather, he or she wants to see logic or evidence for any stance taken on the issue (Miller, 2000). Some authors argue that the success or otherwise of a science education system can be evaluated by reference to the literacy of the citizens (Preece & Baxter, 2000; Yates & Chandler, 2000).

Implementation

Following discussions with officers at FGBM, the schools which had booked a museum visit were listed and then, a primary school was selected randomly for the experimental study. After meeting the staff of the selected school, 31 8th grade primary students were chosen for the experimental group of the visit to be arranged. Prior to the visit, the school was re-visited and the interest scale and academic achievement preliminary tests were given to the students of the experimental group on the school premises under the supervision of school staff.

During the visit to FGBM the students, accompanied by guides, were introduced to various exhibitions and carried out the activities individually.

The exhibitions and activities included an electricity show, a plasma ball, a black hole model, a hot-air balloon, singing bowls, Bernoulli blower and dynamo etc.

The final tests were applied in the week following the school visit. During the week of the visit, the 8th grade students were learning at school the subjects under "Genetics" and this topic was not included in the exhibitions and activities at FGBM. Almost 5 weeks later, the retention tests were given the students in the experimental group.

Analysis of the Data

Within the general framework of the study, Descriptive Statistics, One-Way ANNOVA, and Simple Linear Regression Analyses were utilized for the necessary statistical analyze of the collected data of the sub problems. The numerical data was converted into tables and interpreted. Whether there was a significant difference between the independent variables was tested at $\alpha = .05$ level.

FINDINGS

Findings Regarding the Interest Scale Scores of the 8th Grade Experimental Group students

The overall distribution of the science interest of the students, who visited FGBM exhibitions and participated in the activities in the centre, and the variation of this distribution as to classes are as follows;

The arithmetic average and standard deviation values related to the total scores of the preliminary and final interest tests and retention test of the 8th grade experimental group are given in Table 1.

When Table 1 is examined; arithmetic average of the 8th grade students' total scores of interest preliminary test (carried out before the practice study in FGBM) was found to be ($\bar{x}$=69.48), arithmetic average of total scores of final test was calculated as ($\bar{x}$=83.32), arithmetic average of total scores of retention test was found as ($\bar{x}$=75.03). An increase of almost 14 points can be seen between the average preliminary test scores and average final test scores of the students participating in the research.

Table 3. Central Tendency and Diffusion Measurements of the 8th GradeStudents' Total Scores of Academic Success Preliminary test, Final test and Retentiveness Test.

Academic Success Test	N	$\overline{X}$	S
Preliminary test	31	6.25	2.79
Final test	31	9.38	2.88
Retentiveness Test	31	9.77	2.72

Table 4. Single- Factor ANNOVA Results for the Reiterative Measurements related to the Academic Success Preliminary Test, Final Test and Retentiveness Test Total Scores of the 8th Grade Students of Experimental Group.

Source Of The Variance	Total Of The Squares (KT)	Sd	Average Of The Squares (KO)	F	P	Significant Difference
Between subjects	431.183	30	14.373			
Measurement	230.473	2	115.237	25.09	.000	2-1, 3-1
Error	275.527	60	4.592			
Total	937.183	92				

1. Preliminary Test
2. Final Test
3. Retentiveness test

Table 5. Simple Regression Analysis Results Regarding Predicting the Interest Scores of the 8th Grade Students of the Experimental Group.

Variable	B (Regression Coefficient)	Standard Error (B)	β	t	p
Stable	78.913	6.724	-----	11.736	.000
Academic Achievement	0.470	0.686	0.126	0.685	0.499

$R = 0.126$, $R2 = 0.016$
$F(1\text{-}29) = 0.469$, $p > .05$

Single-factor variance analysis (ANOVA) was carried out for the reiterative measurements related to whether the preliminary interest test, final interest test and retentiveness test scores of the students was different and the results are given in Table 2.

When Table 2 is examined, it was observed that there was a significant difference in favor of final test between the preliminary interest test and final test total scores of the experimental group of 8th grade students and also in favor of the retention test between the preliminary interest test and retention test [$F(2\text{-}60)= 22.778$, $p<.05$]. It is seen that the effect size of this difference is ŋ=0.99. These findings demonstrate that the implementation practices carried out in FGBM had a considerable effect on increasing the interest of the students in scientific subjects. The Interest scores of the students decreased slightly in the retention test when compared to the final test. However, the existence of a significant difference between the preliminary test and retention test interest scores shows that the students' interest in science is maintained.

Findings Regarding the Academic Achievement Scores of 8th Grade Students Constituting the Experimental Group

The general distribution of the academic achievement of the students who visited FGBM and participated in the practice studies, the variation in these distributions according to the classes is given below.

The arithmetic average and standard deviation values related to the total scores taken by the 8th grade students in the experimental from preliminary and final academic achievement tests and retention test are given in Table 3.

When Table 3 is examined; arithmetic average of the 8th grade students' total scores of preliminary test for academic achievement applied before the implementation in FGBM was calculated as ($\bar{x}$=6.25), arithmetic average of total scores of final test was calculated as ($\bar{x}$=9.38) and the arithmetic average of total scores of retention test was calculated as ($\bar{x}$=9.77). An increase of almost 3 points was observed between the average preliminary test scores and the average final test scores of the 8th grade students participating in the research.

Single-factor variance analysis (ANOVA) was carried out for the reiterative measurements related to whether the preliminary and final academic achievement tests and retention test scores of the 8th grade students were different; and the results are given in Table 4.

In Table 4, it can be seen that there was a significant difference between the total scores of preliminary academic achievement test and the final test in favor of the final test and between the preliminary academic achievement test and the retention test in favor of the retention test [$F_{(2\text{-}60)}= 25.09$, $p<.05$]. It is seen that the effect size of this difference is ŋ=0.97. These findings show that the implementation practices carried out in FGBM increased the academic achievement of the students. In addition, existence of a significant difference between the preliminary test and retention test academic achievement scores shows that students sustain their academic achievement.

Findings regarding Predicting the Interest Scores of the 8th Grade Students Composing the Experimental Group

Simple regression analysis results supporting the prediction of the interest scores of the 8th grade students composing the experimental group are given in Table 5.

According to the results in Table 3 in which the relationship with the academic success scores were examined in order to predict the 8th grade students' interest scores, it is seen that academic success has not been a significant predictor of the students' interest scores ($R = 0.126$, $R2 = 0.016$, $F(1\text{-}29) = 0.469$, $p >.05$).

As a result of the research, it can be stated that the tools and the activities carried out in FGBM have a considerable effect on the increase of the interest of experimental student group in science and of their academic achievement. Guisasola, Morentin, and Zuza (2005) found that the school visits to museums affect the students' future opinions, understanding of the concepts of science and their attitudes towards science. The authors commented that combining the educational materials in museums with the education in the school during the training and education process in the museums provides a wider and better science education for the students. In the study they carried out, Jarvis and Pell (2005) found that there was progress in the student attitudes towards science and astronomy. Bowker (2004) stated that associating such kinds of education activities providing cognitive, affective and social learning opportunities for the students with the topics to be taught in the school curriculum will serve as a catalyst in helping the children to understand those topics better. Fadigan and Hammrich (2004) suggested that museum visits should be disseminated as they play an important and positive role in students' education and career development. In their research, Tenenbaum et al. (2004) stated that after visiting exhibitions and participating in activities in science museums student attitudes towards science are affected in a positive way. In particular, several authors commented that combining the curricula of the school and the museums educational program is effective in facilitating the students' acquisition of more accurate information and improves their ability to comprehend the concepts related to various topics. Pace and Tesi (2004) proposed that field excursions have long-term effects in terms of students' acquiring educational and social experiences. This is supported by Falk and Adelman (2003), who reported a positive development in knowledge and attitude of individuals after visiting informal science education institutions such as science centers, zoos, aquariums and natural history museums. Gerber et al. (2001) determined in their research that students gained more scientific thinking skills in rich informal learning environments. Henriksen and Jorde (2001) discovered that students not only reinforced prior knowledge after a museum visit but also learned the concepts they have met for the first time in the informal museum environment. According to Paris et al. (1998), out-of-school activities can provide a certain level of increase in students' interest in science and can facilitate development in students' problem solving skills.

CONCLUSION

The conclusions of this current research are parallel with the results found in the literature review, given above. In this research in Turkey that following the visits to FGBM (or a science centre) has resulted in an increase in primary education students' interest in science and an improvement in their academic achievement. It is considered that this increase is due to the following; that the activities in FGBM were appropriate to the level of the students, the guides were experts and able to help the students (or respond to their questions), and finally, that the students were able to individually participate in each activity in the science centre.

In the framework of the experimental study carried out in FGBM, the relationship between the academic achievement scores and interest scores was examined for predicting the interest scores of the experimental group of 8th grade students. It can be seen that academic achievement is not a significant predictor of the students' interest scores. The reasons for this is thought to stem from the facts that the visits were carried out in a single session of 1.5 hours, that the visits were not repeated in the long term and that there are differences in the internal motivations of the students.

The need for visits to informal education centers to be carried out on a regular and long term basis is supported in the literature. Lukas and Ross (2005) commented that random visits to the zoos did not change the knowledge levels and attitudes of the visitors and thus these kinds of visits do not have any educational function. Pace and Tesi (2004) showed in their study that field excursions do have long term effects on students' acquisition of educational and social experiences, thus, at least one annual field excursion associated with the school curriculum will give the students the opportunity to learn through social interaction out of the class. Knapp (2000) pointed out that long term field excursion practices have important effects on students' cognitive and affective domains. Rapp (2005) determined in his study that long term and renewed museum excursions contributed to students' learning and comprehension.

Students' interest in science and the acquisition of a positive attitude towards it is of great importance for career selection in individual terms and for the development of the country in social terms. Science centers have a very important function in increasing the students' interest in science and scientific subjects and, in promoting their academic achievement. In this context, taking the learning theories and teaching methods into consideration, museum training programs associated with primary education curriculum should be developed, their effects on students' cognitive, affective and psychomotor attitudes should be examined and their practicability should be researched. Furthermore, schools should be able to have the opportunity of visiting sciences centre on a regular and repeated basis.

Furthermore, the importance of these regular visits should be understood particularly by the students' families and teachers and the children themselves. In order for the student's to fully benefit from the visit program, trainee teachers and teachers should be involved in the visit preparation, the planning of the visit and the post visit assessment. Trainee teachers should be given lectures at undergraduate level. Trainee teachers should be made aware of the importance of the visits to science centers and it should form part of their training. Professional teachers should be informed via in-service training courses run by education institutions, and the museum staff. Brochures can be created to inform students' families about science centers and to ensure their participation; these centers should be advertised in visual and written media. Finally, various social activities can be arranged in museums for teachers, trainee teachers and the families of primary age children.

Since it is recognized that visits to science centers has an important effect on the development of the students' cognitive, affective and psychomotor characteristics further research is necessary. Existing studies involving connection between science centers and science education should be examined. Also further work is necessary in the preparation and application of effective scales to be used in this field and they should be used in the curricula to be prepared. Level of interest in science, and their increase in academic achievement, of school visits and the relevance of the science centers exhibitions and activities.

End Note

a) This research is a part of unpublished doctoral dissertation. "Bozdoğan, A. E. (2007). *Bilim ve teknoloji* *müzelerinin fen öğretimindeki yeri ve önemi.* Gazi Üniversitesi Eğitim Bilimleri Enstitüsü İlköğretim Bölümü, Ankara. (Yayınlanmamış Doktora Tezi)."

b) This research was supported by Gazi University Scientific Research Projects Unit.

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Eurasia Journal of Mathematics, Science & Technology Education, 2009, **5**(1), 35-45

The Effectiveness of Smart Schooling on Students' Attitudes Towards Science

Eng-Tek Ong
Sultan Idris University of Education, Perak, MALAYSIA

Kenneth Ruthven
University of Cambridge, Cambridge, UK

Received 13 February 2008; accepted 27April 2008

This article reports the relative effect of Smart and Mainstream schooling on students' attitudes towards science which was measured using ATSSA(M) -- the Malay version of the Germann's (1988) Attitudes Towards Science in School Assessment (ATSSA) instrument. The participants comprised 775 Form 3 (15-year-old) students from two Smart Schools and two Mainstream Schools. Using students' Standardised National Examination (SNE) primary-school science achievement results as covariate, the attitudinal data collected were analysed using analysis of covariance (ANCOVA). The results indicated that the level of attitudes towards science of Form 3 students who had participated in the Smart Schools is statistically significantly higher than the level of attitudes towards science of Form 3 students who had participated in the Mainstream Schools. A "statistical triangulation" was provided by performing two further analyses, namely (i) ANCOVA by school and (ii) like-for-like comparison through independent t-tests for each entry grade of students, so as to make a convincing case that the main result from the ANCOVA by group was truly the outcome of differences between Smart and Mainstream schooling. The article discusses the findings in terms of parallel impact comparison within the available literature and recommends that future studies should look into isolating specific elements of the Smart Schools Initiative that have direct impact on students' attitudes towards science.

Keywords: Academic Success, School Organization, Science Education, Student Perceptions, Teacher Behavior.

INTRODUCTIION: THE MALAYSIAN SMART SCHOOLS

The Malaysian Smart School -- conceptualised in 1996, documented in "The Malaysian Smart School: A Conceptual Blueprint" (Smart School Project Team, 1997a), and subsequently began its 3-year pilot phase with 87 schools in 1999 -- is defined as "…a learning institution that has been systematically reinvented in terms of teaching-learning practices and school management in order to prepare children for the Information Age" (p.10). This innovative project aims to transform the Malaysian educational system so that it is parallel with, and in support of, the nation's drive to realise Vision 2020. The Vision calls for sustained, productivity-driven growth that will be achievable only with a scientifically and technologically literate, critical thinking work force prepared to participate fully in the global economy for the 21st Century. Such transformation of educational system is within the aspiration of the Malaysian National Philosophy of Education that aims towards "developing the potential

Correspondence to: Eng-Tek Ong, Faculty of Science and Technology, Sultan Idris University of Education, 35900 Tanjung Malim, Perak, MALAYSIA.
E-mail: ong.engtek@fst.upsi.edu.my

E-ISSN: 1305-8223

of individuals in a holistic and integrated manner, so as to produce individuals who are intellectually, spiritually, emotionally and physically balanced and harmonious" (Ministry of Education, 1997, p.2). This on-going transformation takes account of the ever evolving world of education in that "the Smart School concept itself is still a work in progress and remains open to evolutionary refinement, including advances in pedagogy and improvement in information technology" (Smart School Project Team, 1997a, p.9). Additionally, the term 'Smart' is expected to be redundant by 2010 when all Malaysian primary and secondary schools would have been transformed to Smart Schools (Smart School Project Team, 1997b).

The most distinctive feature of the Smart School is the teaching and learning environment that builds on best practices from around the world. This includes the mutually reinforcing and coherent alignment of four different dimensions, namely the curriculum, pedagogy, assessment and teaching-learning materials. These dimensions are briefly described in the subsequent paragraphs.

The Smart School curriculum encompasses the four levels of knowledge, namely "content knowledge, problem solving knowledge, epistemic knowledge, and inquiry knowledge" (Smart School Project Team, 1997a, p. 31) alongside the integration of Malaysian cherished values such as "compassion, self-reliance, respect, love, freedom, courage, physical and mental cleanliness, co-operation, diligence, moderation, gratitude, rationality, public spiritedness, humility, honesty, and justice" (Smart School Project Team, 1997a, p.32). These values were not idiosyncratic to the Smart Schools. Rather, these values echoed similar ones stipulated in the Mainstream science curriculum, in particular, and across all other subject curricula, in general. At operational levels, a three-step approach was recommended, namely "being aware of the importance and the need for … noble values; giving emphasis to these …values; [and] practising and internalising these … noble values" (Curriculum Development Centre, 1999, p.11; Curriculum Development Centre, 2002, p.11). Nevertheless, in actual classroom implementation, it was left to the discretion of a science teacher in that continuous and effective inculcation of noble values could be done "casually or systematically" (Curriculum Development Centre, 1999, p.11),

Smart School pedagogy is to be 'student-centred' with the following characteristics (Smart School Project Team, 1997a, p.39): "(1) appropriate mix of learning strategies to ensure mastery of basic competencies and promotion of holistic development, (2) allowance for individual differences in learning styles to boost performance, and (3) classroom atmosphere compatible with different teaching-learning strategies". However, the pedagogy advocated does not propose that student-centred teaching should prevail all the time. Instead, it should be "increase[d] in age and maturity" (ibid., p.39), implying the notion of a "centredness" continuum with teacher-centred at one extreme and student-centred at the other and teacher as mentor and model, and teacher as coach or facilitator in between.

The Smart School assessment system (Smart School Project Team, 1997a) shall be "criterion-referenced" (p.51), "learner-centred" (p.52), "on-line" (p.53), and "conducted in various forms: classroom assessment, school-based assessment and centralised assessment … [so as] to allow different demonstrations of strengths, abilities, and knowledge" (p.54) using "multiple approaches and instruments to perform authentic, alternative, and performance assessments" (p.55). Nevertheless, these aspirations are far from reality when students from the Smart Schools are taking similar school-based and centralised assessments as their counterparts in the Mainstream Schools.

Teaching-learning materials are designed to support teaching-learning strategies for Smart Schools, and have these characteristics: "(1) meet curricular and instructional needs, is cost effective, as well as cosmetically and technically adequate; (2) cognitively challenging, attractive, motivates students to learn, and encourages active participation; [and] (3) combine the best of network-based, teacher-based and courseware materials" (ibid., p.58). These resources, acquired within and beyond schools, are purported to have the benefits of "accommodat[ing] students' different needs and abilities resulting in the fuller realisation of students' capabilities and potential, [and] students tak[ing] responsibility for managing and directing their own learning" (ibid., p.58).

In summary, three key differences in the teaching and learning process of Smart Schools as compared to the Mainstream Schools are self-accessed, self-paced, and self-directed learning. Self-accessed learning means the students learn how to access and use relevant learning materials. Self-directed learning means that students learn how to direct, manage and plan their learning. Self-paced learning means that a student learns at his/her own pace, with enough challenging materials to help him/her achieve a certain competency level. Hence, when a student's role is switched from a relatively dependent and passive one towards self-accessed, self-paced, and self-directed learning, the teacher's role undergoes, in tandem, an evolution from 'sage on the stage' to 'guide on the side'.

Purpose of the Study

For decades, science educators have been interested in understanding students' academic achievement. Research in academic achievement reveals that there is a strong association between science achievement and attitudes towards science (e.g., Nuttall, 1971; Oliver & Simpson, 1998). In TIMSS 1999 International Science Report (Martin et al., 2000), students' attitudes towards science was one of the ways to elicit information that could provide an educational context for interpreting the science achievement results. Therefore, the development of positive attitudes towards science is one of the legitimate goals of science education globally. Gray (1996) points out that it is a mistake to omit attitudinal measures in any comparison of schools. Accordingly, it is important to monitor students' attitudes and ascertain whether or not, the Smart Schools Initiative has the effect on students' attitudes towards science.

Research Question

Inasmuch as the purpose of the study is to establish the comparative effect of Smart Schools and Mainstream Schools on students' attitudes towards science, this study addresses the following question:

What is the effect of science teaching in Smart Schools as compared to the Mainstream Schools on students' attitudes towards science?

LITERATURE REVIEW

Attitudes towards Science

Gardner (1975) acknowledges the broad nature of the term attitude that takes on different meanings in discussions about science education. He distinguishes two broad categories of attitude. The first category, "attitudes towards science" (e.g., interest in science, attitudes towards scientist, attitudes towards social responsibility in science) shows some distinct attitude object such as science or scientist, to which the respondent is invited to react favourably or otherwise. The second category, "scientific attitudes" (e.g., open-mindedness, objectivity, honesty, and scepticism), by contrast, are best described as styles of thinking which scientists are presumed to display. Osborne, Simon, and Collins (2003) subscribe to Gardner's distinction between "attitudes towards science" and "scientific attitudes", reckoning such distinction as not only clear, but "fundamental and basic" (p.1053) in an otherwise "nebulous, …poorly articulated and not well understood" (p. 1049) concept of attitudes in science educational research.

The first of Gardner's (1975) two categories concentrates on the emotional reaction of students. It is on these emotional responses rather than the second set of category which are more intellectual aspects developed through the study of science that was investigated in this study. In this respect, Gardner regards attitudes to science as "learned disposition to evaluate in certain ways objects, actions, situations or propositions involved in the learning of science" (ibid., p.2).

Research on Attitudes towards Science

The science literature search conducted failed to identify any previous study that examines the impact of the Smart Schools Initiative on students' attitudes towards science. Accordingly, this section revisits studies on "attitudes towards science", and unless otherwise specified, these attitudes refer to students' attitudes to school science that are a product of students' experience of school science.

A clear feature of the research is the decline in attitudes towards science from age 11 onwards. Yager and Penick (1984, 1986) found that students in elementary schools perceived science to be enjoyable, interesting and useful. However, a decline in attitude occurs throughout junior high and high school, resulting in young adults who do not feel positive about their school science. Osborne, Driver, and Simon (1998) noted that positive attitudes towards school science appear to peak at, or before, the age of 11 and decline thereafter by quite significant amounts, especially for girls. This claim is supported by the findings of Institute of Electrical Engineers [IEE] (1994) that show a decline in the level of interest in England from +40 to +20 (on a scale of -100 [totally negative] to +100 [totally positive]) between the ages of 10 and 14. Lowery (1967) found that at the age of 10 to 11, science in children's mind was associated with difficult words, monsters, precious metals and jewels, and that science was unsafe.

Another clear feature of the research, supported by meta-analyses of Schibeci (1984), Becker (1989), and Weinburgh (1995), is that boys have a consistently more positive attitude towards school science than girls. The predominant thesis offered to explain this finding is that it is a consequence of cultural socialization that offers girls considerably less hands-on opportunity to manipulate scientific and technological devices (Johnson, 1987; Kahle & Lakes, 1983). Jovanovic and King (1998) have a similar thesis, arguing that girls' antipathy towards science is explained by their own comparative judgements across academic domains, perceiving that they are better at other subjects (i.e., English) and, therefore, not as good at science. However, while boys' attitudes towards science are significantly more positive than girls, the effect is stronger in physics than in biology. Such a bifurcation of interest in physical and biological science between boys and girls (i.e., Harvey & Edwards, 1980) has been given additional salience by the work of Ormerod, Rutherford, and Wood (1989) where boys were found to be far more interested in "space" and girls far more interested in "nature study".

In a meta-analysis study of the effect of computer-based instruction, Kulik and Kulik (1991) found that the scores in attitudes towards instruction (i.e., students liked their classes more when they received computer help in school) and attitudes towards computer (i.e., students developed more positive attitudes towards computers when they received help in school) were raised by 0.28 and 0.34 standard deviations respectively. However, the average effect of computer-based instruction in 34 studies of attitudes towards subject matter was near zero. In a more recent meta-analytic review of six controlled studies of computer-based instruction, Kulik (2003) found a median effect size of 1.10 for attitudinal outcomes. This means that computer-based instruction contributed to the development of favourable attitudes towards instruction (Bain, Houghton, Sah, & Carroll, 1992), towards computers (Jegede, Okebukola, & Ajewole, 1991), and towards subject matter such as chemistry (Yalcinalp, Geban, & Ozkan, 1995).

Studies reviewed in this section support four conclusions of research on attitudes towards science. Firstly, age is related to attitude (i.e., as a student advances to higher levels of schooling, attitude declines). Secondly, gender is related to attitude (i.e., boys have more positive attitudes towards science than girls). Thirdly, gender is also related to biological science relative to physical science (i.e., boys are more interested in physical science while girls are more interested in biological science). Finally, using computer-based instruction affects attitudes (i.e., computer-based science instruction promotes favourable attitudes towards science).

METHODOLOGY

Research Design

Given the research question that aimed to establish the effect of science teaching in the Smart Schools and the science teaching in the Mainstream Schools on students' attitudes towards science, a quasi-experimental design was deemed appropriate in a realistic school setting (Styles, 2006) where it was not possible to randomly assign students to the experimental treatment (experiencing science in the Smart Schools Initiative) and to the control treatment (experiencing science in the Mainstream Programme).

Instrumentation

The parsimonious Malay version of Attitudes Towards Science in School Assessment (see appendix) or ATSSA(M), which is a translation from the instrument developed by Germann (1988), was used in this study. Parsimonious because the initial 14-item Malay translated version of German's (1988) ATSSA was reduced to 11 items based on the psychometric evidence (Ong & Ruthven, 2002). Results from the initial principal component factor analysis show that, while all the 14 items load on Factor 1 with factor loadings (or correlations) greater than 0.4, the pattern of loadings of items 4, 5 and 10 suggests that these items are 'noisy' in that they all load relatively weakly on the first factor but strongly on the second factor. With the removal of the three items, the results from the subsequent principal component factor analysis indicated that these 11 items seem to cohere into one factor solution with an eigenvalue of 5.91 which accounted for 53.73 per cent of the total variance. This supports the unidimentionality of the ATSSA(M). Furthermore, its test-retest and Cronbach's alpha reliabilities were found to be at 0.93 and 0.90 respectively. Accordingly, the use of the 11-item ATSSA(M) justifies the use of summated-ratings procedure to measure students' attitudes towards science.

Sampling

The subjects were 186 male and 201 female students from two Smart Schools and 184 male and 204 female students from two Mainstream Schools in Malaysia. Table 1 shows the detailed breakdown of students by school. By means of purposive sampling, the choice of the two Smart Schools was a function of three predetermined criteria: (i) high implementation of smart schooling as gleaned from the monitoring report of the School Division (2002) of the Malaysian Ministry of Education, (ii) among Mainstream Schools which were turned into Smart Schools, and (iii) in the two states of Penang and Perak. Meanwhile, the two Mainstream Schools chosen were roughly parallel in terms of location, race composition, gender, proximity and socio economic status (SES).

Data Collection Procedures

Prior to the commencement of the study, permission was sought from the Educational Planning and Research Division (EPRD) of the Malaysian Ministry of

Table 1. Distribution of participating students by school.

	Male	Female	Total
Smart School 1	111	123	234
Smart School 2	75	78	153
Mainstream School 1	105	139	244
Mainstream School 2	79	65	144
Total	370	405	775

Education (MoE) as mandated by the MoE General Circular 112/86 on 'Ministry of Education Research Coordination'. Upon gaining the approval, further approvals at State Level, a hierarchy below the Ministerial Level, were sought. In this regard, letters for permission were forwarded to the two state education departments, namely the Perak and Penang State Education Departments, given our sampling of four schools from the two states. Finally, the principals of the schools were contacted and they permitted the conduct of the research at their respective schools. Students' Year 6 science achievement results in the Standardised National Examination (SNE) was accessed from the school records. This serves as the entry grade level, or covariate in further data analysis. Students in the Smart Schools received their 3-year lower secondary science instruction which, on the basis of the observation of 25 science lessons, was very much ICT-based than their counterparts in the Mainstream Schools (Ong, 2004). In each school, the administration of the ATSSA(M) was done simultaneously for all the classes under the supervision of teachers in school time.

Data Analysis Procedures

With the significance level set at 0.05, the scores on ATSSA(M) for the Smart Schools group and Mainstream Schools group were compared using the analysis of covariance (ANCOVA) with Year 6 Standardised National Examination science achievement as covariate. The dataset was initially screened for normality, linear relationship between covariate and dependent variable, and homogeneity of regression slopes. If any of the necessary assumptions was not met, other appropriate statistical technique(s), data transformation, or outlier deletion were performed accordingly.

RESULTS

Entry Profile Screening

The students' Year 6 Standardised National Examination science achievement results (henceforth referred to as UPSR science achievement, where UPSR is a Malay acronym for *Ujian Pencapaian Sekolah Rendah*, which literally means Primary School Attainment Test) were used as the entry level (covariate) in ANCOVA. Table 2 shows the distribution of entry grades by group and school.

As shown in Table 2, the initial difference between the Smart and Mainstream Schools in terms of students' entry grades favours the former. Although such initial difference, according to statisticians (e.g., Ferguson & Takane, 1989; Glass & Hopkins, 1996; Hinkle, Wiersma, & Jurs, 1998) has been taken into account in ANCOVA by making compensating adjustments to the posttest means of the two groups, it is understandable for critics to be sceptical of the results presented. However, two further analyses are performed to dispel the suspicion.

It is the entry profile of SS2 which is primarily responsible for the differences between groups; the profile of SS1 is much more similar to those of MS1 and MS2. First, then, in order to make a convincing case that the results from the ANCOVA for the dependent variable (i.e., attitudes towards science) are truly the outcome of differences between Smart and Mainstream science teaching, a further analysis of covariance by school is performed.

The entry profile of SS2 lacks students graded D or E, and this produces a corresponding imbalance in the grade profiles of the two groups. Second, then, independent t-tests for each entry (covariate) grade of student are performed so as to establish a like-for-like comparison in which the scores obtained in ATSSA(M) for students in Smart Schools are compared to those students in Mainstream Schools with identical entry grades.

As observed in Table 2, there is a very small sample size at E entry grade. According to Kraemer and Thiemann (1987), the number of participants is directly related to power, where power is the ability to detect "real" differences (i.e., correctly reject the null, when an alternate hypothesis is true). Furthermore, Cohen (1988) recommends 80% power achievable through having 30 participants per cell, as the minimum power for an ordinary study. Therefore, the independent t-test for students at E entry grade should be given little weight.

These complexities arise because the data are drawn from a real-world situation. However, by analysing the data in these different ways, it should be possible to draw firmer conclusions.

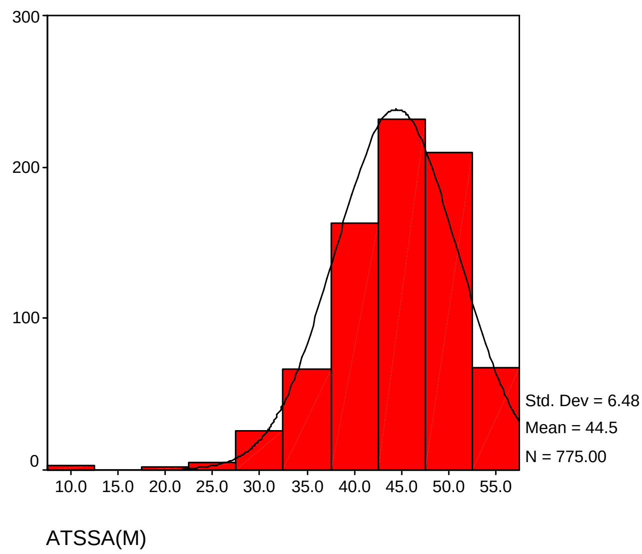

Figure 1. Histogram for distribution of scores on ATSSA(M).

ATSSA (M) Data Screening

The distribution of scores on ATSSA(M) was not normally distributed, assessed by its skewness and kurtosis values which were measured at –1.04 and 2.47 respectively. There are ways of getting round this problem of non-normal distribution, such as through a suitable variable transformation, or resorting to the use of non-parametric alternatives. However, by inspecting the shape of the histogram (see Figure 1), a handful of cases with much lower scores were observed. They tailed off from the normal distribution curve and 'sat' on their own, out on the extremes.

Through the exploration in which the most extreme cases were successively deleted, it was found that by deleting the 5 most extreme cases, the skewness and kurtosis values improved to that of –0.57 and 0.28, suggesting a normal distribution for the scores on ATSSA(M) (see Figure 2). Table 3 gives information on the five deleted extreme cases.

Given the normal distribution for ATSSA(M), it was intended that ANCOVA be used to test the research hypothesis. First, however, the data were analysed to see if (1) there was a linear relationship between the covariate and the dependent variable; and (2) the assumption of homogeneity of regression slopes was not violated. The former was checked graphically using scatterplots, while the latter was established graphically and tested in the "Custom General Factorial Model" for interaction between group and covariate.

The scatterplots in Figure 3 show that there was a linear (straight-line) relationship between the covariate (i.e., UPSR science achievement) and dependent variable (i.e., students' scores on ATSSA(M)) for each of the

Table 2.Distribution of entry grades by group and school for attitudes towards science analysis

Entry Grade	Smart Schools			Mainstream Schools		
	SS1	SS2	Total	MS1	MS2	Total
A	24	26	50	15	4	19
B	52	102	154	60	34	94
C	106	26	132	141	73	214
D	42	0	42	24	28	52
E	10	0	10	4	5	9
Total	234	153	387	244	144	388

Table 3.Information on five deleted extreme cases

Case	ATSSA(M) Score	Gender	School	UPSR Science achievement
165	11	F	SS2	B
521	11	M	MS1	C
530	11	M	MS1	C
539	20	M	MS1	C
543	21	M	MS1	C

Table 4.Results obtained from Analysis of Covariance by group for attitudes towards science Analysis of Covariance

Source	Sum of Squares	df	Mean Squares	F	p
Group	844.12	1	844.12	27.13	.000
Covariate	2565.12	1	2565.12	82.44	.000
Error	23866.47	767	31.12		

Mean

		Covariate		ATSSA(M)		Adjusted	
Group	N	Mean	SD	Mean	SD	Mean	Δ*
Smart	386	3.49	0.94	46.07	5.04	47.72	0.68
Mainstream	384	3.16	0.80	43.24	6.59	43.59	
Total	770	3.33	0.89	44.66	6.03		

* Δ , effect size (ES) = (Smart adjusted mean – Mainstream adjusted mean)/(pooled SD of 6.03)

groups (i.e., Smart and Mainstream). Additionally, the R-squared value of approximately 0.10 for both Smart and Mainstream Schools indicate that 10% of variance in attitudes scores could be predicted from UPSR science achievement.

Furthermore, the slopes of regression lines were 'roughly' parallel, consistent with homogeneity of regression slopes. This was confirmed by the interaction testing for homogeneity of regression slopes in which the group and covariate interaction effect was found to be non significant [$F_{(1, 766)} = 3.64$, $p > .05$].

Therefore, the use of ANCOVA was justified given that there was a linear relationship between the covariate and dependent variable, and that there was homogeneity of regression.

Hypothesis Testing

Null Hypothesis, H_0: There is no statistically significant difference in attitudes towards science between Form 3 students from Smart and Mainstream Schools, as measured by the 11-item Attitudes Towards Science in School Assessment [ATSSA(M)].

Research Hypothesis, H_A: There is a statistically significant difference in attitudes towards science of Form 3 students who have participated in the Smart schooling and the attitudes of Form 3 students who have participated in the Mainstream schooling.

As shown in Table 4, the analysis of covariance yielded an F-ratio of 27.13 that was statistically significant ($p = .000 < .001$) and an effect size of +0.68 that was educationally significant. The adjusted mean obtained for the Smart Schools (47.72) was statistically significantly higher than the adjusted mean obtained for the Mainstream Schools (43.59). Therefore, the research hypothesis is accepted.

The level of attitudes towards science of Form 3 students who had participated in the Smart Schools is statistically significantly higher than the level of attitudes towards science of Form 3 students who had participated in the Mainstream Schools. Indeed, inasmuch as the obtained effect size ($\Delta = +0.68$) was equivalent to approximately two thirds of a standard deviation, it can also be argued that the difference favouring Form 3 students who participated in the Smart Schools is also educationally significant.

While five extreme cases (i.e., one in Smart Schools, and four in Mainstream Schools) were deleted, the deletion had a negligible impact on the overall mean. The deleted case in Smart Schools only incurred a difference of 0.1 point [i.e., $\{(46.07 \times 386) + 11\} \div 387$] from the mean score of 46.07, and the four deleted cases in Mainstream Schools, taken together, only incurred a difference of 0.3 points [i.e., $\{(43.24 \times 384) + (11 + 11 + 20 + 21)\} \div 388$] from the mean score of

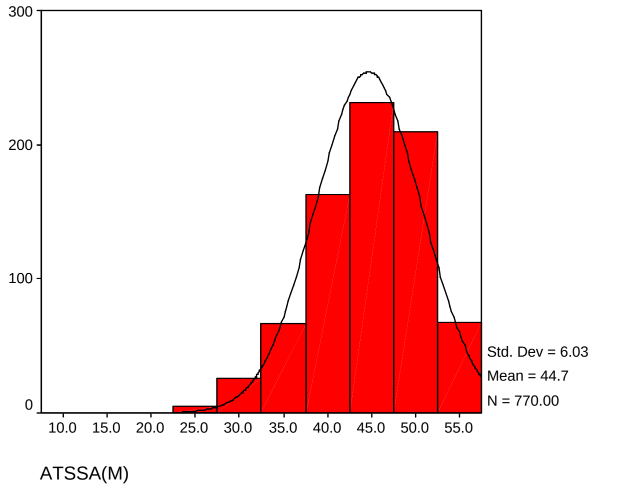

Figure 2. Histogram for distribution of scores on ATSSA(M) after deletion of extreme cases

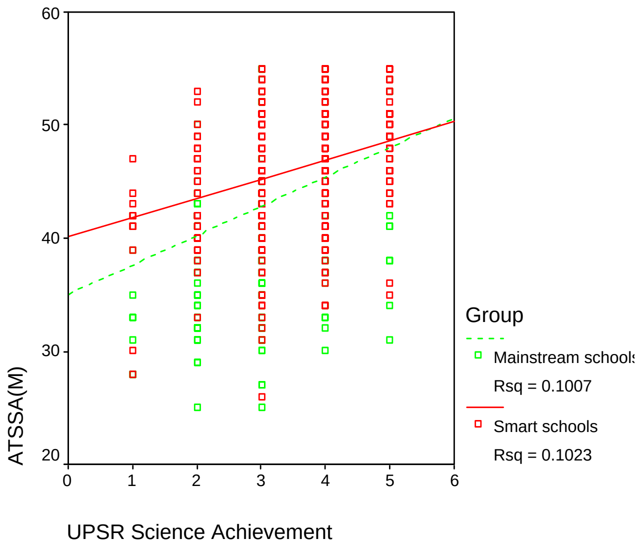

Figure 3. Relationship between the covariate and the dependent variable

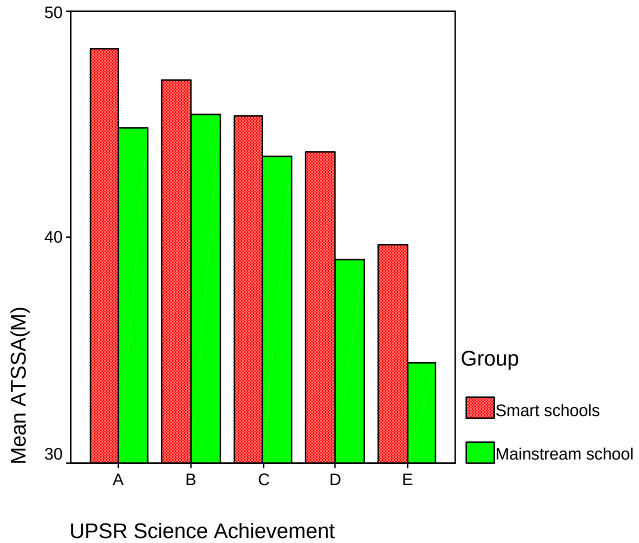

Figure 4. Bar charts for group mean ATSSA(M) score differences by UPSR science achievement

43.24. As such, the results from the ANCOVA, despite the five-case deletion, were considered to be robust.

Next, ANCOVA by school was performed. As shown in Table 5, the adjusted mean attitude scores ranked schools in the order SS1, SS2, MS2, MS1. The analysis of covariance by school yielded an F-ratio of 10.59 that was statistically significant ($p < .001$), suggesting a significant difference in at least one of the pairwise comparisons. The post hoc tests (see Table 5) revealed that within each group, the differences between schools were not significant whereas between groups, all but one of the school differences were significant. This suggests that the significant group differences found earlier were indeed due to group rather than disguised school effects.

Further insight and understanding of the relative effects of Smart and Mainstream science teaching can be gained if a further comparison through an independent t-test is performed to compare the ATSSA(M) scores of students for each of the covariate (entry or UPSR science achievement) grades.

Figure 4 shows the bar chart comparing the mean scores between Smart and Mainstream Schools for students at each grade level of UPSR science achievement. Broadly, it shows that students in the Smart Schools consistently rated their attitudes towards science more favourably than did identical students in the Mainstream Schools across UPSR science achievement grades.

As shown in Table 6, the t-tests were significant at

Table 5. Results obtained from Analysis of Covariance by school for attitudes towards science Analysis of Covariance

Source	Sum of Squares	df	Mean Squares	F	p
School	985.03	3	328.34	10.59	.000
Covariate	2620.94	1	2620.94	84.51	.000
Error	23725.56	765	31.01		

Mean

		Covariate		ATSSA(M)		Adjusted
School	N	Mean	SD	Mean	SD	Mean
SS1	234	3.16	0.98	45.72	5.07	46.09
SS2	152	4.01	0.58	46.61	4.96	45.09
MS1	240	3.24	0.78	43.11	5.80	43.30
MS2	144	3.03	0.83	43.47	7.76	44.14
Total	770	3.33	0.89	44.66	6.03	44.66

Pairwise Comparisons

School (I) – School (J)	Mean Difference (I-J)	p+
SS1 – SS2	1.00	.621
MS1 – MS2	-0.84	.934
SS1 – MS1	2.79	.000**
SS1 – MS2	1.95	.006*
SS2 – MS1	1.78	.020*
SS2 – MS2	0.95	1.00

* Significant at $p < .05$ ** Significant at $p < .001$ + Adjusted for multiple comparisons: Bonferroni

Table 6. Results obtained from unpaired samples t-test for attitudes towards science by UPSR science achievement grade

Science Achievement Grade UPSR	Smart Schools			Mainstream Schools					
	N	Mean	SD	N	Mean	SD	t	p (2-tailed)	Δ+
A	5048.32		4.15	19	44.846.52		2.17	.041*	0.68
B	15346.95		4.54	94	45.416.17		2.09	.038*	0.29
C	13145.40		5.30	210	43.566.30		2.90	.004*	0.31
D	4243.79		4.30	52	38.985.73		4.64	.000**	0.85
E	1039.70		6.04	9	34.445.25		2.01	.060	0.86
Total	38646.07		5.04	384	43.246.59				

* significant at $p < .05$ ** significant at $p < .001$

+ **Δ,** Effect Size = (Smart mean – Mainstream mean) / (pooled SD)

[Note: 5.11, 5.27, 6.00, 5.65, and 6.14 are pooled SDs for A, B, C, D, and E graders respectively]

A, B, C, and D covariate grades. Given the very small sample size, the no significant group difference at E entry grade carries little weight. Therefore, taken together, the results from the independent t-tests support the earlier ANCOVA findings that students in the Smart Schools achieved a higher mean score in attitudes towards science than students in the Mainstream Schools.

CONCLUSION AND DISCUSSION

The ANCOVA results for the ATSSA(M) scores showed that the Form 3 students involved in the 3-year Smart Schools Initiative had a significantly higher adjusted mean score compared to students involved in the Mainstream Programme. The students from Smart Schools achieved a 4.13 point higher adjusted mean score on the ATSSA(M) compared to students in Mainstream Schools [47.72 and 43.59 respectively, $F_{(1, 767)} = 27.13$, $p < .001$]. Such a difference, favouring Form 3 students who participated in the Smart Schools, is also educationally significant given the obtained effect size of +0.68, which is equivalent to approximately two thirds of a standard deviation. This finding was supported by follow-up analyses using ANCOVA by school and independent t-tests by entry (UPSR science achievement) grade. The former confirmed that the significant group difference was indeed contributed by both Smart Schools while the latter, discounting the weight from E entry grade comparison due to low sample size, revealed that group difference in attitudes towards science was significant across all entry grades.

Accordingly, in terms of impact, the results indicated that students in the Smart Schools have significantly more positive attitudes towards science than their counterparts in the Mainstream Schools. However, we are not able to find any previous studies with which these findings could be directly compared. This explains the novelty and distinctiveness of this study, and reflects the infancy of the Smart Schools Initiative. Nevertheless, comparison could still be made based on the logic of parallel impact of other science-based curricular innovations so long as their distinctive features are clearly identified. As such, by parallel impact comparison, the attitudinal outcome in this study is not consistent with research on attitudes towards science and activity-based programmes (i.e., Freedman, 1997; Turpin, 2000; Wideen, 1975). The results from Turpin's (2000) study indicated no significant difference between students involved in the activity-based Integrated Science (IS) programme compared to students involved in the traditional science programme. Equally, Wideen (1975) found no significant difference in attitudes towards science between students in the SAPA (Science – A Process Approach) programme and students in the traditional science programme. When the treatment and control groups covered the same science content with the treatment group additionally participating in one hands-on activity per week, Freedman (1997) found no significant difference in mean attitudes towards science between the two groups.

By virtue of the high level of ICT use in the Smart Schools, then, the attitudinal outcome in this study lends empirical support to optimist-rhetoric, defined as "official claims for the effectiveness of ICT" (Reynolds, Treharne, & Tripp, 2003, p.151) in raising students' motivation and attitudes towards science. Such empirical support is deemed necessary because, as Lewis (2003) observed, "Evidence that the use of ICT has any significant effect on attainment [and attitudes] remains elusive. There is much anecdotal evidence of improved attainment [and attitudes] being linked to effective use of ICT, but little published research" (p.42). Equally, the attitudinal outcome in this study is consistent with the meta-analytic findings of Kulik (2003) where computer-based instruction contributed to a development of favourable attitudes towards school science.

The Smart Schools Initiative promotes the use of ICT alongside other smart teaching elements such as constructivist practice, mastery learning, self-accessed, self-paced and self-directed learning. Additional research is needed to determine which smart teaching elements have greatest effect on students' attitudes towards science. Equally, given that the impact of various possible combinations of these smart teaching elements remains unclear, further study to isolate the relative impact, be it positive or otherwise, of these possible combinations would be illuminating and beneficial. It would also contribute significantly to the research and literature if the future research could determine whether other ICT-based science programmes have a similar impact on attitudes towards science compared to the Smart Schools Initiative

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Eurasia Journal of Mathematics, Science & Technology Education, 2009, **5**(1), 47-62

A Design Based Research of an Earth Systems Based Environmental Curriculum

Orit Ben-Zvi Assaraf
Ben-gurion University of the Negev , ISRAEL

Nir Orion
Weizmann Institute of Science, ISRAEL

Received 17 July 2008; accepted 25 November 2008

This article presents a model for the development of an environmentally oriented unit designed to be implemented as an integral part of the science core curriculum. The program's main goal is encouraging students at the junior high-school level to develop systems-thinking and environmental insight as a basis for environmental literacy. A design-based research was employed in order to construct the learning program and improve it in consecutive cycles. The findings indicate that junior high school students who were involved in the learning process – through knowledge integration activities, scientific inquiry, and outdoor learning – achieved a meaningful improvement of their cyclic and systemic understanding of the water cycle. The article concludes with a summary of the program's design elements we recommend using in other programs seeking to foster students' understanding of natural cycles within the context of their influence on people's daily lives, rather than in the isolation of their specific scientific domains. It is suggested that an environmentally based science curriculum should involve authentic, real environmental topics, and at the same time, it should emphasize the role of scientific knowledge and skills that are needed for the development of environmental literacy

Keywords: Literacy, Religion, Science, Sociocultural, Superstition

INTRODUCTION

All students (like all citizens) are 'consumers' of scientific information in their everyday lives – as they make personal choices (e.g. about health, diet, use of energy resources, etc.) and as they form views on issues affecting society (e.g. waste disposal, genetic modification of organisms, global climate change and CO2 emissions). One aim of science education is to make these 'consumers' more intelligent and informed; able to respond in an informed and appropriately critical manner to information they receive (Millar & Osborne, 1998). The publicly aired concerns regarding the environment have influenced educational systems in many western countries. However, educators and researchers from all over the world have pointed out a number of shortages and limitations of environmental education (e.g. Bachiorri, 1995; Benedict, 1999; Gough, 2002; Kuhlemeier et al, 1999; Membiela, 1999; Orion, 2002; Salmon, 2000; Tilbury & Turner, 1997). A review of the literature on this topic indicates that environmental education (EE) in most western countries is still not part of the core science curriculum. Gough (2002) provide a number of reasons why this situation is upheld: the inflexibility of the curriculum, which does not allow teachers plan their own schemes of work; the strong influence of scientists on drafting the curriculums to include their own priorities, which in many cases do not accord with EE priorities; the view

Correspondence to: Orit Ben-Zvi Assaraf, Lectures in Science Education, The Science Teaching Department, Ben Gurion University of the Negev, P.O.B. 653 Beer-Sheva 84105 Israel
E-mail: ntorit@bgu.ac.il

E-ISSN: 1305-8223

held by many educators of EE as yet another "pressure" in an already overloaded curriculum; the persistence of some science teachers in teaching their own discipline rather than adopting an interdisciplinary approach; and finally, the superficial understanding of EE commonly held by many of those responsible for the science curriculum. Gough (2002) further asserts that the limiting factor for introducing environmental issues as an integral part of the science curriculum is the extent to which discipline-oriented teachers are able to deal with interdisciplinary subjects.

In recent years, a number of educational packages, which combine sustainability strategies regarding the various aspects of water conservation issues from an interdisciplinary perspective, were developed (D'Agostino et al., 2007; Scoullos, Alampei & Malotidi, 2004). However, of the environmentally-oriented programs that do find their way into the schools, the majority primarily deal with the awareness aspect of environmental education. These programs are not profound enough to further the development of what Orion (2002) termed as environmental insight. Environmental insight is a deeper aspect of environmental education; it includes the understanding that life influences -and is influenced by- the natural environment, and the understanding that the natural environment is a system of interacting natural subsystems, each influencing the others. Mayer (1995) presented the earth systems approach as a venue for science for all education. In the field of earth science education, the environmental aspect is achieving a central position in the overall system. Mayer, (1995), and Orion, (1996) stated that one of the advantages of studying the earth sciences is in the development of environmental awareness and insight. The Earth sciences gives the student - the future citizen - the knowledge and the ability to draw conclusions regarding subjects such as: preservation of energy, economizing on water, proper utilization of global resources. In addition, the teaching of earth sciences may raise the students' consciousness of what is happening around them, in their local environment, in their country, and in the world. Orion (2002) suggested the Earth systems approach as a holistic framework for the science curricula that integrate the earth sciences education together with the environmental education. Therefore, this approach could serve as a powerful platform for understanding the interrelations between life and the physical environment, and for developing environmental insight. The "Blue Planet: The Water Cycle within Earth-Systems" program was developed according to the earth systems approach. The program was constructed through a design-based, spiral model of research, development and implementation; and is designated for the science education of junior high school students'. This research presents the "Blue Planet" program and the design-based research that led to its construction.

RESEARCH APPROACH AND DESIGN

The "Blue Planet" unit's development was supported by a design-based research approach. Design-based research focuses on studying the way the design of a learning environment influences variables relating to known learning and instruction methods (Barab & Squire, 2004; Collins, 1992; Brown, 1992; Shavelson et al., 2003).

The first phase of any design-based research is to examine an initial design, and as the study evolves, to implement certain changes and adjustments according to findings obtained in the data-collection-and-analysis phase. Design-based research must provide a continuous change of design elements, so it will be possible to test and build different learning theories regarding certain environments on the basis of relevant study findings (Collins et al., 2004). The design of successful curriculum materials depends on a process of iterative refinements as a response to the complex systems that impact classroom learning.

The increasing tendency in recent years to conduct design-based research has lead to the development of well established theories regarding the ways of reporting this sort of research. The report should describe all of the different phases of the study, not just its final results. According to Collins (2004), the way of presenting a design-based research should be different than the usual quatrain pattern of background and description of problem; presentation of research tools; findings; and discussion. Collins (2004) suggests five elements for presenting design-based research: a) Goals and elements of design (learning material, activities, designing principals and the interaction between them); b) Setting where implemented (detailed description of changes in the setting during different phases of the study); c) Description of each phase (here all the different phases of the design as well as the changes undertaken for each design should be specifically described); d) Outcomes found (describing the changes of the permanent variables as they took place during design phases); and e) Learned lesson (reference to limitations and successes of the research, both on operation and results levels). In the present research, Collins's presentation guidelines are adopted but are slightly modified, so as to accommodate the needs of the study. The first element is presented and discussed in length in the following section; the remaining elements are organized under the headings of the case descriptions of study 1 and 2.

The design of the curriculum reflects two successive cycles of formative evaluation. The first cycle included about 140 junior high school students (8th grade) from one urban junior high school; the second cycle included about 500 junior high school students (7th-8th grades) from four different urban schools. From the latter research cycle, three 8th grade classes were selected as a case study. As the main purpose of design-based research studies is to improve their design, the amount of success, or lack of success, of every element should be tested. In this study, an emphasis was placed on documenting each of steps of the design improvement process, and therefore, data was collected throughout both cycles of research implementation. In this article we mainly present data relevant for the process of the program's design, especially in regard to the instruction of systems-thinking, on whose implementation there is relatively little research.

As most of the research tools employed in this study were custom made, careful measures were secured for ensuring their validity and reliability. For this purpose, 3 senior earth science researchers assisted in the process of the initial design of the research tools, suggesting improvements and noting shortcomings. As well, a pilot study was conducted with 20 8th grade students (from one of the schools from which a larger sample was later obtained) who studied the unit a year before the main study took place, and after its completion, answered 20 in-depth, open questions as part of a semi-structured interview. In order to enhance the questionnaires' validity the students were asked in this pilot study to write an explanation for each of the statements. This step made it possible to examine whether the students' erroneous replies stemmed from wrong interpretation of the statement's meaning or from cognitive difficulties.. As a result, each of the research tools (to be mentioned later) was refined and later on evaluated further through an expert judgment procedure.

Goals and elements of design

Ben-Zvi Assaraf and Orion (2005) suggest that in order to provide our future citizens with basic tools for knowledgeable dealing with their environment, science education should emphasize studying natural cycles within the context of their influence on people's daily life, rather than in the isolation of their specific scientific domains. This calls for an environmentally-oriented program that not only furthers environmental education toward awareness, but that also helps develop environmental insight and understanding. The "Blue Planet" program is an earth systems-based curriculum package that focuses on the study of water-related issues in an environmental context. The program promotes students' conceptualization of the water cycle as a dynamic, cyclic system. The main goal of the program is to encourage students at the junior high school level to develop systems-thinking as a platform for environmental literacy. For this purpose, we adopted Orion's (2002) tenets for system-based earth science education. Accordingly, the following goals and elements of design of the "Blue Planet" program are presented and discussed: design of the learning environment; the development of the inter-disciplinary scheme; addressing students' need for an authentic learning environment; and the development of environmental insight.

Design of the learning environment

The “"Blue Planet"” program is a 30-hour learning program destined to junior high school students, which was developed to be part of the new Israeli curriculum: "Science and Technology". Within the learning sequence, the "Blue Planet" program is preceded by "The Rock Cycle" program, which focuses on geological processes that transform the materials found within the crust of the earth (discussed in length in Kali, Orion & Eylon, 2003; Orion & Kali, 2005); and as well, follows its pedagogical approach. The manner of designing the activities is derived from the constructivist epistemology, which claims that when students confront new learning material, scientific material included, they use their existing knowledge, beliefs, interests, and goals to interpret the new information; and that this may result in a modification or revision of their previous ideas. In this way, learning proceeds as each individual’s conceptual schemes are progressively “reconstructed” as he or she becomes exposed to new experiences and ideas (Palmer, 2005). Palmer further highlights several features that positively impact motivation in constructivist-informed teaching models, these include: teaching techniques for eliciting students’ views, providing clear explanations of the scientific viewpoint, carrying out hands-on activities, and applying the learned material to real life.

Following Kali, Orion and Eylon (2003), all of the program's activities are conducted in an inquiry method, the main resources of which are concrete items - natural materials of the earth – brought to the lab or studied in the field. The inquiry is guided by means of a booklet, which mainly includes questions with a minimal amount of textual information. In this manner, groups of three or four students work collaboratively to "discover" by themselves the hydrological processes.

The development of the interdisciplinary scheme

Interdisciplinary implies the cooperation and integration of the contributing disciplines; the aim being to create a common and single framework shared by all the disciplines involved. The knowledge and methods from the different disciplines go through an alteration and merging process, where each discipline's impact is

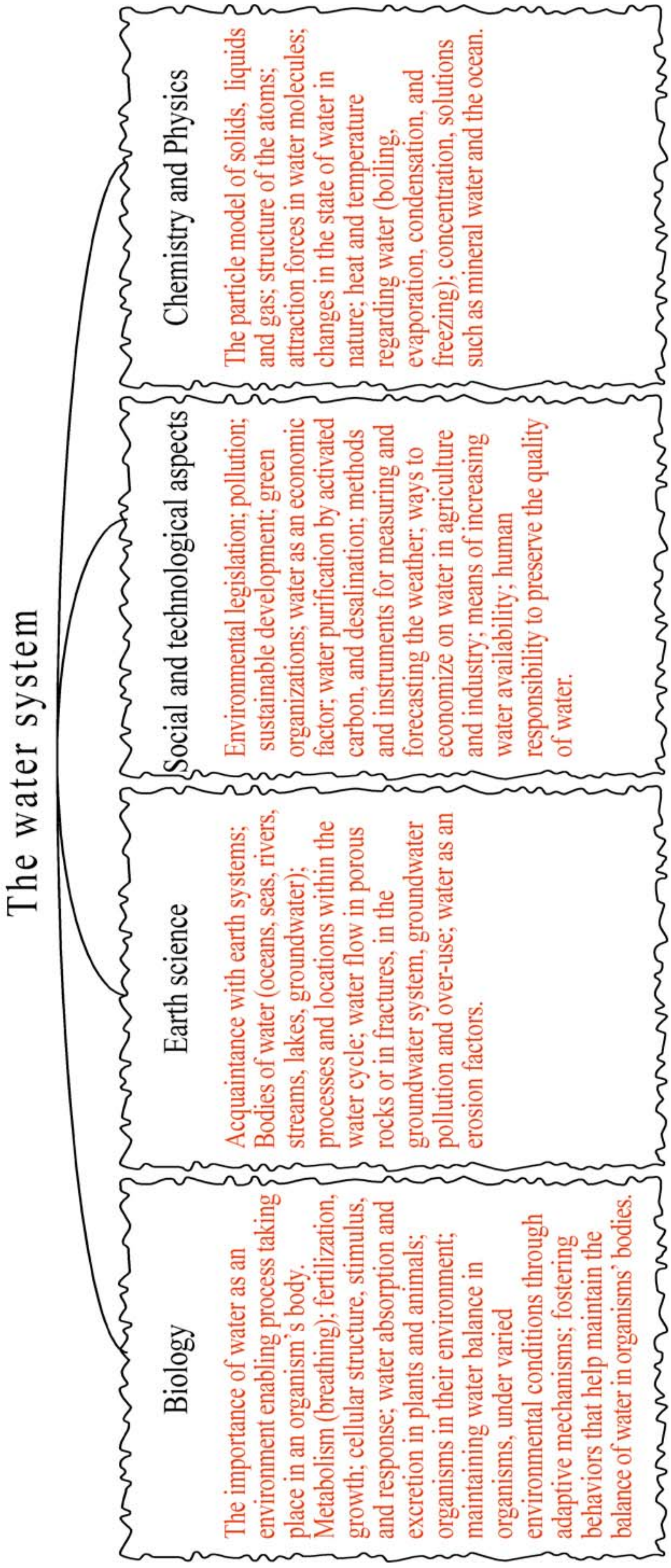

Figure 1. The distribution of water-related contents among the different disciplines of the Israeli junior high school curricula

reduced and it becomes possible for a specific issue to be examined in a systematic way (Scoullos, Alampei, & Malotidi, 2004). However, implementing interdisciplinarity is not without difficulties, recently, Osborne (2007) has claimed that the science education community suffers from the delusion that the offered science learning material must be both broad and balanced; the result being a smattering of all sciences cramming more and more into a limited curriculum. He continues with the plea: "has the time not come to recognize that it is our responsibility to select a few of the major explanatory stories that the sciences offer? And surely it is the quality of the experience, rather than the quantity, which is the determining measure of a good science education?" (op. cit. pg. 175). In this study, the water cycle was selected as the theme or "cover story" of the environmentally-based curriculum development. The reason for choosing the water cycle was because it enables communicating ideas from various knowledge domains, developing environmental insight, and constructing basic scientific knowledge, understanding, and skills. Appendix 1 details the main goals and principles of each of the "Blue Planet" chapters.

The development of a successful interdisciplinary scheme involves the selection of a content area that involves authentic, real environmental topics and at the same time, allows the incorporation of important scientific concepts lying at the heart of the core science curriculum. Water is an obvious content area that fits the above characteristics. This topic is associated with everyday environmental issues such as the quality of drinking water, contamination of ground water supplies, and river pollution. Brody (1995) suggests that the concept of the hydrosphere is one of the most integral concepts related to life and the earth, and thus is critical for achieving an understanding of the complexity and interrelatedness of the earth's systems. As well, the water system can provide a framework for constructing almost any part of the core science curriculum. These include those scientific principles, concepts and skills that are at the base of the major conservative science disciplines – physics, chemistry, geology and biology. Figure 1 below presents the scientific concepts related to the topic of “water” of the Israeli “Science and Technology” curriculum for junior high school. It illustrates a common model for dealing with an interdisciplinary subject (using water as an example).

As part of the curriculum, the water-related concepts in Figure 1 are studied as a set of chapters, each one looking at these concepts through the lenses of a certain scientific discipline; namely, the chemistry of water, the physics of water, water and biology, and water and the earth sciences. Although there are, potentially, numerous links between the different chapters, many students (and some teachers as well) may fail to perceive them because while all the concepts are related to water, relations between the concepts themselves are not clarified within the different chapters. The result is that there is not much of a difference between such “interdisciplinary” programs and the traditional one. Therefore, while developing the "Blue Planet" program, we did not cover the whole range of water-related scientific concepts; rather, we selected only those concepts that were aligned with the program's "cover story". The outline of the program, laid out chapter by chapter with a listing of the various activities, can be found online at http://stwww.weizmann.ac.il/g-earth/blueplanet.

Addressing students’ need for an authentic learning environment

For some time now, it has seemed that science learning (especially at ages 14–16) is all too often boring and irrelevant for the majority of the students (Millar & Osborne, 1998). While environmental topics have the potential to arouse interest in science education, in practice, this is not always the case. Water is being an important topic which drives a great interest among Israeli citizens. This interest probably stems of the substantial shortage of water, which is getting worse continuously. Thus, the water might serve as a platform for authentic learning. Brown, Duguid, and Collins (1989) suggest that authentic learning must make information meaningful to the students. It should reflect actual practice that provides authentic contexts that reflect the way the knowledge will be used in real life. However, although the water cycle is strongly related to daily life, especially in Israel which is a semi-arid area, it seems that merely choosing a real-world subject is insufficient for making it relevant in the students’ eyes (Ben-Zvi Assaraf & Orion, 2005). Orion (1993) suggested that the main role of using the outdoor learning environment within the learning process is to directly experience concrete phenomena and materials as they appear in the real world. Thus, in order to address the students’ need for an authentic learning environment, the whole learning process should be considered in light of its relevancy to the students' actual daily surroundings – their real world. Our conception is that there is no substitute for the real world other than the real world itself. Thus, any curriculum that deals with natural phenomena should, as much as possible, use the outdoors as a learning environment that provides the authentic context for the learning.

Orion (1993) argues that an outdoor learning event should be planned as an integral part of the curriculum rather than as an isolated activity. The "Blue Planet" program adopts this view and implements Orion’s (1993) outdoor learning model. As part of the program, the students participate in three field trips in which they explore (a) a polluted river and water treatment plant, (b) a spring and a stalagmite cave, and (c) a winter-rain puddle in their near environment. In each of these sites they conduct the following scientific observations: they explore the earth, rocks and their characteristics, and how they react to water; they compare the water quality in the different locations; they identify the components of the ecological system; they present the interrelationships between earth systems and man; and they raise authentic questions which are later discussed in class. Examples of such questions, actually raised by the students, are: "What are the differences between the tap water that I drink and the mineral water that I buy?"; "What are the properties of the water solution on earth?" and "What influences the groundwater that I eventually drink?". While confronting each of these questions, students learn how scientific knowledge plays a central role in understanding environmental phenomena. Thus, the science class serves as an authentic learning environment. As well, the interaction between the student and the environment outside the classroom results in students perceiving the activities as relevant, and consequently, as interesting.

The development of environmental insight

In order to facilitate the students' development of sound decision-making abilities concerning environmental issues, they first need to develop environmental insight. Such insight is based on an understanding of the systemic and cyclic mechanisms that govern our planet (Orion, 1997). The development of environmental insight is based on the understanding of two main concepts: (a) the systemic perception of the earth - the natural environment - as interacting natural subsystems, and (b) the perception that man plays a role as a part in the natural system. Thus, teaching environmental phenomena regarding the hydrosphere should emphasize the transportation of water within the earth's subsystems and their interrelationships, as derived from the holistic nature of the system. Accordingly, the following three scientific principles were formulated during the program development: The first principle is that dynamic relationships exist between the earth's spheres (biosphere, geosphere, atmosphere, and hydrosphere systems) on the globe; for example, (1) the hydrosphere and geosphere (e.g., chemical dissolution of minerals in seawater, the quality and contamination of groundwater supplies); (2) the hydrosphere and atmosphere (e.g., evaporation and condensation); (3) the hydrosphere, biosphere, and atmosphere (e.g. transpiration). The second principle formulated in the program's development is that the effects of the interaction between the earth's systems result from the energy and substances that pass between and within the systems – biogeochemical cycles. Finally, the third principle is that sustainable development will preserve the capacity of the environment to be a life supporting one. The Johannesburg Declaration on Sustainable Development has suggested that in a sustainable world, society's demand on nature is to be balanced with nature's capacity to meet that demand. Therefore this development should meet the needs of the present without compromising the ability of future generations to meet their own needs (UNESCO, 1997; WCED, 1987).

The ability of students to perceive the hydrosphere as a coherent system depends on both scientific knowledge and cognitive abilities, specifically, cyclic thinking and systems thinking – the ability to perceive the water cycle in the context of its interrelationship with the other earth systems (including Man) (Ben-Zvi Assaraf & Orion, 2005; Kali, Orion, & Eylon, 2003). The "Blue Planet" program emphasizes the development of these cognitive abilities. In order to promote students' construction of the water cycle as a dynamic, cyclic system, the students were engaged in a number of knowledge-integration activities. Such activities include drawings, concept maps, flow charts, and creation of small-group posters, which were conducted in various points of the learning sequence. Figure 2 illustrates one example of a knowledge-integration activity where students used drawings in order to communicate their understanding of complex and abstract concepts regarding the natural environment. In this task the students were instructed to incorporate within their drawings as many items as possible and were assured that they were not expected to perform an artistic drawing. In their drawings they were asked to present their scientific knowledge in a way that emphasizes the water cycle components (stages and processes) and their interrelationships through a network of connections. This framework of connections served as a mechanism by which students could create an entire cycle. In fulfilling these assignments, the students identified the chemical and physical processes that take place within the water resources, such as evaporation, condensation, precipitation, and transpiration, which serve as water transportation mechanisms within the water cycle.

Case description and results: Study one

Participants

The first implementation cycle of the Blue-Planet program included about 140 junior high school students (8th graders) from one urban junior high school. The implementation involved a study aimed at evaluating the influence of learning the "Blue Planet" program on students' perceptions of the water cycle. The two main objectives of the study were (a) to identify junior high school students' previous understanding of the water cycle, and (b) to explore students' perceptions of the cyclic and systemic nature of the water cycle.

Research tools and analysis

The following Likert-type questionnaires, which were distributed before and after the learning sequence, were developed for this study based on categories found in the interviews of the pilot research (see Research approach and design section) and on the relevant literature. For validity purposes, the explanations provided by the students were categorized by relations to unifying statements by three science education senior researchers. Each of the researchers worked individually and only then results were compared. Only categories agreed upon by both researchers were included. For the purpose of content validation, 3 senior earth science educators were presented with a tentative list of the suggested items and were asked to assess their quality, to assign their classification according to the scale, and to suggest items in need of revision. Then, based on the pilot study's findings, we deleted and modified a number of the items. Due to the sample size, no statistical measures for reliability and validity were employed. While the participants were filling the questionnaires, one of the researchers was always present in the classroom to explain the meaning of sentences students found to be unclear. This was important as one of the Likert-type questionnaires' shortcomings is that students which have reading comprehension difficulties may receive lower scores.

Groundwater Dynamic Nature Questionnaire (GDN): This questionnaire was developed for identifying students' ability to identify relationships among the components of the water system (Ben-Zvi Assaraf, & Orion, 2005). To be more specific, it measured students' previous knowledge and understanding of the dynamic nature of the groundwater system, and its environmental relationship with humans. The statements used, sample sizes, and statistical significance – of both pre and post results in the present study and Study 2 (to be described in the next section) – are summarized in Table 1.

Cyclic Thinking Questionnaire (CTQ): This questionnaire was developed to identify students' understanding of the cyclic nature of the hydrosphere and the conservation of matter within the earth systems (Ben-Zvi Assaraf, & Orion, 2005). The McNemar's test (Siegel & Castelan, 1988) was employed in order to check for statistical significance. The statements used, sample sizes, and statistical significance – of both pre and post results in the present study and Study 2 (to be described in the next section) – are summarized in Table 2.

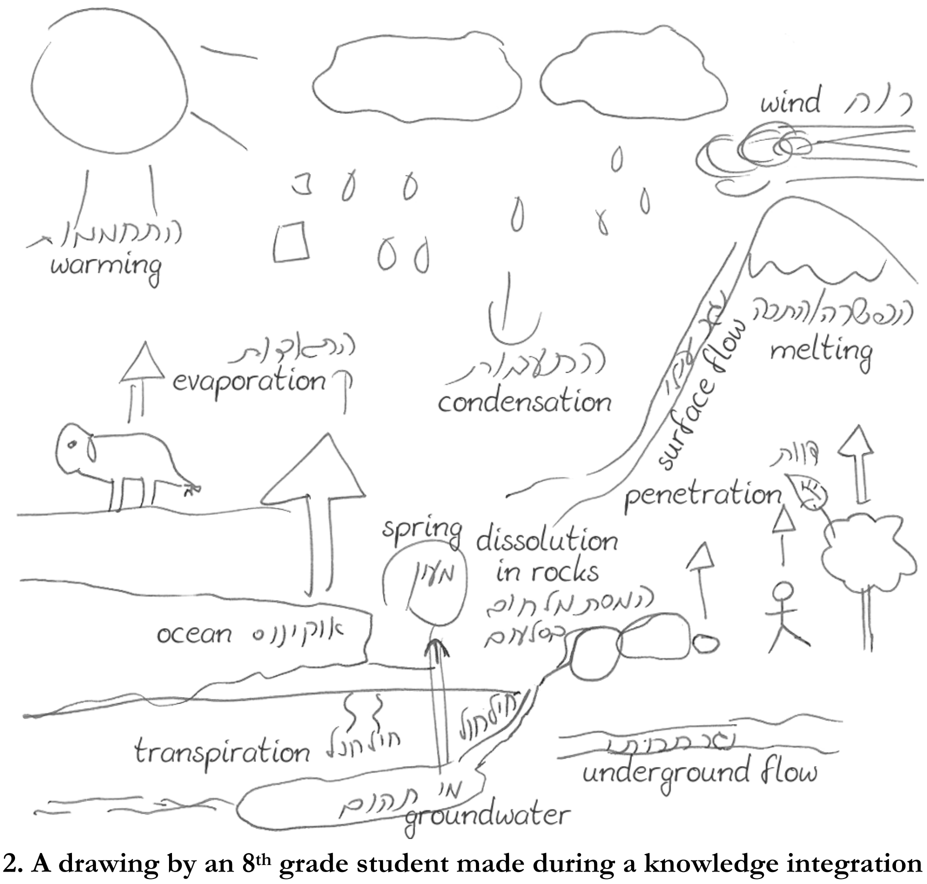

Figure 2. A drawing by an 8th grade student made during a knowledge integration activity.

Table 1. Students' perceptions as shown in a Likert-type questionnaire (GDN), for assessing students' understanding the dynamic nature of the groundwater system and its environmental relationship with humans.

Statements		Level of agreement- Pre			Level of agreement- Post			
S1=Study 1, (N=140). S2= Study 2, (N= 187)		AG %	UC %	NA %	AG %	UC %	NA %	
1. Most of the underground water persists in the small pores of the rock, similarly to a well-watered sponge.	S1	31.8	36.5	31.7	57.1	26.2	16.7	NS
	S2	40	40	20	69.4	16.7	13.9	$P<0.01$
2. Underground water is similar to underground lakes that are located in spaces inside the soil.	S1	55.9	11.6	32.5	41.8	23.3	34.9	NS
	S2	75	19.4	5.6	58.3	13.9	27.8	0.04
3. Rocks don't influence the composition of water that penetrates them.	S1	14.3	26.2	59.5	14.3	31	54.7	NS
	S2	27.8	30.6	41.7	17.1	14.3	68.6	$P<0.01$
4. Only when rocks are cracked can water penetrate them.	S1	29.3	29.2	41.5	37.2	14.6	48.2	$P<0.01$
	S2	13.9	33.3	52.8	19.4	5.6	75	$P<0.01$
5. Ground water can be found only in rainy areas.	S1	33.3	23.8	42.9	23.3	26.2	50.5	NS
	S2	27.8	50	22.2	13.9	19.4	66.7	$P<0.01$

AG= agreement , UC= uncertainty, NA= disagreement

Table 2. Students´ perceptions as shown in a Cyclic Thinking Questionnaire (CTQ). A Likert-type questionnaire for assessing student's understanding the cyclic nature of the hydrosphere.

Statements		Level of agreement- Pre			Level of agreement- Post			
S1=Study 1, (N=140). S2= Study 2, (N= 187)		AG %	UC %	NA %	AG %	UC %	NA %	
1. Clouds are the starting point of the water cycle and the tap at home is its end point.	S1	58.3	7.3	34.4	42.8	9.5	47.6	NS
	S2	25.7	51.4	22.9	36.1	8.2	55.7	$P<0.01$
2. The amount of water in the ocean is growing from day to day because rivers are continually flowing into the ocean.	S1	25.6	30.2	44.2	16.7	28.6	54.7	NS
	S2	11.1	61.1	27.8	16.7	5.6	77.8	$P<0.01$
3. Amplification of evaporation as an effect of earth global warming may lead to a decrease in the amount of water on earth.	S1	66.6	9.6	23.8	28.5	16.7	54.8	0.03
	S2	47.2	25	27.8	41.7	2.8	55.6	0.04
4. If the population on earth will continue to grow, water consumption will increase, thus decreasing the amount of water on earth.	S1	57.2	21.4	21.4	57.2	11.9	30.9	NS
	S2	63.9	19.4	16.7	45.7	20	34.3	$P<0.01$
5. Ocean is the starting point of the water cycle and the Ground water is its end point.	S1	50.2	11.7	38.1	33.4	16.6	50	$P<0.01$
	S2	27.8	47.2	25	20	21.4	58.6	$P<0.01$

AG= agreement, UC= uncertainty, NA= disagreement

Outcomes found

Transformation of matter within the earth system serves as a basic principle for understanding its dynamic nature. Most of the students had difficulties in perceiving matter (water) transformation within the earth's reservoirs, and to synthesize the water-cycle components into a coherent system. In the water cycle, phenomena such as the quality of ground water and the formation of mineral water stemmed from the interrelationship between rocks and water. Yet, as can be seen in Table 1, after studying the program, only about 50% of the students acknowledged the connection between rocks and water, and perceived the scientific view of the dissolution process as a mechanism by which rocks and water interact (item 3, Table 1). Furthermore, despite students' acquaintance with the evaporation process, they diminished its influence as a mechanism for transferring water from the ocean to the atmosphere (item 2, Table 2).

Learned lesson

Analysis of the research results indicates that in order to develop teaching materials in an environmental interdisciplinary context, it is necessary to take into account the students' cognitive difficulties in understanding their natural environment as a system.

Therefore, the following changes were made in order to improve the teaching sequence in this regard:

a) The revealed difficulty, evidenced by many students, to perceive the underground water in the porous rocks, and to perceive the underground system as a dynamic one, lead to the development of three dimensional models set for simulation of the underground system. The process of modeling engaged students in the scientific practice of using models as tools for observation, exploration, synthesis, and, to a lesser extent, prediction of earth systems and their behavior.

b) The students' difficulty to perceive earth - the natural environment - as interacting natural subsystems required the development of new knowledge-integration activities. For example, Figure 3 presents an 8th grade student's outcome of such an activity, in which he summarizes the inter-connections and transference of matter, after he explored a polluted river, spring, stalagmite cave, and a water treatment plant during a field trip.

c) The students' difficulty to acknowledge their involvement, as human beings, in environmental aspects, such as water pollution, sewage, and water consumption, lead to the development of workshops that facilitated the development of environmental perception.. An example of an activity designed to develop environmental participatory decision-making abilities is the factory assignment. In the factory assignment the students were told about a chemicals factory that is planned to be built in their town. The students were provided with a list of experts in the fields of geology, economy, environment, hydrology and chemistry. They were required to ask each expert three questions in order to decide whether they would recommend building the factory. In addition, the students elaborated on their questions and explained, for each question, why they thought it was important and relevant to the assignment. The use of such participatory decision-making processes is necessary for educating for sustainable development since, it is value-driven and the expected norms are made explicit in order to be examined, debated, tested and applied (Springett & Kearins, 2005).

Case description and results: Study two

Participants

The second implementation cycle was conducted with about 500 junior high school students (7th-8th grades) from four different urban schools. Three 8th grade classes from two urban schools were selected from this population for a case study. The case study deals with the development of systems-thinking skills at the junior high school level. The sample of the current study includes 70 junior high school students (8th grade) from three classes in two different schools. These specific classes were selected because their teachers were

In the field trip you were exposed to processes of transportation of matter between the earth systems participitating in the water cycle. Write in the table examples of those processes that you observed in the field trip.

The matter	Transport from the sub-earth system	To the sub earth system	Throughout the process of
Rain	Atmosphere (clouds)	Geosphere (earth's crust)	Penetration
Calcite ($CaCO_3^-$)	Geosphere (limestone rocks)	Hydrosphere (groundwater)	Dissolution
Ions of Calcite	Hydrosphere (groundwater)	Geosphere (stalagmite cave)	Sedimentation
Water	Hydrosphere (groundwater)	Biosphere (plant roots)	Absorption
Chemicals	Hydrosphere (rivers)	Hydrosphere (groundwater)	Penetration
Water	Hydrosphere (groundwater)	Hydrosphere (spring)	Underground flow
Sewage	Biosphere (humans and man-made environment)	Hydrosphere (rivers)	Surface flow

Figure 3. An outcome of a knowledge integration activity of an 8th grade student following an outdoor learning activity involving a spring, a stalagmite cave, a polluted river, and a water treatment plant.

willing to participate in a professional development course regarding the "Blue Planet" program and because they agreed to one of the author's observation of all the classes. The objectives of this study was twofold: (a) to identify the higher-order thinking skills that were involved in the systems thinking process; and (b) to evaluate the influence of learning the “"Blue Planet"” program on the development of systems thinking of junior high school students.

Research tools

Data for this study was obtained through a series of quantitative and qualitative research tools. We re-administered the GDN and CTQ questionnaires mentioned above to determine whether the changes we have made yielded improved results, and we added a further research tool – drawings of the water cycle in nature with captions explaining the processes – in order to arrive at a more qualitative view of the students' grasp of the cyclic and systemic nature of the water cycle. It is important to note that this second cycle of testing was conducted in the same school as before and with classes of the same level and with the same teachers.

Students' drawings - Students' drawings can serve as “windows” to children's conceptual knowledge. They are one of several meaningful tools that can be employed to assess scientific conceptual knowledge, observational skills, and the ability to reason (Dove, Everett, & Preece, 1999; Rennie, & Jarvis, 1995; White, & Gunstone, 1992). In this study, the students were asked to draw, both before and after the learning sequence, "what happens to the water in nature"? The students were assured that they were not expected to perform an artistic drawing and were instructed to incorporate as many items as they could in their drawings. No resistance to performing the drawing assignment was observed among the participants.

The students' drawings were analyzed using Rennie and Jarvis's (1995) coding framework. Within this framework, researchers determine the appearance frequencies of certain pre-defined elements in order to arrive at a vista of the conceptual model of the participants regarding the topic under investigation. The elements can be represented pictorially and/or verbally by captions. In order to increase reliability and consistency of the analysis procedure, both authors of the present study coded the drawings individually, and only after comparing and discussing their analyses, developed a standardized coding system. As a result of this procedure, the following criteria were finally arrived at: (a) the appearance of the earth systems; (b) the appearance of processes; (c) the appearance of human consumption or pollution, and (d) cyclic perception of the water cycle according to the connection point among the water cycle components.

Outcomes found

The analysis of the GDN and CTQ tools reveal that the program's effectiveness in regard to the students' ability to identify dynamic relationships within the system (GDN), and cyclic thinking (CTQ) improved. Tables 1 and 2, 3 show that items in which the changes between the pre and post test were not significant (NS) in study 1, were significant in study 2 ($P<0.01$). This is especially evident in item 5 in Table 1, “Ground water could be found only in rainy areas”, where in study 1 the students' improvement between the pre and post tests was statistically insignificant, while in study 2, the students improved their answers from 22.9% in the pre-test to 66.7% in the post-test.

There is an interesting finding in regard to items 1 and 2 of the GDN (in table 1). In fact, these two statements are contradictory. Either most of the underground water persists in small pores of rock (item 1) or in underground lakes. However, our findings indicate that while in item 1 in the post- test of study 2, 70% of the students presented a scientifically correct model of underground water movement through porous rock (in relation to 40% in the pre test); in parallel, in regard to item 2 in study 2, 58% of the students described the groundwater as a static, sub-surface lake. This finding is strengthened by the analysis of the drawings, in which about a third of the students who included ground water in their drawing also evidenced this contradictory phenomenon. An example of this can be seen in Figure 4. We will further discuss this phenomenon in the Learned lesson section.

Analysis of the students' drawings before the learning process indicates that significant improvements took place between the pre and post tests. Table 3 summarizes the distribution of the water-cycle processes indicated by the students both verbally and pictorially, before and after the learning sequence.

As can be seen in Table 3, in the pretest, students who drew the water cycle usually represented the upper half (i.e. evaporation, condensation and rainfall) and ignored the ground water system. More than 50% of the students did not identify components of the ground water system even in cases where they were familiar with the associated terminology. The post-learning drawings revealed that most of the students increased their acquaintance with the components and processes of the water cycle significantly. For example, 90% of the students incorporated the penetration of rain within the soil and rocks in their post-learning drawings. In the water cycle, phenomena such as the quality of ground water and the formation of mineral water stem from the interrelationship between rocks and water. Yet, before studying the program, only 30% of the students acknowledged in their drawings the connection between the composition of the water solution and the rocks that

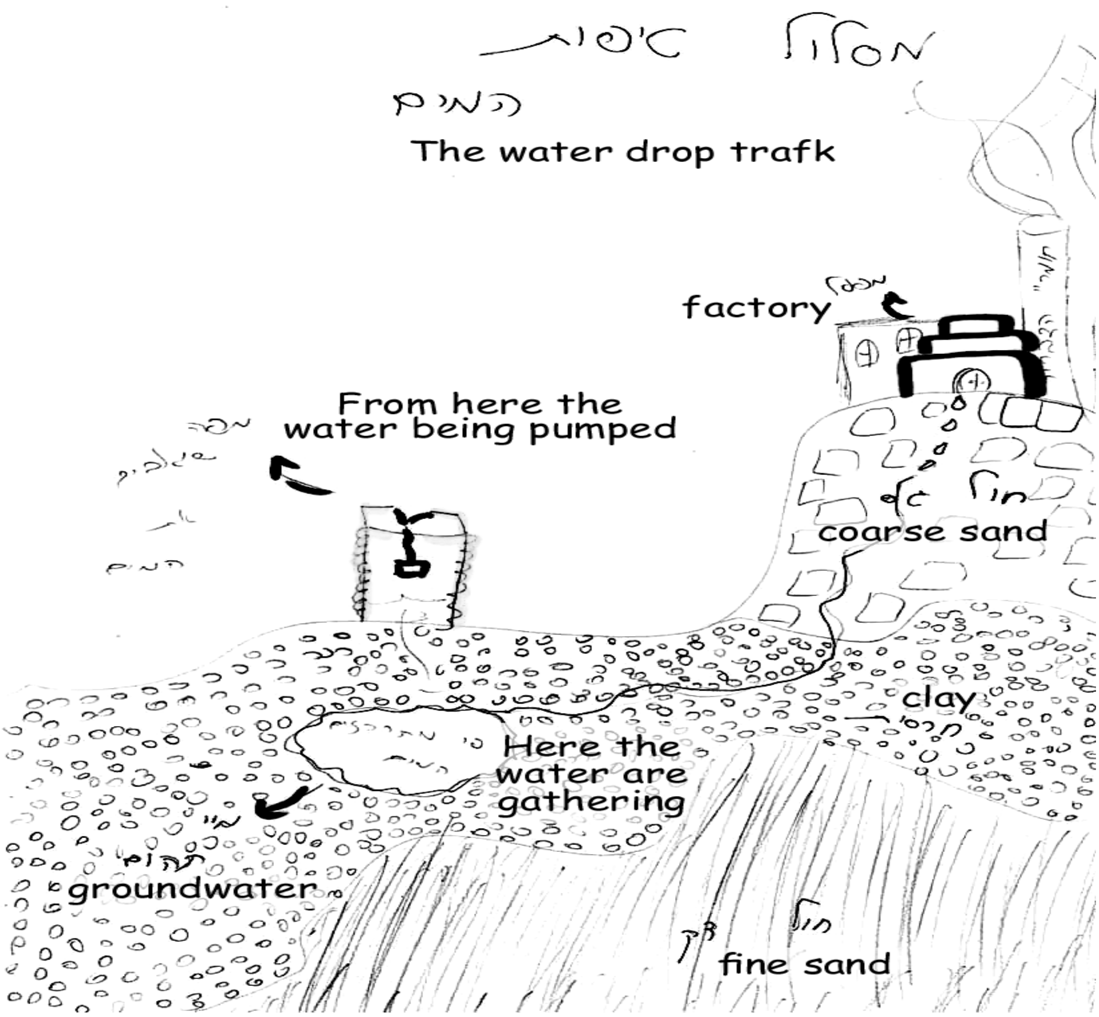

Figure 4: Student drawing evidencing both scientific and non-scientific models of water underground movement.

they passed through. After studying the program, about 70% of the students acknowledged the connection between rocks and water. Consequently, about 37% of the students presented in their post-learning drawings a connection through the rivers, through underground water flow or transpiration, compared to 3.7% of them in the pre-learning ones.

To sum, the drawings' analysis indicates that most of the students had significantly shifted from a fragmented perception of the water cycle to a more holistic view of the water cycle. However, it is important to mention that many students still presented difficulties in understanding the hidden processes that demonstrate the cyclic nature of the system. This can also be viewed in the CTQ post test results study 2, where about 40% of the students still did not realize that in a cyclic process the overall amount of matter is being conserved (Table 2, items: 1, 5). Another disturbing result, is the absence of Man in the conceptual models represented by the drawings. Only 15.3% noted pollution and only 20.92% noted water consumption in their drawings (items 12 and 13 respectively, in Table 3)

Learned lesson

In general, study 2 revealed that junior high school students could focus on recognizing the inter-connections between the parts of a system and then synthesize them into a unified view of the whole. Students who were involved in the learning process – through knowledge integration activities, scientific inquiry, and outdoor learning – achieved now a meaningful improvement of their cyclic and systemic understanding of the water cycle.

This last statement is not clear. Do you want to say that therefore a number of changes were incorporated into the curriculum based on the outcomes of Study Two?

In regard to the parallel conflicting scientific and non-scientific conceptions regarding how water was stored underground, it is important to mention other conceptual change studies suggesting that the shifting to the scientific model does not happen in a replacement fashion, but rather occurs in parallel (Marques and

Table 3: Student perceptions of the water cycle as shown in their pre and post drawings (McNemar's test) n=220

A – Process within the water cycle	Pre (%)	Post (%)	M - value	P - value
1. Evaporation	94.59	97.3	0.33	NS
2. Condensation	62.16	70.27	0.69	NS
3. Precipitation	100	98.1	1.1	NS
4. Penetration	67.57	94.59	8.33	0.004
5. Underground flow	10.81	59.46	16.2	0.001
6. Surface flow	37.8	59.46	4.57	0.033
7. Melting	0	27.03	-	0.01
8. Freezing	0	5.41	-	NS
9. Dissolution	0	21.6	-	0.01
10. Transpiration	0	24.9	-	0.001
11. Capillarity	0	29.73	-	0.001
12. Pollution	0	15.3	-	0.012
13. Water consumption by man	13.5	20.92	0.5	NS

Thompson, 1997). In regard to groundwater, Libarkin et al, (2005) and Libarkin and Kurdziel (2006), found that university students evidence both scientific and non-scientific models. Nevertheless, in order to try and facilitate this, apparently robust, conceptual change, we added an outdoor learning activity in which students explored a modern well which supplies water to their city. In this activity, the students saw that the well model (developed as a result of study 1) was indeed a reflection of real wells, where there were no underground lakes even as far as 200 meters down.

This statement is also confusing. Consider rearranging it as: Man's involvement in the water cycle, as mentioned above, was largely ignored by many of the students.

In other words, the preservation of underground water quality and water reservoirs seemed irrelevant issues from the perspective of their daily life experience. To rectify this situation we decided, in accordance with Linn & Hsi (2000), to structure the interdisciplinary learning unit around authentic questions that directly relate to environmental phenomena that students can interact with. We integrated Linn and Hsi's approach with the "Explanatory stories" approach suggested by Millar and Osborne (1998). This latter one emphasizes that understanding is not concerned with individual propositions or concepts, but rather with inter-related sets of ideas that provide a framework for the understanding. Therefore, a crucial step in our model was to identify a current, ongoing environmental challenge frequently talked about and debated in the Israeli media. This topic – water availability and quality – was then utilized as an environmental "cover story" to head the cross-curricular learning process. Figure 5 illustrates our model for dealing with an interdisciplinary subject such as the hydrosphere.

As can be seen, the sequencing of the authentic questions constitutes a cover story which provides smooth passage from one chapter to another and from one discipline to another throughout the book. Our model tries to distinguish between the curriculum developers' goals and the students' needs. For example, for us, curriculum developers, the main objective of the ""Blue Planet"" program was to develop environmental insight through the development of students' cyclic and systems thinking abilities. However, for the students, we had to find a relevant question that would motivate them to become involved with the learning process. For example, "Will we have enough drinking water forever?" This question raises a series of questions such as: Where can we find water on earth? What influences the water quality? While confronting such secondary questions, students learn basic core curriculum scientific knowledge. For instance, in order to answer the question "What is the relationship between life and water?" students construct concepts such as metabolism (breathing), fertilization, growth, cellular structure, and stimulus and response. It is suggested that in order to determine the availability of water resources for humans, students could explore the distribution of water on Earth. For example, while dealing with the question "How did the oceans become salty?" the students learned some chemistry-based concepts such as dissolution and evaporation, particles, water molecules and compounds, and the concentration of ions. While dealing with these concepts, in inquiry-based programs, the students begin to understand the meaning of some of the most basic concepts used in scientific methodology for an independent inquiry process. Such an understanding provides them with the means for making hypotheses, designing experiments, collecting and analyzing data, and reporting their findings. Moreover, they learn how to use higher-order learning skills and how to apply scientific methodology for making their own investigations.

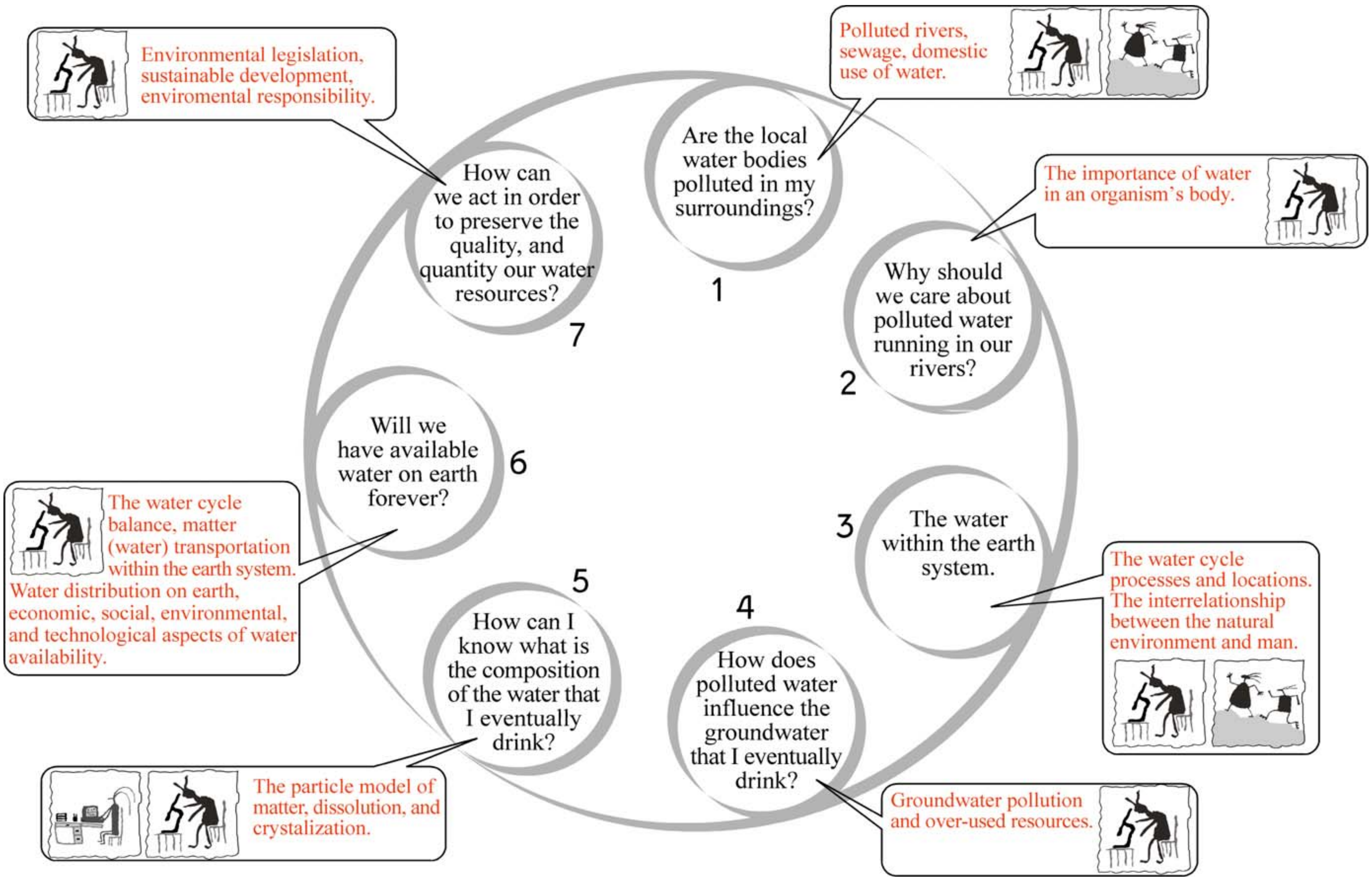

Figure5.A model of the program's learning sequence. In the circles: the authentic questions that "move" the "story" from one chapter to another. The boxed external remarks: the main concepts, which are discussed in the various chapters. The boxed icons: the various learning environments that are involved in the learning process (lab, outdoors and computer).

Based on the collected data, it was possible to revise the curriculum materials into its final form consisting of a workbook: "The Blue Planet – the water cycle within the earth systems", a field workbook, and a project guidebook, that is available at (http://stwww.weizmann.ac.il/g-earth/blueplanet).

SUMMARY AND DISCUSSION

This study presented a spiral, designed-based research, which aimed at developing a meaningful learning experience that would lead to the development of environmental insight among junior high school students. The improved learning outcomes and program design suggest that the model presented here for development and implementation of an interdisciplinary environmental program within the science curriculum is promising, and that the learning programs resulting through such design procedures have a high potential of being successful. A summary of "Blue Planet" program design elements follows. We recommend using them in other programs seeking to foster students' understanding of natural cycles within the context of their influence on people's daily life, rather than in the isolation of their specific scientific domains.

The Blue Planet program presents a "cover story" about the water cycle on Earth. The choice of stories should balance between several factors. On the one hand, the breadth of the scientific knowledge requires a selection of the subjects that the curriculum will employ. On the other hand, the curriculum should leave sufficient time for discussion, thinking and analysis. For example, using knowledge integration activities, students were able to connect and integrate knowledge acquired in school with components of the earth systems observed in the field trip. Thus, the students confronted their difficulties in identifying the system components; created relationships among the components and organized and placed them within a framework of relationships. Consequently, they were able to develop high-order thinking skills such as systems thinking and environmental insight.

It was attempted to design a learning environment that on the one hand, presents an interdisciplinary scheme for presenting the scientific mechanisms underlying natural phenomena, and on the other hand, presents a learning program that focuses on relevant environmental topics in the students' immediate environment. Many programs and researchers call for structuring science curriculums so as to connect them to students' lives. Calls for using "authentic tasks" making science "relevant", promoting community connections, and building from local contexts are common features in today's science education reform initiatives (Dillon, 2003; Palmer, 2005; Rivet & Krajcik, 2008). Furthermore, it is not sufficient for the problems only to be of interest to the students. A necessary characteristic for relevancy is that the problems should be meaningful and provide a need-to-know situation to learn specific scientific ideas and concepts (Rivet and Krajcik, 2008).

This sentence is not clear. Consider re-writing as: The fact that the student selects the task and conducts within small working groups, with the teacher acting as a moderator of enthusiasm and interest is, undoubtedly, essential for the learning process (Palmer, 2005).

The role of the teacher is to mediate between the students and scientific knowledge, by helping students use the inquiry method to investigate the Earth and its processes (Kali, Orion & Eylon, 2003). One of the main barriers for the success of the "Blue Planet" program was the lack of teachers' willingness to get out and teach in an outdoor learning environment. They preferred to remain in their usual settings of the laboratory. Braund and Reiss (2006) explain that, since teaching within a laboratory becomes part of teachers' professional identity (reinforced, we suspect), laboratory-produced knowledge is seen as having higher worth than other sorts of knowledge. It is suggested that the teachers' positive experiences with teaching an environmentally based program outdoors may help in altering their professional identity and consequently play a central role in their motivation to adopt an interdisciplinary approach. Hopefully, this will result in the teachers' becoming fine models of enthusiasm and interest.

Regarding interdisciplinary, understanding nature's phenomena is not possible without an interdisciplinary outlook, and this outlook can only be developed in the real world; in the natural environment. In order to maximize the cognitive benefit of school trips, DeWitt & Osborne (2007) suggest that they should be conducted in the following manner: teachers should be encouraged to become familiar with the setting before the trip; to orient students to the setting and agenda and clarify learning objectives; to plan pre-visit activities aligned with curriculum goals; to allow students time to explore and discover during the visit; to plan activities that support the curriculum and also take advantage of the uniqueness of the setting; and to plan and conduct post-visit classroom activities to reinforce the school trip experiences (p.686). These suggestions are in line with the manner in which the fieldtrips in the present research were conducted (detailed in Orion, 1993). However, in order to allow the outdoor learning environment to become an integral part of the learning sequence in environmental education, the way students learn from direct and concrete experiences, in a real and relevant environment should be further explored.

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Eurasia Journal of Mathematics, Science & Technology Education, 2009, **5**(1), 63-70

Investigation of A Pattern Between Students' Engagement in Argumentation and Their Science Content Knowledge: A Case Study

Handan Eşkin
Çemberlitaş Anatolian High School, Istanbul, TURKIYE

Feral Ogan-Bekiroğlu
Marmara University, Istanbul, TURKIYE

Received 05 April 2008; accepted 19 July 2008

The aim of this study was, first, to investigate any pattern between students' quantitative contribution to argumentation and their science understanding, and second, to analyze any relationship between students' qualitative contribution to argumentation and their scientific knowledge. Participants of the study were four tenth-grade students. The participants were videotaped during the argumentations embedded in the physics class. Two interviews were conducted with each participant in order to examine their scientific understanding deeply. Argumentations were analyzed as quantitative and qualitative by using Toulmin's Argument Pattern. Results from the study illustrate no significant relationship between students' engagement in argumentation and their science content knowledge.

Keywords: Argumentation, Engagement, Contribution, Physics, Scientific Knowledge

ARGUMENTATION IN SCIENCE EDUCATION

While the traditional alternative for concept learning has been process learning, newer ideas in cognitive and social psychology emphasize instructional sequences/units that seek outcomes related to students' reasoning and communication in science contexts (Duschl, Ellenbogen & Erduran, 1999). It is in argument that higher order thinking and reasoning figure in the lives of most individuals (Kuhn, 1992). If students are to develop the skills of scientific argument for themselves, and not just provide an audience for the teachers' reasoning, then science classrooms need to offer opportunities to practice such reasoning for themselves (Driver, Newton & Osborne, 2000). Argumentation is a reasoning strategy and comes under the reasoning domains of informal logic and critical thinking (Jimenez-Aleixandre, Rodriguez & Duschl, 2000). Students in an argumentation process articulate reasons for supporting a particular claim, attempt to persuade or convince their peers, express doubts, ask questions, relate alternate views, and point out what is not known (Driver, Newton & Osborne, 2000). Erduran, Simon and Osborne (2004) claim that when students engage in a reasoning process and support each other in high-quality argument, the interaction between the personal and the social dimensions promotes reflexivity, appropriation, and the development of knowledge, beliefs, and values.

There is ample research on the investigation of effects of promoting argumentation on students' learning. Niaz, Aguilera, Maza and Liendo (2002), for instance, found that given the opportunity to argue and discuss, students' understanding of atomic structure

Correspondence to: Feral Ogan-Bekiroğlu, PhD in Science Education, Marmara Üniversitesi, Atatürk Eğitim Fakültesi, OFMAE Bölümü, Fizik Eğitimi AD, Göztepe İstanbul , TURKEY
E-mail: feralogan@yahoo.com

E-ISSN: 1305-8223

went beyond the simple regurgitation of experimental details. Similarly, Nussbaum and Sinatra (2003) showed that argumentation endorsed conceptual change. In addition, Mason (1998) discovered that while reasoning and arguing collectively, students constructed more advanced knowledge by sharing cognition. Eskin and Ogan-Bekiroglu (2007) revealed that the students in the experimental group, where argumentation was embedded in the instruction, developed more correct and detailed reasoning of the physics concepts they argued than the students in the control group. Literature review presents positive effects of argumentation on construction of scientific knowledge. That is, explicating, comparing and challenging ideas can improve students' learning.

Purposes of the Study

Studies show that different types of groupings, in terms of ability levels, gender, and the number of participants affect group discussion and individuals' behavior (amount of verbal participation, giving and receiving explanations, etc.) (Alexopoulou & Driver, 1996). In addition, students' willingness to acknowledge and deal with situations that may involve argument depends on their perceptions and interpretations of the purpose and the context of the task, and the learning situation (Perret-Clermont, Perret & Bell, 1991). However, within both Vygotskian and Piagetian traditions, the focus has been on the interaction process itself so that cognitive capacities of the individuals have not been examined (Kuhn, Shaw & Felton, 1997). A small number of studies examined the relationship between students' contribution and their scientific knowledge. Eichinger, Anderson, Palinscar and David (1991), for example, found that the students who were already skillful in constructing scientific arguments participated more. Sadler and Fowler (2006) suggested that science content knowledge could affect the manner in which individuals defended and justified their positions. Therefore, the aim of this study was, first, to investigate any pattern between students' quantitative contribution to argumentation and their science understanding, and second, to analyze any relationship between students' qualitative contribution to argumentation and their scientific knowledge.

METHODOLOGY

This qualitative research was utilized as a case study design focusing on one group during the argumentation process.

Instructional Context

The first author was the physics teacher of the class where there were 26 tenth-grade students in a state high school. Five argumentations were embedded through the dynamics chapter in ten-week duration. All of the argumentations were dialogical where different perspectives were being examined and the purpose was to reach agreement on acceptable claims or courses of action (Driver, Newton & Osborne, 2000). The contents of the argumentations were related to the following subjects: Free fall, Newton's Second Law, Newton's Third Law, motion in the space, and rotational motion. As the context and content of argumentation may affect participants' argumentation quality (Duschl & Osborne, 2002), argumentations were promoted in different contexts. According to Kuhn et al. (1997), the number of argumentation is directly proportional to the quality of participants' argumentation. Therefore, the third and fourth argumentations were taken into account in this study under the assumption that the students got used to argue. The third argumentation was related to Newton's Third Law and promoted in the prediction-observation-explanation context. The fourth argumentation, on the other hand, was related to motion in the space and promoted in the competing theory context. Students worked as groups in the beginning of the argumentations and then, each group expressed their ideas in a whole-discussion. There were three or four students in each group.

Participants

Participants of the study were four students in one group. They were volunteers for the study and coded as P1, P2, P3 and P4. Since it was an all-girls school, all of the participants were female. In order to be able to work with the participants having different levels of science content knowledge, the students in the class answered Force Concept Inventory (FCI) before the instruction. FCI is composed of 30 multiple-choice questions and designed to monitor students' understanding of force and related kinematics. The students were required to give their reasons for their choices during the implementation of the inventory. Based on the results of the implementation, P1's content knowledge was determined as moderate, while P2's content knowledge was diagnosed as very high. Furthermore, P3's content knowledge was found as high, whereas P4's level of knowledge was low.

Data Collection

Due to the fact that the participants were in the same group through the instruction, some of the factors that might affect contribution, such as group dynamics, gender and number of the participants, were kept constant in the research. The participants were videotaped during the argumentations. Data for this research were gathered from their group discussions.

Two interviews were conducted with each participant in order to examine their science understanding deeply. Think-aloud protocol was used in the interviews where the explanation questions were asked. Four questions, all had a few sub-questions, related to Newton's Third Law were asked in the first interview. Likewise, five questions about motion on a frictionless area were used in the second interview's protocol. However, because of the content of the questions, the students needed to use other dynamics concepts, such as Newton's First and Second Laws, in order to answer the questions. Most of the questions were the generation of the previous question and prepared by changing the condition of one parameter in that question. The interviews were done in the physics laboratory and lasted 20 to 30 minutes. The interviewer was the teacher; hence, the participants were ensured that their answers would not affect their grades in any way.

Data Analysis

Erduran et al. (2004)'s methodological approach was used in the argumentation analysis. In their approach, they contextualized the use of Toulmin's Argument Pattern (TAP) and analyzed argumentation as quantitative and qualitative. Transcripts of the video recordings of the argumentations were divided into sub-arguments and each sub-argument was analyzed. There were six sub-arguments in each argumentation. Content was the factor in determination of sub-arguments.

Regarding components of TAP, data supports the claim and warrant provides a link between the data and the claim. In addition, backing strengthens the warrant and is a generalization making explicit the body of experience. Erduran et al. (2004) state that rebuttal points to the circumstances under which the claim would not hold true. In other words, rebuttal is the extraordinary or exceptional circumstance that might undermine the force of the supporting arguments (Erduran et al., 2004). Qualifier, on the other hand, is a phrase that shows what kind of degree of reliance is to be placed on the conclusions (Erduran et al., 2004). Figure 1 represents Toulmin's Argument Pattern.

An episode is given below from one sub-argument in the motion in the space argumentation. Students were working on the following question: "What would happen if the astronaut trying to reach the satellite was three times heavier? Please describe his motion (from the scene of "Mission to Marst" movie)".

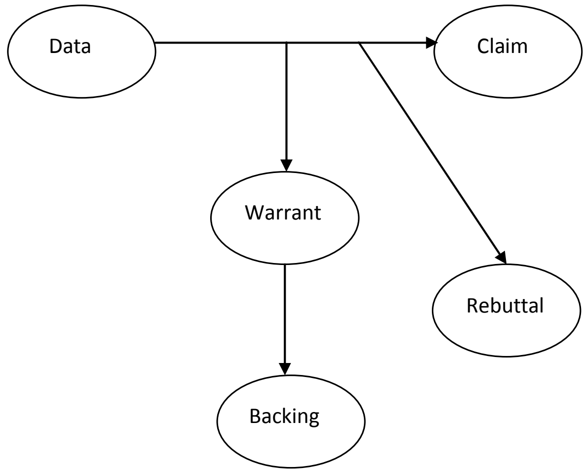

Figure 1. Toulmin's Argument Pattern (Retrieved from Erduran et al., 2004)

P2: If the mass of the astronaut increases, his acceleration will decrease (claim)
P2: If we use f=m.a, it will change. This is more logical. For example, if the force is 10 and the mass is 1, it will move with the acceleration of 10. OK? This time, the force is 10 but the mass is 2. It will move with the acceleration of 5. OK? (data). Therefore, he (the astronaut) would move slower (warrant).
P3: To me, it (velocity) does not change according to mass (rebuttal). I will say something: If we leave a hammer and a quill at the same time, will both of them drop with the same velocity? (rebuttal).
P1: They will drop at the same time in the space (qualifier).
P3: It will be the same on the frictionless area..... I mean, If there is air maybe it will change..... There need to be gravitation in order to be acceleration, right? They will drop at the same time (warrant)...............

For the quantitative measure, the features of TAP scheme were determined. For example, if the sub-argument was composed of the claim (C) and data (D), it was coded as C.D. Nonetheless, if the sub-argument was composed of the claim (C), data (D), warrant (W), backing (B) and rebuttal (R), it was coded as C.D.W.B.R. Counter-claims were coded as CC and qualifiers were coded as Q. Total number of the components in one sub-argument was equaled to 100 and then, each student's contribution to the sub-argument was calculated as a frequency percent value. Overall contribution of the student to the argumentation was determined by calculating the average of six percentage values.

The qualitative measure focused on the quality of rebuttals. According to Erduran et al. (2004), if the sub-argument included a claim versus a counter-claim or a claim versus a claim, it was coded as Level 1. If the sub-argument was composed of a claim versus a claim with either data, warrants, or backings but did not contain any rebuttals, it was coded as Level 2. If the sub-argument had a series of claims or counter-claims with either data, warrants, or backings with the occasional weak rebuttal, it was coded as Level 3. Moreover, if the sub-argument consisted of a claim with a clearly identifiable rebuttal, it was coded as Level 4. Finally, if the sub-argument displayed more than one rebuttal, it was coded as Level 5. Each student's contribution to the sub-argument was determined. Then, the student's overall contribution to the argumentation was found by calculating the average of six values.

Bidimensional coding scheme developed by Hogan and Fisherkeller (1996) was used to analyze students' science content knowledge. Based on this scale, the participant's understanding concurring with the scientific proposition and having sufficient detail to show the thinking behind them was coded as compatible elaborate. However, if the essential details were missing, it was coded as compatible sketchy. The participant understands disagreeing with the scientific proposition and having details or coherent logic was coded as incompatible elaborate. Nevertheless, if very few details or logic were given for the participants' nonscientific understanding, it was coded as incompatible sketchy. If the participant made sketchy statements concurring with the scientific proposition and also made sketchy statements disagreeing with the scientific proposition, his/her understanding was coded as compatible/incompatible.

P4's excerpts from the first interview related to Newton's Third Law were given below as an example. The question was as following: Are there any forces exerting on the table, which is stationary and being pushed by a person? What would you do to move the table? Why?

P4: ……. I would push the table more to move it.
Teacher: What would you do to push it more?
P4: I would get a support from somewhere. I would lean on the wall.
Teacher: Why would you need a support?
P4: It would give me an impulse and I apply it to the table.
Teacher: Why?
P4: I don't know. We did something like that in the experiment. Maybe it (the wall) would give me an impulse, a support, and I would take power from it. If I lean on the wall, it would give me an impulse. If I take power from the wall, I would push the table.

P4 did not consider the function of the frictional force in moving the table. Although her answer was correct, she did not use much conceptual knowledge in generating her explanations. Instead, she tried to explain the reasons based on her observations in the experiment. Therefore, P4's knowledge related to Newton's Second Law was coded as compatible sketchy.

The dialogue between the teacher and P4 from the second interview related to motion on a frictionless area was provided for another bidimensional coding example. The participant was answering the following question: Explain the motion of an object that is placed on a frictionless inclined plane of angle θ and subjected to one constant force.

Teacher: What do you think about the values of velocity and acceleration of two objects on a frictionless area; one is subjected to one constant force, while the other one is subjected to one instant force?
P4: According to the law, when an instant force acts on an object at rest, it remains at rest; on the other hand, when an instant force acts on an object in motion, it continuous its motion. Because of the frictionless area, it moves until it comes across with an obstacle. However, when a constant force acts on an object I think it (the object) moves continuously with the velocity caused by the constant force. But I cannot think the difference between the two. What is the difference?
Teacher: What do you think?
P4: I think, both objects move with a constant velocity.

Since P4 had alternative conceptions about the acceleration of the object subjected to one constant speed and was not sure about her explanations, her knowledge related to Newton's Second Law was determined as incompatible sketchy.

The first author coded both the arguments and the students' understanding and then, the codes were revised by two authors many times. High agreement was achieved. Comparisons were made between the argumentations as well as within the argumentation in order to detect any pattern between students' engagement in argumentation and their scientific knowledge.

RESULTS

Table 1 and Table 3 illustrate the quantitative and qualitative analyses of argumentations. Table 2 and Table 4, on the other hand, present the coding schemes of the participants' science content knowledge. Comparison of argumentation tables and knowledge tables enabled to trace any relationship between two phenomena.

P1's scientific understanding was moderate according to other students' understanding. Although her understanding of Newton's Third Law and measure of inertia somewhat concurred with the scientific propositions, her understanding of effects of force on motion was not completely compatible with scientific knowledge. Regarding the argumentations, she was always the third contributor in terms of quantity (25.6% and 24.3%). The average Level of her qualitative contribution was 2 (Level 2.5 and Level 2). Thus, P1's both quantitative and qualitative contributions to

Table 1. The quantitative and qualitative analyses of the Newton's Third Law argumentation

SA	TAP	P1	QNC (P1)	QLC (P1)	P2	QNC (P2)	QLC (P2)	P3	QNC (P3)	QLC (P3)	P4	QNC (P4)	QLC (P4)	LSA
SA_1	C.D. W. CC.	CC. C.	18.2	1	C.D. W.	27.3	2	C.D. C.D.	36.4	2	C.W.	18.1	2	2
SA_2	C.D. W. CC. R.	C.R. D. CC	20	3	C.D. R.R (CC. D.W. B)	35	5	C.D. C.D. W.	25	2	C.R. C.D.	20	4	5
SA_3	C.D. W.	D.W.	33.3	2	C.C. D.	50	2	C	16.7	1	-	-	-	2
SA_4	C.D. W. CC. R.	CC.	5	1	R (CC. D.W) C.D. W.R.	35	5	D.C. D.C. D. C.C.	35	2	C.D. C.D. W.	25	2	5
SA_5	C.D. W.R.	C.D. C.D. R.	38.4	4	C	7.7	1	C.D. W. C.D. W.	46.2	2	R.	7.7	4	5
SA_6	C.D. W. CC. R.	C.D. R.CC D.C. D.	38.9	4	C.D. W. D.W. CC	33.3	2	C.C.	11.1	1	C.D. D.	16.7	2	4
AQNC			25.6			31.4			28.4			14.6		
AQLC				2.5			2.8			1.7			2.3	3.8

SA: Sub-Argumentation; TAP: Components of Argumentation; P1-P6: Participants; QNC: Quantitative Contribution (%); QLC: Qualitative Contribution; AQNC: Average Quantitative Contribution; AQLC: Average Qualitative Contribution; LSA: Level of Sub-Argumentation

Table 2. The Coding Scheme of The Participants' Understanding of Newton's Third Law

Subjects	P1	P2	P3	P4
Newton's First Law of Motion	Compatible / Incompatible	Compatible / Incompatible	Compatible elaborate	Compatible elaborate
Measure of inertia	Compatible sketchy	Compatible elaborate	No evidence	Compatible sketchy
Newton's Second Law of Motion	Compatible sketchy	Compatible sketchy	Compatible sketchy	Compatible sketchy
Kinematics	Compatible sketchy	Compatible / Incompatible	Compatible / Incompatible	Compatible / Incompatible
Newton's Third Law	Compatible elaborate	Compatible elaborate	Compatible elaborate	Compatible elaborate

argumentation and her science content knowledge were directly proportional.

P2's scientific understanding was higher than P1's understanding. While her understanding of Newton's Second and Third Laws was scientific, her understanding of Newton's First Law and effects of force on motion integrated many non-scientific claims. P2 was the one who quantitatively contributed most to two argumentations (31.4% and 46.9%). Likewise, P2's qualitative contribution was the highest among the other participants. The average Level of her qualitative contribution was 3 (Level 2.8 and Level 3.2). There seemed to be no correlation between P2's both quantitative and qualitative contributions to argumentation and her scientific knowledge.

P3's scientific understanding was the highest among four participants' understanding. None of her codes was completely incompatible. That is, she had some scientific propositions for every concept discussed in the argumentations. On the other hand, she was the second contributor in two argumentations regarding

Table 3. The quantitative and qualitative analyses of the motion in the space argumentation

SA	TAP	P1	QNC (P1)	QLC (P1)	P2	QNC (P2)	QLC (P2)	P3	QNC (P3)	QLC (P3)	P4	QNC (P4)	QLC (P4)	LSA
SA_1	C.D.W. CC. R.Q.B	CC. W.B. R.R	31.2	5	C.D. C.D. C.D.W.	43.8	2	W.Q. CC. W.	25	2	-	-	-	5
SA_2	C.D. W.R.	-	-	-	W.R (CC. D)	50	3	C.D. C.	50	2	-	-	-	3
SA_3	C.D. W.R.	C.D. W	50	2	R (CC. D.W)	50	4	-	-	-	-	-	-	4
SA_4	C.D. W.R.	C.D	25	2	C.D. W.	37.5	2	R (CC. D.W)	37.5	4	-	-	-	4
SA_5	C.D. W.R.	C.D. W	30	2	C.D. W.R (CC. D)	50	3	C.D.	20	2	-	-	-	3
SA_6	C.D.W. CC. R.B.	B	10	1	C.D. W. R.B.	50	3	CC. R.W. B.	40	3	-	-	-	5
AQNC			24.3			46.9			28.8			0		
AQLC				2			3.2			2.2			0	4.0

SA: Sub-Argumentation; TAP: Components of Argumentation; P1-P6: Participants; QNC: Quantitative Contribution (%); QLC: Qualitative Contribution; AQNC: Average Quantitative Contribution; AQLC: Average Qualitative Contribution; LSA: Level of Sub-Argumentation

Table 4.The coding scheme of the participants' understanding of motion in the space

Subjects	P1	P2	P3	P4
Newton's First Law of Motion	Compatible elaborate	Compatible / Incompatible	Compatible elaborate	Compatible elaborate
Measure of inertia	Compatible sketchy	Compatible / Incompatible	Compatible / Incompatible	Compatible sketchy
Newton's Second Law of Motion	Incompatible sketchy	Compatible elaborate	Compatible elaborate	Incompatible sketchy
Kinematics	Compatible / Incompatible	Compatible sketchy	Compatible elaborate	Incompatible elaborate
Effects of force on motion	Compatible / Incompatible	Compatible / Incompatible	Compatible / Incompatible	Incompatible sketchy

quantity (28.4% and 28.8%). Like P1's situation, the average Level of P3's qualitative contribution was 2 (Level 1.7 and Level 2.2). Hence, there seemed to be no correlation between P2's both quantitative and qualitative contributions to argumentation and her science content knowledge.

P4's scientific understanding was quite inconsistent comparing the two argumentations. Even though her knowledge related to the concepts discussed in the Newton's Third Law argumentation partially agreed with scientific claims, her understanding in the motion in the space context was mostly incompatible with scientific knowledge. In terms of quantitative contribution, she was always the last contributor (14.6% and 0%). Her qualitative contribution was also low as it matched with Level 1 (Level 2.3 and no contribution). P4's quantitative contribution and her scientific knowledge were inversely proportional for the

Newton's Third Law argumentation and directly proportional for the motion in the space argumentation. In addition, her qualitative contribution and her scientific understanding were directly proportional for the motion in the space argumentation.

In order to make analysis within the argumentations, the participant's content knowledge in each argumentation was determined by assigning numbers to the codes given Table 2 and Table 4 and summing the numbers. In this way, "1" was given to compatible elaborate, "0.5" was given to compatible sketchy, "0" was given to compatible/incompatible, "-0.5" was given to incompatible sketchy, and "-1" was given to incompatible elaborate. The participants were sorted according to their understanding of the concepts in the Newton's Third Law argumentation as the following: P4 > P1 = P2 = P3. Additionally, their order based on their quantity of contributions was as follows: P2 > P3 > P1 > P4. When these two orders were compared, no similarity was found between the students' quantitative contributions and their scientific knowledge regarding the Newton's Third Law argumentation. Moreover, the participants were arranged according to their science content knowledge in the motion in the space argumentation as the following: P3 > P2 > P1 > P4. Their classification based on their quantity of contributions as follows: P2 > P3 > P1 > P4. Similarity was found between two orders for the motion in the space argumentation.

The quality of contributions was identified by probing the level of argument. The participants were sorted according to their qualitative contributions to the Newton's Third Law argumentation as the following: P2 > P1 > P4 > P3. Comparison of this result with the students' understanding in the Newton's Third Law context (P4 > P1 = P2 = P3) did not present any pattern. Furthermore, the participants' order based on their qualitative contributions to the motion in the space argumentation was as follows: P2 > P3 > P1 > P4. There was small pattern between the students' qualitative contributions and their scientific knowledge in the motion in the space context (P3 > P2 > P1 > P4).

CONCLUSIONS AND IMPLICATION

Though some proportions and similarities, results from the study illustrate no significant relationship between students' quantitative contributions to argumentation and their scientific understanding. Equally, there is no consistent pattern between students' qualitative contributions to argumentation and their scientific knowledge. There is consensus that argumentation can facilitate learning. However, research presented here suggests that teachers should not use argumentation as an assessment tool for formative evaluation and they should not try to make decisions about students' content knowledge based on their engagement while they are arguing.

The factors that might affect contribution were taken under control in this research, apart from context. Two argumentations were promoted in the different contexts. Researchers (Duschl & Osborne, 2002; Kelly, Druker & Chen, 1998; Perret-Clermont, Perret & Bell, 1991) mention the relationship betweeen context and participants' argumentation quality. Different contexts in this study might cause unfound patterns and relationships. Further studies are needed to expand this postulation.

Williams (2004) points out that case studies do not depend on statistical generalization from sample to population, as in survey research, but on logical inference from prior theorizing. Consequently, theoretical generalization does not aim to say anything about populations but instead makes claims about the existence of phenomena proposed by a theory (Williams, 2004). Case study methods do present evidence for readers to make their own generalizations based upon the particulars of the case (Faltis, 1997). Theoretical corroboration can be increased by further instances of a phenomenon in repeated case studies (Williams, 1994). This case study adds to the literature investigating the relationship between students' science content knowledge and their quality and quantity of arguments.

Acknowledgement

Support for this research has been provided by Marmara University BAPKO with grant no EĞT-YLS-290506-0158.

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Eurasia Journal of Mathematics, Science & Technology Education, 2009, **5**(1), 71-78

Towards a Dialogical Pedagogy: Some Characteristics of a Community of Mathematical Inquiry

Nadia Stoyanova Kennedy
Stony Brook University, Stony Brook, NY, USA

Received 02 June 2008; accepted 27 October 2008

This paper discusses a teaching model called community of mathematical inquiry (CMI), characterized by dialogical and inquiry-driven communication and a dynamic structure of intertwined cognitive processes including distributed thinking, mathematical argumentation, integrated reasoning, conceptual transformation, internalization of critical thinking "moves," and collectively constructed concepts. As a form of pedagogy, community of inquiry is non-hierarchical, democratic, pluralistic, ethically and culturally sensitive, and inherently egalitarian. In addition, the structure of the inquiry process in CMI is understood as one in which every individual has an effect on the system as a whole, which is therefore emergent, self-correcting, self-directed, and self-organizing. This paper draws some implications of this form of pedagogy for mathematics education.

Keywords: Dialogical Pedagogy, Community of Inquiry, Mathematical Thinking

DIALOGICAL PEDAGOGIES: THE VYGOTSKIAN TRADITION

It is commonly accepted that the Russian psychologist Lev Vygotsky was the one of the first to articulate an understanding of learning and development as dynamic processes in dialectical relationship, and to emphasize how the relationship between the individual and the social mediates these processes. Over the last few decades, Vygotskyan scholars have introduced alternatives to cognitive and developmental individualism based on a model that features participation in a shared activity. Since at least the early 90's , participative, dialogical pedagogies such as apprenticeship (Rogoff, 1990; Lave & Wenger, 1991), guided participation (Rogoff, 1990), distributed thinking, community of inquiry (Lipman, 1991) and many more have been experimented with in one form or another.

Correspondence to: Nadia Stoyanova Kennedy, Assistant Professor , Stony Brook University, Department of Mathematics, Mathematics Education Program
Stony Brook, NY, USA
E-mail: nadia@math.sunysb.edu
nadiakennedy@verizon.net

E-ISSN: 1305-8223

There has also been a change of focus in the area of mathematics education from individualistic learning to learning in the social context of the classroom. The theory and practice of community of mathematical inquiry are coming to be recognized as offering possibilities for rich pedagogical activities and creative approaches in mathematics teaching and learning. In keeping with the goal of constructing a pedagogical system which both allows for and encourages the fundamental notion of learning as cognitive reconstruction in a social context, several prominent instructional theories, both inside and outside of mathematics teaching, have emerged in the last two decades. Brousseau's theory of "didactique des mathematiques" (1986), understands learning as adaptation to new situations, and seeks to define the systemic conditions necessary for it to take place. Artigue (1994) uses the term "didactic engineering" to refer to the teacher's work in developing the conceptual and methodological means for controlling interacting phenomena in the classroom, and their relation to the construction and functioning of students' mathematical knowledge. Lave's and Wenger's theory of "situated learning" (1991) emerged from the idea of cognitive apprenticeship—a notion widely popular in 1980s. Based on Leontiev's activity theory, situated learning theory focuses on the relationship between learning and the social situations in which it occurs. Lave and Wenger (1991) situate learning in certain forms of co-participation, emphasizing the kinds of social engagements which provide the proper context for learning, rather than just the cognitive processes and conceptual structures involved. Situated learning assumes the relational character of learning, the negotiated character of meaning, the engaged nature of learning activities for the participants involved, and a highly interactive role for participants in the learning process.

Magdalene Lampert's understanding of teaching and learning through what she calls the "problem approach" has elements in common both with Brousseau's "didactique" and Lave and Wenger's theory of situational learning. The problem approach to teaching involves creating learning situations for students, evaluating them in terms of students' various levels of sophistication, and modifying the situation to keep it "challenging, but attainable" (Lampert, 1990). Lampert also introduces the idea of mathematics teaching as operating in a "community of discourse," which she characterizes as a little-explored territory (Lampert, 1990). In addition, Deborah Ball (1999) takes up Brousseau's idea that part of the teacher's role is to take noncontextualized mathematical ideas and to embed them in a context for student inquiry, a process that she calls "community of reasoning" (Ball, 1999).

Paul Cobb, Terry Wood and Erna Yackel are probably among the first mathematics researchers in the USA to have drawn analogies from the philosophy and sociology of science for understanding classroom life as a community of inquiry (Cobb, Wood, & Yackel, 1991). Their sociological analysis focuses on the creation of "taken-as-shared knowledge" in the community, and the establishing of classroom social norms (Cobb, Wood, & Yackel, 1991; Cobb, Wood, & Yackel, 1993; Cobb et al, 1997; Wood, 1985). According to these authors, "taken-as-shared" implies that participants achieve a sense that some aspects of knowledge are shared within a collective interpretative framework that constitutes the basis for communication among the participants in the community. The notion of "social norms" implies common agreement as to the expectations that the participants--including the teacher--have of themselves, and a shared conception of what it means to practice mathematics in a community, which includes an understanding of the ways that mathematical validity can be established.

In a practice analogous to that of establishing procedural norms in a community of philosophical inquiry, Cobb et al. describe negotiating what constitutes effective and appropriate mathematical practice in the classroom through engaging the learning community in conversations about how to practice mathematics collaboratively. This kind of discussion corresponds to Brousseau's (1994) *contract didactique*, or negotiated agreement between students and teacher. The initial student-teacher contract is a prerequisite to creating a specific mathematics classroom culture. As Schoenfeld (1994) suggests, one of the major goals of teaching is to create, together with the group, a "classroom culture" with a shared linguistic medium, and to help students "acculturate" to this particular context. Other interpretations of and approaches to community of mathematical inquiry have been under development for at least twenty years (e.g. Goos, 2004; Siegrist, 2005). None of them are incompatible with the approach adopted and the form of communal inquiry described here.

Community of Mathematical Inquiry

Community of inquiry may be broadly described as the collective execution of a dialogical, language-based activity whose goal is to reach communal agreement through argumentation. The model of community of philosophical inquiry developed by Mathew Lipman and Ann Sharp in the 1970's at the IAPC (Institute for the Advancement of Philosophy for Children) at Montclair State University (Lipman, 1991; Sharp, 1992), a question-based (as opposed to a propositional or apodictic) approach to teaching and learning, is eminently adaptable to disciplines other than philosophy—or rather, it offers a straightforward and comprehensive way to approach other disciplines from a philosophical perspective. This formulation of Community of mathematical inquiry (CMI) described here embodies most of the essential characteristics of Lipman's model of a community of philosophical inquiry, which has its roots in a combination of John Dewey's ideas of communal inquiry and C.S. Pierce's notion of scientific community of inquiry. In keeping with Lipman's formulation, it is a communal discursive event which is *dialogical* and *inquiry-driven* (Dewey, 1910, 1939; Pierce, 1958, 1966). Its main objective is the construction of meaning and the formation of concepts, not through teacher transmission, individual reflection or debate, but through what is referred to as "building on each other's ideas"— that is through *distributed thinking* in a dialogical context.

Lipman and Sharp's approach to communal inquiry clearly resonates with the Vygotskyan approach applied to education, which views learning and development as dynamic, dialectically driven. In such a context, the individual subject and his cognitive processes must be understood in terms of their incorporation into different systems of collective practical and cognitive activities (Bauersfeld, 1994). A pedagogical approach attuned to Vygotskyan psychology pays as much attention to mediated group process as to the individual, capitalizes on the notion of distributed thinking, and recognizes the collective subject and its dialectical, systemic processes as vital to learning and development (Toulmin, 1999; Lushyn & Kennedy, 2000).

Such a modality of social cognition suggests the form of social organization that we know as education in the sense of the German word *bildung* (i.e. culture itself understood as an educational process), and considers this dimension of education to be fundamental to conceptual development and all that implies for human development as a whole. Vygotsky viewed learning as a process of acquiring a cultural sign system, which he characterized as a "tool" for filling in the "cognitive gaps" within one's own developmental zone. Since language is the most powerful cultural sign system, a complex and dynamic relationship connects language and thinking; and given that language is a social phenomenon, it follows that thinking is deeply embedded in social activities and cultural practices (Vygotsky, 1962). Language and thought are understood as overlapping activities—that is, the verbalization of one's thought is not only making the implicit explicit, but also generates thought.

Discussion in community of mathematical inquiry advances through identifiable critical thinking interventions or "moves," including questioning, offering examples and counter-examples, asking for justification, giving reasons, offering clarifications, making propositional statements, exploring alternative positions and hypotheses, drawing conclusions, reasoning syllogistically, making inferences, and many others (Kennedy, 2005) . As it enters the conversational system, the verbalized material undergoes a continual process of *translation* that involves listening and responding, clarification and reformulation, taking turns, remaining sensitive to context and open to new interpretations, translating between various expressive, cognitive, and discursive styles, entertaining different perspectives, and self-correcting (Kennedy, 2004).

Along with the "technical" moves that comprise the dialogue and are listed above, several key assumptions are immanent to the inquiry, which resonate with the notion of "social norms" discussed above. There might be more than one perspective or interpretation, and in dialogue those perspectives interact as equal interlocutors. Each perspective enters dialogue with the possibility of being modified or changed by the others. Moreover, dialogue presents a possibility for reconstruction, not only of perspectives and ideas, but also of values, modes of practice, beliefs, attitudes, dispositions, and relationships. Finally, the individuality of each interlocutor is recognized and valued as unique in communal dialogue, but only through its relation to each other individuality. In dialogue "one thinks for oneself and with others" (Kennedy, 1999).

The ideal mathematical inquiry proceeds through a form of argumentation which, because it is inherently dialogical, is thus by implication a dialectical process, which is to say a process which moves forward through encountering and attempting to resolve inadequacies or inconsistencies. *Argumentation* is understood here as a new form of collective classroom discourse, not as a debate but as a cooperative competition in constructing a collective argument whose purpose is to arrive at commonly agreed-upon conclusions by way of open and free deliberation, which is characterized by distributed thinking and communal scaffolding. Any given argument is built on a previous argument or entertained as a counter-argument to a previous one. As such, argumentation in community of inquiry is inherently both chaotic and teleological. It can be influenced by any single element of the system—for example by any single participant—as well as by any element in the cognitive medium, for example the initial problem under consideration, by specific examples and counterexamples, or by the presence of conscious or unconscious assumptions.

Community of Mathematical Inquiry and Mathematical Classroom Culture

Mathematical argumentation relies on processes such as reasoning and explicit justification of claims and inferences. Getting students accustomed to justifying their claims and the mathematical operations they use is also a form of acculturation, and constitutes an aspect of the specific "mathematical classroom culture" that recent theorists in mathematics education emphasize (Schoenfeld, 1992). Such a culture cannot be implicitly assumed. Fischbein (1982), for example, comments that most high school students have not been enculturated into the practice of giving reasons. Coe and Ruthven (1994) found that when a proof context is data-driven and students are expected to form conjectures through generalization or counterexample, their justificatory strategies are primarily based on examples or counterexamples. Similarly, Finlow-Bates, Lerman and Morgan (1993) found that even many first year undergraduates had difficulties following chains of reasoning. There are studies of elementary and middle school students that suggest that if students are systematically and consciously initiated, in a suitable environment, into the practice of making mathematical arguments and justifying their ideas and procedural moves, their ability to make inductive and deductive judgments shows progressive development (e.g. Maher & Martino, 1996; Zack, 1997; Lampert, 1990).

In addition, Cannon and Weinstein (1993) understand the process of reasoning as manifesting primarily through four of its dimensions—formal, informal, interpersonal, and philosophical–some of which seem to be completely absent in current school practices. In the context of CMI, I have argued (Kennedy, 2006) that in fact communal mathematical inquiry is conducive to a form of multi-dimensional reasoning that includes formal, informal, interpersonal, and philosophical/metacognitive dimensions, and have suggested ways of introducing argumentative discourse through the practice of what I call integrated reasoning.

Indeed, the connection between mathematical thinking and reasoning in the teaching and learning of mathematics tends to be obscured when the process of doing mathematics is not only removed from the need to develop any habits of inference, but it is stripped of the opportunity for or encouragement of conscious guessing, the tracing of conjectures, exploration of hypotheses, argumentation, or of any attempt to assume a mode of inductive or deductive reasoning (Schoenfeld, 1994; Lampert, 1990). In addition, it seems that students generally believe that practicing mathematics is a quick and predetermined process in which one either knows or doesn't know "the answer," when in fact finding the answer demands continuous cognitive reconstruction and cognitive efforts. In this respect, I would argue that CMI is a form of mathematical practice that carries the potential for individual and collective reconstruction of habits of reasoning, not only of beliefs about mathematical practices, but of attitudes and dispositions towards mathematics in general.

Dialogue and Dialectic in Community of Mathematical Inquiry

Patterns of argumentation in CMI are understood and practiced as dialogue rather debate, for dialogue provides the conditions for the emergence of new perspectives within and between interlocutors (Forman et al., 1998). Tolerance and even encouragements of a diversity of perspectives prompts the awareness of oppositions between the views or beliefs of participants, and triggers reflection on the information they are provided with. Numerous studies suggest that the experience of being exposed to conflicting views in a context of argumentation leads to significant restructuring of participants' understanding of a topic (Forman et al, 1998; Leitao, 2000; Van Eemeren and Grootendorst, 1994; Krummheuer, 1995; Resnik et al., 1993; Pontecorvo, 1993). Other researchers note that examining opposite sides of an argument does not always lead the participants to cognitive change and to a change of views, but rather to further polarization (Stein & Miller, 1993; Perkins, Allen, & Hafner, 1983; Kuhn, 1991). Toulmin (1969) offers something of an explanation of this discrepancy by emphasizing the importance of developing "proper" inferring-habits and "rational" canons of inference, which can serve as stepping-stones for knowledge-building mechanisms. But he emphasizes that such habits and cannons must be preceded by the development of proper attitudes towards mathematical practices, and by the presence of dispositions toward reflective thinking.

The chief pedagogical significance of the constructive process of community of inquiry is that it operates in the collective zone of proximal development, which acts to "scaffold" concepts, skills and dispositions for each individual. The concept of the zone of proximal development, which represents the distance between actual and possible development that can be bridged when learning is facilitated by someone with greater expertise than the learner—neatly operationalizes the educational implications of Vygotsky's theory. The scaffolding process functions through subprocesses such as clarification, reformulation, summarization, and explanation, as well as through challenge and disagreement. The emergence of different perspectives inevitably gives rise to oppositions, inadequacies, or contradictions, and thus forces discrimination and the production and resolution of differences.

In this context, *collective concept transformation* is understood to operate through the emergence of cognitive conflict and the ongoing resolution of that conflict in a dialectical manner—which is to say through the recognition and articulation of contradictions and inconsistencies, and their mediation through the processes already discussed—communal dialogue, integrated reasoning, distributed thinking, collective argumentation, and their dynamic interplay within the CMI. Consistent with Vygotsky, the process of concept transformation or conceptual building proceeds from participants' "spontaneous" or "everyday" concepts towards more scientific concepts, i.e. in a "bottom-up" fashion (Vygotsky, 1962).

It has also been argued (Lipman, 1991) that community of inquiry represents the ideal situation for Vygotsky's notion of the intrapersonal appropriation of the interpersonal—or "*internalization*"—not only on the conceptual but on the behavioral level, i.e. in the development of habits of both cognitive and behavioral self-control and self-regulation. Furthermore, community of inquiry as an open, emergent, inquiring system is continually mediating further cognitive advancement, through the re-externalization of the internal in the ongoing discourse of the community, followed by further internalization, and so on in an ascending spiral of development. Given that we view the community of inquiry as a complex and dynamic system of interrelated subjects, mutually intertwined individual and collective processes, distributed thinking, argumentation, and concept transformation, we reflect on and analyze the external conceptual and argumentation processes as they are manifested in the *collective subject*, which reveals itself through practical activities and collective cognitive processes.

The Role of the Teacher in Community of Mathematical Inquiry

From a systemic perspective, community of inquiry is an open, interactive system, and all of its elements exercise what Lushyn and Kennedy (2000) call "ambiguous control" over each other. The role of a facilitator in such a system is also ambiguous, since she has, if necessary, to encourage the scaffolding process without providing direct answers or authoritative perspectives, but more through a form of the Socratic elenchus—that is, through provocative questioning, reformulation, and the offering of counterexamples and counter-perspectives. Vygotsky's notion of appropriate intervention in the process of concept formation and advancement is obviously more subtle and indirect than in traditional pedagogy, which typically satisfies itself with a behaviorist model and leaves it at that.

The ultimate achievement of a community of inquiry as a pedagogical system is to move the group as a whole and each member in it in the direction both of enhanced cognitive/conceptual and behavioral self-organization and self-regulation, a movement which has implications, not only for students' mathematical learning, but also for student empowerment through the development of democratic skills and dispositions and the skills of communal deliberation.

One primary goal of the facilitator in a community of mathematical inquiry practice has been to create a context for mathematical inquiry ("contextualizing") to be used as springboard for discussions of mathematical ideas that are meaningful to students and which correspond to their mathematical knowledge—that is, which are challenging and yet still accessible to students' inquiry. This is what we might refer to as problematization, and it is at least analogous to what Brousseau calls "devolution," and Balacheff refers to as "toward a problematique" (Balacheff, 1990). Its basic goal is to embed the mathematical idea in a context which "perplexes" students and evokes the student's felt responsibility for the pursuit of meaning through offering a stimulus as a starting point for inquiry (Dewey, 1910). A stimulus presents a "rich" mathematical problem—a problem which might be is set in or evokes a narrative context, and which not only requires calculation, but offers possibilities for interpretation. It could be referred to as a "thinking story"—whether presented as a short narrative, a video clip, or an image (a painting by Escher, for example).

One of the operative assumptions of a pedagogy that is more appropriate to human beings and their learning processes than the traditional model must, I would argue, be that the acquisition of new concepts is most meaningful to students when they have the opportunity to construct those concepts and their relationships for themselves, through interactive participation in activities which provide motives and goals for them. In the Vygotskyan model, the role of the facilitator is to construct *with* the students opportunities for interacting with meaningful ideas, and for collaborating with others in activities that define meaningful goals. One of the challenges for such a facilitator is to identify activities which scaffold students' learning to a more advanced level of their potential development.

Such a view would implicitly suggest that any rigid or formulaic kind of instructional planning in a CMI faces an inherent tension. Most of the researchers reviewed above suggest that students must have the freedom to respond to learning situations on the basis of their past knowledge and of their current understanding of the problematized situation, rather than being expected to give either uniform answers or answers which are merely expected by the instructor (e.g. Resnick, 1980). If this tension is taken seriously, it implies the necessity for teacher adaptation to the paradigm shift from "teaching as telling" to a dialogical model, which is the prime characteristic of community of inquiry theory.

The community of inquiry teacher is not just a planner but also an organizer—the initiator of a process of negotiation aimed at establishing social norms for the communal practice of mathematics. She is the one who initiates students into mathematical discourse--or the "language game" which provides the fundamental meaning-context for mathematical symbols and ideas (Wittgenstein, 1966). Furthermore, she does not introduce it as a static form, but is continually modeling and shaping the classroom discourse through offering restatements, clarifications, examples, and summarizations, and asking students to do so as well, even as she is all the while actively listening.

CONCLUSION

The perennial problem of pedagogical sterility in mathematics education can be traced to a set of much larger epistemological and ontological beliefs, which have come increasingly to be challenged over the course of the last half century. One of the greatest challenges to these beliefs is presented by Vygotsky (1978) and his concept of "developmental teaching," the fundamentals of which have been sketched here, and which presents a great challenge to mathematics teachers and teacher education in general—the challenge of coming to understand themselves as agents of such an emergent pedagogy.

Understanding mathematical knowledge construction as an emergent process suggests the idea of a dynamic, non-linear pedagogy, from which it follows that the learning process produced by such a pedagogy would be dynamic and non-linear as well. The teaching/learning process can be altered at any moment when a confrontation of multiple contradictory perspectives presents itself. The resolution of this confrontation represents, not the mutual acceptance of one imposed unilateral perspective, but a "sublation" (that is, the overcoming of contradiction through dialectical negation), which emerges as a result of the recognition of all presented perspectives, and transforms the whole system to a new level of development. This presents a sharp contrast to traditional mathematics instruction, which is compartmentalized into segments representing units of instruction, made uniform by mathematics textbooks, focused on one idea at a time, and aimed at forming certain skills through practicing planned exercises. In contrast to the traditional teaching model, the goal of the teacher who facilitates mathematical learning in a community of inquiry is to support the development of students' constructive abilities, their self-concept as learners, and their capacities for internally driven, self-organized cognitive transformation through the practice of argumentation.

As a discursive form, community of inquiry pedagogy is distinguished from traditional practice by its multilogical as opposed to monological style and character. Since everyone in the system can exercise control to some degree, and every characteristic of the system--whether social, psychological, logical, conceptual, linguistic or some other—can change it, the system undergoes a continual dialectical process of deconstruction and reconstruction. This identifies it as an open, emergent system, which in turn describes it as a system in continual transition, over which no one can exercise anything but "ambiguous control." Thus construed, the process of teaching/learning in a community of inquiry is implicitly understood as a developmental and a dialectical process often marked by uncertainty and lack of clarity, which itself implies the capacity to trigger system change and self-organization, and is often associated with the emergence of new forms of knowledge.

The inquiring system described and analyzed here offers the possibility of fulfilling—as much as is possible for a normative ideal—the prerequisites for what Habermas (1990) has called the "ideal speech situation," which requires that all its members have equal opportunity to participate in and contribute to the dialogue, free from internal constraints or external coercion. This implies the need for a pedagogy which not only develops communicative competence, but which models a form of argumentation that understands itself as a *cooperative* competition in constructing a better collective argument—with the major goal of an agreement arrived at collectively through open, free communication. In short, the model of collective inquiry whose developmental and transformative potential has been described here offers the institution of education an egalitarian and democratic model that stresses the equality and freedom of each participant, that can function as a matrix for collective knowledge construction and, through its promotion of integrated reasoning, represents a more sophisticated approach to learning than is currently in place in the vast majority of schools. Finally, it offers an outline of a methodology and a pedagogy which understand mathematical development as a dialectical, emergent phenomenon, and thus represents a new direction for mathematics education.

Community of inquiry theory and practice offer new ways of understanding and rethinking the teaching and learning of mathematics, and new insights into how school mathematics might be reconstructed as collaborative dialogical inquiry. Its emphasis on communal dialogue makes of it an ideal medium for the interplay between individual and collective cognitive and psychodynamic processes in the development of mathematical concepts, and in the development of the skills and dispositions of argumentation. In addition, it offers a promise for the transformation of mathematics teaching and learning from a rigid, transmissional model to one which is student-centered, self-regulatory, and inquiry-driven.

That the CMI model points to the advantages of sensitivity to social setting, to collaboration, and even to some form of dialogue, is nothing new. It is the radical epistemological difference—which in turn is determinative of differences in learning theory—which distinguishes it from the transmission or even the individual problem-solving model. Community of inquiry takes the notion of distributed learning and thinking with the utmost seriousness, which amounts to the epistemological claim that knowledge constructed in an inquiring system—a group whose chosen activity is collaborative, dialogical deliberation—has qualitative differences from knowledge attained individually, or even as a result of a dyadic interaction. Such knowledge construction demands skills, dispositions, and even fundamental beliefs on the part of teachers that require a radical reconstruction of the logical terms of teaching and learning itself.

On a practical level alone, the role of the facilitator in a community of mathematical community of inquiry is far more complex than the traditional teacher's, requiring as it does sensitivity, flexibility and creativity in the organization and planning of content and activities, the courage to take risks and to endure suspense in the facilitation and scaffolding of the inquiry, and trust in the inherent self-organizing capacity of groups in the management of communal dynamics. As such, the application of the community of mathematical inquiry model to mathematics education poses a profound challenge, given both the nature of the discipline and the pedagogical traditions that still dominate it. It also offers the possibility of the development of a form of classroom practice capable of transforming the field of mathematics education.

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Eurasia Journal of Mathematics, Science & Technology Education, 2009, **5**(1), 79-85

A Study on the Effect of Mathematics Teaching Provided Through Drama on the Mathematics Ability of Six-Year-Old Children

Serap Erdoğan
Anadolu University, Eskişehir, TURKIYE

Gülen Baran
Ankara University, Ankara, TURKIYE

Received 10 April 2008; accepted 17 July 2008

This study was conducted to examine the effect of mathematics teaching given through the drama method on the mathematical ability of six-year-old children. The research was conducted in Ankara on 105 children from the kindergarten classes of two different primary schools of the Ministry of National Education, which are at middle socio-economic level. Thirty-five of the 105 children were selected as the experimental group, 35 of them as the control group and finally 35 as the placebo control group. The placebo control group was formed in order to determine the differences resulting from group interaction. Data were collected by means of the "General Information Form" and the "Test of Early Mathematics Ability-3 (TEMA-3)" developed by Ginsburg and Baroody in 1983. Results showed that mathematic teaching based on the drama method has a positive effect on the mathematical ability of six year of children.

Keywords: Pre-school period, mathematics teaching, mathematics concepts, drama in education

THE DEVELOPMENT OF MATHEMATICS CONCEPTS

Early childhood period is a period when the child has the most rapid development and starts to learn basic concepts actively. Children in this period progress from pre-operation stage to concrete operations. In other words, the child passes from visual thinking to mental development during the early childhood period (Wortham, 1998; Yildiz, 1999; Frakes & Kline, 2000; Jacobson, 2001).

Experiences regarding mathematics, which constitute a significant part of life, are realized in a long and difficult process following the initiation of learning the fundamental concepts. Children constantly face mathematical concepts in their daily lives. In the early childhood period, the initial experiences about mathematics are acquired generally through the experiences with objects, depending on the child's stage of development. Therefore, an active learning environment and methods are required in the early childhood period for the development of the mathematical concepts and abilities to be used in the future by the child. Children should be aware of the transition from concrete to abstract, simple to complicated, and from trial to making. Many studies have revealed that the information that the child learns

Correspondence to: Serap Erdoğan, Asist. Prof.
Anadolu University, Faculty of Education,
Department of Primary Education, Pre-school Education Program, Yunusemre Kampüsü, Eskişehir, TURKEY
E-mail: seraperdog@gmail.com

E-ISSN: 1305-8223

in an active learning environment is retained (Graham, Nash, & Paul, 1997; Raida, 1999; Trisha, 1999; Bennet, 2000; Fleege, 2000; Young-Loveridge, 2004). Moreover, Peker and Mirasyedioglu (2008) stated that the use of concrete materials for a long time, especially in the primary education period, is positively related to increasing students' mathematics success.

The mathematical concepts to be used in the future are first formed in the first year of childhood. The child starts to acquire the initial mathematical abilities first physically, then mentally and finally by hand-counting via the experiences he/she gains during his/her interaction with his/her environment (Chao, Stigler, & Woodward, 2000; Frakes & Kline, 2000; Geist, 2001). There are various concepts in the field of mathematics. In addition to the basic concepts related with numbers, such as multiplicity, counting, numbers, sets, addition-subtraction, division-multiplication etc., the child also starts to learn concepts like shapes, weight, volume, length etc. in various stages in time beginning from the birth depending on his/her development. Mathematics is a continual education. In order to make a simple addition operation, numbers should be known and how they are used should be learned first. Concepts related with mathematics may be covered in all preschool education programs. Therefore, a mathematics program should be planned well. The program should be based on experiences which will improve the child's capability of expression and will enable him/her to have new experiences. The instruction methods and materials used in planning should be used in accordance with the objective. The program to be developed should also emphasize that mathematics is easy to learn, useful, practical and entertaining. In the study they conducted, Tudge and Doucet (2004) observed the children in their environment and recorded children's behavior in settings that particularly contained pre-formed mathematical materials. They reported that children dealt with mathematical concepts more easily in their natural settings. Many studies on this issue revealed the importance of the use of different techniques in mathematics education for children (Raida, 1999; Trisha, 1999; Young-Loveridge, 2004). Children should believe that they can learn mathematical concepts and they should not be afraid of mathematical studies. One of them will be enthusiastic to learn mathematics when he/she comprehends the way how he/she will learn mathematics and understands the reasons behind mathematical concepts. The child's self-confidence and his/her awareness of learning skills will improve his/her cognitive learning potential (Kline, 2000; Yildiz, 2002).

One of the basic objectives of pre-school education is raising children who are creative, problem-solving, and sensitive to themselves and to their environment, whose communication skills are developed and who can think in a scientific manner. The use of drama in mathematics teaching courses started in the beginning of the twentieth century. In these courses, first a desire for learning mathematics is aroused in children, and then it is ensured that they get adapted to mathematics, and learn to enjoy it by thinking, understanding the relations and problem solving. In pre-school education, children have the chance of learning many mathematics concepts by imagining through drama studies. In drama studies, creating real situations, going to places where there are real situations and imagining these situations ensure that the effects of education are permanent. Imagining realized by seeing, hearing, tasting or smelling something that does not really exist requires mental processes, which improves the intellectual capacity of the child. Thus, many subjects become livelier and more life-related. Many concepts in mathematics subjects as well as descriptive and explanatory information related to these concepts are learnt faster through drama. For example, creating a shopping environment for children and counting vegetables and fruits in this medium are suitable mathematical settings for children. Mathematics teaching provided by means of drama changes abstract mathematical concepts in children's minds into concrete and attractive. Therefore, it is important that families and educators provide a creative environment for children in mathematics teaching (Tanriseven, 2000; Aral et al., 2003; Ozsoy, 2003a; Peterson, 2004; Erdogan & Baran 2006).

Rationale of the study: aims and hypotheses

Drama, which is used as an instruction method in pre-school educational institutions, can also be used for mathematics teaching. Children can learn best by experiencing and playing. Imagination is the most needed material when the child is playing. This requires mental processes such as seeing, hearing, feeling, touching, tasting or smelling, the implementation of which will develop the mental capacity of the child. The subject learnt will subsequently become more lively and livable. Topics related with mathematics can also be taught more quickly and permanently through drama. With the help of real objects or symbolic objects replacing them, the drama method may facilitate learning many concepts in various topics (size, weight, shape etc.) and complimentary, descriptive information about these concepts. The topics taught are comprehended faster as the child learns during games (Peterson, 2004). In terms of supporting mathematical abilities in the pre-school period, despite the studies made on cooperative learning, the use of physical materials, and the impacts of methods such as music, game etc. (Kaaland-Wells, 1994; Raida, 1999; Trisha, 1999; Rose, Parks, Androes, & McMohan, 2000; Karşal, 2004; Young-Loveridge, 2004), there are a few study related the impact of the drama method (Ozsoy, 2003a/2003b; Fleming, Merrell, & Tymms, 2004).

Based on this consideration, this study aims to analyze whether the mathematics teaching provided through drama for six-year-old children in kindergarten has any impact on their mathematical abilities or not.

METHOD

Participants

The study involves children who are six years old. In the study, there is one experimental and two control groups. The sampling consists of 105 children, 35 of whom are in the experimental group, while 35 are in the control and the remaining 35 are in the placebo control groups. The children in the experimental and control groups have been selected from the same school. The placebo control group has been selected from a different school in order to identify any difference that may arise from group interaction. Children to be covered under the experimental, control and placebo control groups were required not to have attended any preschool education institution previously, to have started kindergarten in that education year and not to have participated in drama activities at or after school.

Instruments

The Test of Early Mathematics Ability–3 (TEMA-3) was used in the study to evaluate the mathematics abilities of children. The Test of Early Mathematics Ability (TEMA) was developed by Ginsburg and Baroody to evaluate the mathematical abilities of children between three years and eight years eleven months old. It was reviewed and republished as TEMA – 2 in 1990. The TEMA-2 test, which was reviewed again, was developed as TEMA-3 in 1993 (Ginsburg&Baroody, 2003). The validity and reliability studies of TEMA-3 for Turkish six-year-old children were performed by Erdogan & Baran (2006). Within the scope of test-retest reliability study, TEMA-3 was administered to two hundred children, one hundred of whom were given Form A, while the remaining one hundred were given Form B. Three weeks after the first administration of TEMA-3, Form A and Form B were administered again to 120 children. The correlation results (reliability coefficients) of the scores in the first and second administration of the test were .90 from Form A to Form A, .88 from Form A to Form B, .90 from Form B to Form B and .90 from Form B to Form A. The interior consistency coefficient was calculated in order to test the reliability of the test and KR-20 value and the internal consistency was found as .92 for Form A and as .93 for Form B.

The mathematics ability levels of six-year-old children were taken as the external criteria to analyze the criterion validity of TEMA-3. Form A and Form B were administered to thirty children, with the lowest and highest mathematics abilities according to their teachers' viewpoints. The results of Mann Whitney U-Test showed that Form A and Form B scores of thirty children with the highest mathematics ability according to the teacher were significantly higher than the Form A and Form B scores of thirty children with the lowest mathematics ability. This reveals that TEMA – 3 can distinguish between children with strong and weak mathematical abilities.

The test consisting of seventy two items evaluates the areas of informal mathematics such as less-more, counting, informal calculation etc. as well as the areas of formal mathematics such as numbers, relations between numbers, calculation and decimal concepts. TEMA – 3 consists of two separate forms as Form A and Form B. Form A and Form B are two parallel forms which are mostly similar and which measure the mathematical abilities of children. The forms are suggested to be used as pretest and posttest in experimental studies (Ginsburg & Baroody, 2003).

Pictures, mathematical symbols, countable small objects are used as materials in Forms A and B of TEMA-3. The increase in mathematics score acquired as a result of the evaluation of the test administered individually to the children points to an improvement in the mathematics ability of the child (Ginsburg & Baroody, 2003). The administration of the test takes an average of half an hour for each child.

Procedure

First, a "Mathematics Teaching Program Based on Drama Method" was developed in the study in order to support the mathematics ability of children in the experimental group. The program covered activities based on drama to develop the abilities of counting, corresponding objects equivalent to numbers, arranging

Table 1. The distribution of the participants in the experimental, control and placebo control groups by their schools

Schools	Experimental Group		Control Group		Placebo Control Group	
	N	%	N	%	N	%
Dikmen Central Elementary School	-		-		35	100.00
Province General Council Elementary School	35	100.00	35	100.00	-	
Total	35	100.00	35	100.00	35	100.00

objects according to their numbers, recognizing numbers, pointing at objects at a given number, knowing the following number, and the concept of operations for children at the six age group.

Twenty-four education situations of the Mathematics Teaching Program Based on Drama Method were presented to seven experts who are specialized in drama, programme development in education and pre-school education, to take their viewpoints. The experts were asked to evaluate the program against seventeen criteria such as the adequacy of the education situations and the appropriateness of the mathematics teaching, the adequacy and appropriateness of the materials used, the appropriateness of the distribution of the objectives, the appropriateness of the drama studies and the clarity of the instructions. The experts have also specified their points of view on the Mathematics Teaching Program Based on Drama Method (twenty-four activities) given to them in more details.

The researcher, then, determined the schools where the study would be conducted. The sampling of the research consisted of six-year-old children attending, in the 2005-2006 instruction year, the kindergarten classes of formal elementary schools affiliated to the Ministry of Education, in the province of Ankara.

One hundred and five children, attending the kindergarten classes of two elementary schools determined by randomly selection, constituted the research sample. The schools were selected from among the schools, in the province of Ankara and affiliated to the Ministry of Education, which are at middle socio-economic levels as per data from the State Statistics Institute. The schools from which the samples were selected are presented.

The Test of Early Mathematics Ability – 3 (TEMA-3) Form A was administered as a pre-test to the experimental, control and placebo control groups. TEMA-3 was administered individually to the children in a silent environment independent from the education environment. Following the tests, the teacher prepared some materials for the setting where the program would be implemented for the experimental group (35). The materials, such as cards with objects that the program involved, number symbols, large and small boxes, books, cassettes, beads, blocks, costumes suitable for the program, and paper and pencils, were prepared before the children came to the area of implementation. Role play, dramatization, and pantomime, which take place in drama, were all considered in designing the activities in the education program. After the implementation, it was ensured that an assessment was made and children's views were taken. The duration of treatment in a day lasted for about 45-50 minutes for one group. Mathematics activities based on the drama method were conducted with children for two days a week, for twelve weeks.

The educational situations for the placebo control group, on the other hand, involved "placebo" activities, i.e. activities that did not support the development of mathematics ability and mathematics concepts. In addition, activities such as music, games, and story reading, which are irrelevant to mathematics, were organized for the children in the placebo control group (one day in two weeks). The educator planned the activities by discussing them with the group teachers one week before the implementation.

The children in the control group (35), selected from the same school with the experimental group, continued to attend their education program in the kindergarten. Following the implementation of the Teaching Program based on Drama Method with the experimental group (for twelve weeks after the pre-test), TEMA-3 Form B was administered as a post-test to the children in the experimental, control and placebo control groups.

Finally, TEMA-3 Form B was administered again to the experimental group in order to identify whether the teaching was retained four weeks after the administration of the posttest (retention test).

Analysis of the Data

A mixed pattern of 3x3 was used in the study (experimental group, control group, placebo control group x pre-test, post-test and retention test). In the pattern, the dependent variable is the mathematics abilities of the children while mathematics teaching program is the independent variable, whose effect on mathematics abilities of the children is studied.

In the analysis of the data collected by means of the Test of Early Mathematics Ability–3 (TEMA-3), the Analysis of Covariance (ANCOVA) was used to test the effect of the Mathematics Teaching based on Drama on the mathematics abilities of children. The Bonferroni Test was administered to identify the group with a difference according to ANCOVA. Also, the effect of Mathematics Teaching based on Drama Method on mathematics abilities of children, immediately after and four weeks after the experiment, were evaluated. The T-test for correlated samplings was used to evaluate the posttest and retention test correlation of the experimental study.

RESULTS

The findings of this study, which reveal the effect of mathematics teaching based on drama on the mathematics ability of six-years-old children, are presented in the following tables.

Pretest–posttest score means of TEMA-3 in Table 2 show that there is a meaningful difference between pretest and posttest score averages of the experimental group (pretest mean: 86.06, posttest mean: 96.43). When the pretest scores of the groups are checked, the

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Table 2. Descriptive statistics for six-year old children's TEMA-3 scores

		Pretest	*Posttest*		
Group	**N**	*Mean*	*Mean*	*SD*	*Estimated Means*
Experimental	35	86.06	93.34	11.59	96.43
Control	35	95.88	98.60	11.94	94.18
Placebo Control	35	87.77	87.34	14.08	90.64

Table 3. Summary of ANCOVA for six-year old children's TEMA-3 scores

Source of Variance	***Sum of Squares***	***df***	***Mean Squares***	***F***	***p***
Experimental	11804.11	35	337.26	5.183	**.000**
Group	367.26	2	144.38	2.822	**.005**
Error	4360.05	67	65.07		
Total	18385.00	105			

Table 4. The t-test results of posttest and retention test mean scores of TEMA-3 in experimental group (n=35, df=34)

		Mean	*SD*	*t*	*p*
	Posttest	93.34	11.59		
TEMA-3 Scores	Retention test	94.05	11.38	-.671	.507

estimated means of the posttest scores are observed as mean = 96.43 in the experimental group, mean = 94.18 in the control group and mean = 90.64 in the placebo control group. It is also noted that there is a decrease in the estimated means of the posttest scores according to the pretest scores of the control group and the difference between the pretest and posttest is more obvious in the experimental group. It is further observed that the experimental group has the highest mean, followed by the control group and the placebo control group.

The ANCOVA analysis revealed that there was a significant difference between the estimated posttest mean scores according to the pretest mean scores of TEMA-3 [$F_{2\text{-}67}$=2.822, p<.01]. The Bonferroni Test applied in order to identify the reason for the difference showed that there was a significant difference between the experimental group and the placebo control and control groups, as well as the placebo control group and the control group. This result was due to the high score of the experimental group. High scores of the children in the experimental group revealed the influence of the instruction method followed. On the other hand, the difference between the placebo control group and control group was considered to be arising from the selection of the children in the control group and the experimental group from the same school. Despite the fact that the children in the experimental and control groups were not selected from the same grade or the children in the control group were not subject to any program implementation was in line with the objective of the study, they might get higher scores than the children in the placebo control group due to the interaction between the children and teachers.

According to Table 4; the posttest score mean was 93.34, the retention test score mean was 94.05 for TEMA-3 of children in the experimental group. The results of the t-test showed that there was no significant difference between TEMA-3 posttest and retention test scores ($t_{(34)}$= -.671, p>.05). However, the score means revealed that the mathematics ability scores of children in the experimental group in the posttest were maintained in the retention test given one month later and the effect of the experimental study was consequently maintained.

DISCUSSION

Drama is a child-centered method which creates an independent learning environment since the child is constantly active and enabled to express his/her ideas freely in drama. The child is involved in more activities during this process and may enjoy this environment as he/she enjoys playing games. The child learns various concepts about life while he/she is enjoying game processes. Mathematical concepts are among these concepts with vital importance. Mathematical concepts are taught to children through the use of the drama method may become enjoyable activities which are easy to learn for children (McCaslin, 1990; Ozsoy, 2003a; Peterson, 2004). These results explain the high scores of the children in experimental group since the mathematics teaching provided through drama ensures the active participation of children and aims to improve the mathematics abilities of children in an enjoyable environment.

Urkun's (1992) study intends to reveal the effect of en education model based on supportive mathematics concepts for children at the age group of four-five. The findings of this study note that the education given supports the mathematical concept development of children. Chao *et al.* (2000) studied the impact of using structured blocks in teaching numbers to the children in kindergarten and children showing each number with various objects in various ways. The findings of the study concluded that the relation between physical materials and abstract numerical concepts is not easy to comprehend unless it is gradual and takes place in steps. Raida (1999) studied the impact of mathematics education given through books of mathematical concepts to one hundred and twenty-eight children at the age group of six on the mathematics abilities of children. The findings of the study revealed that the mathematics abilities of children are significantly affected by the mathematics education given to the experimental group.

Tarim-Gozubatik and Deretarla-Gul (2004) studied to identify the subtraction-addition abilities of children and strategies that followed. The Test of Early Mathematics Ability -2 (TEMA-2) has been used in the study as a measurement tool. Test forms involving three types of problems, namely, non-verbal problems, verbal problems and subtraction-addition operations, were administered to children. The study concluded a linear relation between the scores of the children in TEMA-2 test and the answers they gave, depending on the type of the problem.

Young-Loveridge (2004) carried out a study to design an effective program to improve the counting abilities of children at the age group of five. This program was based on numerical concepts, books and games. The study was conducted on one hundred and six children. The mathematical knowledge of children was evaluated by means of a test covering topics such as counting, subtraction-addition, enumeration, recognizing shapes etc. As the children in the control group continued to attend the daily education program, a program covering stories of numbers, rhythm and games was implemented to the children in the experimental group. At the end of the study, a significant rate of increase was observed in the mathematics knowledge of the children in the experimental group.

These studies, suggesting the impacts of the support of mathematics abilities with education, further support the positive effects of the mathematics teaching given through the drama method in this study.

Drama provides the multilateral development of the child. The child learns to share and cooperate with his/her friends during activities since drama is a group activity while (s)he also learns to consider cases in various dimensions and aspects as (s)he acts and watches his/her friends act. Learning is much easier and it has retainable impacts as the child learns via trial and error in drama process (Girgin, 1999; Peterson, 2004).

CONCLUSION

The study revealed an increase at a significant rate at the end of the education process in the TEMA-3 scores of the children in the experimental group in relation with the impact of the mathematics teaching based on the drama method. The scores of the children in the experimental group were found to be higher than those of the children in the control groups ($p<.01$). No significant difference was observed between the scores of TEMA-3 posttest and retention test scores of children in the experimental group ($p>.05$).

This study concludes that the mathematical abilities of six-year-old children can be supported with education. Mathematics education in the early childhood period is not the direct transfer of knowledge to the child, but it is based on child's learning by directly performing and experiencing the knowledge. How to teach the mathematics concepts to the children in early childhood period is a significant issue.

As the mathematics world of adults is generally filled with abstract concepts, the world of children is more related with concrete concepts and realities. Therefore, mathematics activities of the early childhood should cover activities that can be implemented by the child in real world and should be based on learning with making- living. It is possible to teach many things by means of drama activities in the preschool period. This is due to the fact that the child can learn various concepts through drama activities while improving his/her potential of creativity. An entertaining and enjoyable environment can be created by including mathematics concepts in the drama education program, introducing mathematics concepts to the children, which is one of the objectives of the program.

Teaching of the mathematical concepts through entertaining activities, in which children want to participate and can be active, will be more appropriate since these concepts are abstract and relatively hard to learn in the preschool period. Therefore, due to its features, the drama method should be used in teaching mathematical concepts in pre-school education institutions.

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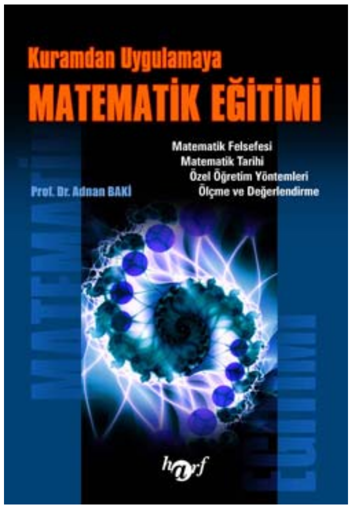
Eurasia Journal of Mathematics, Science & Technology Education, 2009, **5**(1), 87-89

Book Reviews

Mehmet Fatih TAŞAR, Section Editor
Gazi Üniversitesi, Ankara, TURKEY

KURAMDAN UYGULAMAYA MATEMATİK EĞİTİMİ (MATHEMATICS EDUCATION FROM THEORY INTO PRACTICE)



By Adnan Baki
2008
Harf Eğitim Yayıncılığı, Ankara, Turkey
xi+ 647 pp.
ISBN 978-975-6048-39-9 (hard cover)

With developing science and technology human beings are trying to cope with the resulting changes. In this adaptation process, mathematics education has an important potential in improving individuals' creativity, reasoning and problem solving skills. Nowadays mathematics instruction requires people to gain some mathematical features: (i) using mathematical rules/formulas properly, (ii) performing arithmetic operation (iii) having a higher level mathematical thinking, and (iv) becoming a good problem solver. Of course, such trends/expectations depend on changes in both learners' and teachers' views of learning and teaching. With this purpose, in Turkey, as a case of developing countries, contemporary learning and teaching approaches have been taken into consideration to implement them practically. To overcome these theoretical, pedagogical and practical deficiencies towards contemporary approaches of learning and teaching, to inform teachers and student teachers on these new mathematics teaching programs, source books need to be written and provided. The book under review also presents important literature at the end of each chapter for readers who wish to obtain further information about related topics.

In the first chapter, nature of mathematics is explicated concerning school mathematics and academic mathematics separately and deeply. In this chapter following topics are discussed: definition of mathematics, whether mathematics is discovery or invention, distinguishing modern and classical mathematics, tools used by mathematicians, purpose of teaching mathematics in schools, the aesthetic and fun aspects of mathematics, approaches and sorts of questions and proofs which mathematicians use in their teaching activities and topics related to nature of mathematics are discussed with examples. In summary, in the first chapter philosophy of mathematics education, discussions made by philosophy of mathematics education on the nature of mathematics, social groups affected by these discussions are introduced. Then the sorts of results that can be obtained from these discussions are explicated and the importance of these results for mathematics educators are emphasized.

In the second chapter, the value of history of mathematics for mathematics education, mathematics arising from daily needs, Mathematics in Ancient Greek, the Islamic-world mathematicians and contemporary mathematics are introduce and how teachers can enrich their teaching activities by adding history of mathematics are discussed. Briefly, based on the structure of mathematics introduced in the first chapter,

E-ISSN: 1305-8223

in the second chapter how mathematics shapes our world of thought and how it helps us get to know the universe are discussed. Additionally, lives, philosophies, works, and contributions of famous mathematicians are presented in a historical perspective based on their countries and cultures.

In the third chapter, some learning theories and related terms are introduced (e.g. learning areas, (cognitive, emotional, and psychomotor domains; learning approaches, learning through group works, learning through problem solving, teaching methods and multiple intelligences theory). Then how these theories can be reflected to classroom settings with sample activities are discussed. Shortly, in this chapter learning theories were explicated in detail and how these theories could be projected to classroom settings are discussed.

In the fourth chapter, operational and conceptual learning and how misconceptions could be determined were examined. By considering students' ways of learning mathematics and what misunderstandings they might have in some subjects (such as numbers, algebra, analysis, geometry etc.), the requirement of balance of operational and conceptual learning was emphasized. Moreover, in this chapter levels of geometric understanding were introduced in detail.

In the fifth chapter, the main objects of school mathematics were dealt with and what main domains of mathematics teaching program should have included was discussed. The philosophy and vision of new mathematics teaching programs (primary and secondary programs) and changes in teachers' roles according to new mathematics teaching programs was expressed and assessed from different aspects.

In the sixth chapter, substantial concepts about a teaching program and its main elements were introduced. Cognitive, emotional and psychomotor teaching domains' features, their classification and examples of them were represented. Strengths and weaknesses of teaching methods could be used in teaching settings were argued, and moreover, teaching principles and how mathematics lessons should be planned was emphasized. After the validity and reliability concepts were discussed within the context of evaluating of learning, features of several measurement and evaluation tools used for assessing of learning domains were referred. Furthermore, it was stressed on how assessment should be done and then alternative assessment approaches besides classical ones were introduced with examples.

In the seventh chapter, after from how computer-assisted teaching is understood and how it has been applied so far was explained. The innovations and changes brought by information technology to mathematics education in general and ones brought particularly by computer technology was discussed. In addition, the potentials of these technologies for mathematics teaching were expounded and how to add these technologies in teaching-learning process was addressed with sample activities which were selected from mathematics subjects (primary, secondary and higher education programs). We believed that these sample activities would help readers to get some new perspectives in teaching-learning mathematics.

Finally in the eighth chapter, how recommendations (given previous chapters such as teaching mathematics considering nature of mathematics, constructing individual mathematics by students actively, and balance of operational and conceptual learning) could be reflected on teaching-learning activities was presented with examples. These sample activities were selected from mathematics subjects (primary, secondary and higher education programs) such as basic calculations, rational numbers, algebraic operations, matrices, set concept, function concept and its teaching, analyze subjects, conics, graphics. We hope that these sample activities would help readers to embrace contemporary teaching approaches.

This book, named as *"Mathematics Education Theory to Practice"* is one of the earliest resources published on mathematics education in Turkey. Comparing with some other books, it can be said that this book has a more comprehensive and rich content. The aims of this book includes to inform readers about problems discussed in mathematics education, theories and approaches concerning teaching-learning, results and recommendations coming from researches on mathematics education, mathematical activities appropriate modern education approaches and their application in classroom, and how students learn mathematics. In this context, this book presents samples activities that applicable in classrooms. Contrary to previous books written in mathematics education in Turkey, this book has a potential to reveal the beauty, mystery, aesthetic and attraction of mathematics besides overcoming deficiencies mentioned in the first paragraph. Considering that mathematics' beauty, feature of encouragement of thinking and usefulness, has long been ignored, the value of this book increases more. So we hope that this book would help both teachers- student teachers and educators and researchers who master on mathematics education to construct their own models and philosophies according to modern education approaches in the process of application new mathematics programs.

Written in Turkish, this book is fluent and can be understood easily. This Hard covered book has 647 pages. This book includes the content of five main topics (i.e. philosophy of mathematics education, history of mathematics, special teaching methods, computer-assisted mathematics teaching, and measurement-evaluation). Consequently, we think that the book can fill a big gap in the mathematics education in Turkey.

Davut Köğce, Research Assistant
Karadeniz Technical University, Fatih Faculty of Education
Department of Elementary Mathematics Education
61335 Trabzon / Turkey
E-mail: d_kogce@yahoo.com

Mehmet AYDIN, Research Assistant
Karadeniz Technical University, Fatih Faculty of Education
Department of Secondary Mathematics Education
61335 Trabzon / Turkey
E-mail: Maydin2005@ktu.edu.tr

Cemalettin YILDIZ, Research Assistant
Karadeniz Technical University, Fatih Faculty of Education
Department of Elementary Mathematics Education
61335 Trabzon / Turkey
E-mail:cemalyildiz61@hotmail.com

www.ejmste.com

EURASIA Journal of Mathematics, Science & Technology Education

Volume 5, Issue Number 1, February 2009

E-ISSN: 1305-8223