EXAMINING WHEN INSTRUCTIONAL ACTIVITIES WORK WELL IN RELATION TO SCIENCE ACHIEVEMENT

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Abstract

This study examines the instructional activities that underlie achievement in science using data from the TIMSS-R database. The focus population for this study is 15-year-old students from Cyprus. The results revealed a number of variables that were found to be negatively correlated with achievement as well as variables that were positively correlated with achievement. It appears that the negatively correlated variables that formed factor 1 fall into two broad categories, namely, use of technology and use of homework-related activities. In addition, the negatively correlated variables that fall into factor 2 could also be separated into two broad categories: using the board, and paper and pencil types of activities. Finally, the third factor included teaching strategies and group interactive activities which were associated with higher levels of science achievement. These results provide some insight into how instruction can be improved in Cypriot middle schools.

INTRODUCTION

The science education literature is filled with numerous research articles that suggest that many types of instructional methods are helpful in increasing the achievement levels and knowledge of students in the area of science. However, many of these results are based on small-scale studies that took place in well-controlled experimental conditions where teachers were excited about using new teaching methods, while the children were excited by the novelty of those activities. In addition, many such studies lack generalizability. Therefore, although some teaching methods might work exceptionally well when trained science educators use them, they might not work as well when teachers are not committed fully or do not know how to use the methods properly. Other teaching methods might also tend to work well in western and developed countries, although there is no guarantee that such results can be generalized to other non-western or developing countries.

Consequently, there is a need in all education research to correct the western bias that exists in a large majority of research studies, and to eliminate false generalizations from research conducted in western countries to other, very different developing countries in terms of culture and educational context.

The purpose of this study is to examine, through the TIMSS-R data, what type of teaching activities or methods used by science teachers work or do not work well in eighth grade science classrooms in Cyprus. This will be achieved through examination of the types of science activities that are associated with higher and lower levels of science achievement in this country.

The rational for this study is that by better understanding the relationship between specific instructional activities and achievement, educators can make more informed decisions on how to improve instruction in science. More specifically, many instructional activities might not work well in the classroom, if teachers do not know how to use them correctly, or when schools do not have the necessary equipment to use them optimally. Therefore, a careful examination of this issue could offer insights into why some teaching practices do not work well in certain situations in middle schools in Cyprus. Based on the same rationale, practices that work well in science classrooms because they are associated with higher levels of science achievement should also be identified.

Theoretical framework

It has been shown that poor science achievement can be remedied through more effective teaching strategies and more positive attitudes towards learning science (Papanastasiou & Zembylas, 2004). The development of more active and creative learning environments in classrooms is needed for the same purpose (Suárez et al., 1998). As a result, a substantial body of research has accumulated over the last three decades concerning the importance of various instructional activities for science and the relationship between these activities and science achievement (e.g. House, 2000; Haury & Rillero, 1992). For example, many researchers advocate instructional approaches that emphasize activities and learning by doing (hands-on science), which have proven to have a positive effect on students' science achievement (Haury & Rillero, 1992). This extensive literature includes national studies and international comparisons using numerous research methods (see e.g., Lemke et al. 2000; Martin et al., 1999). However, there has not been a consensus on the magnitude and direction of the relationship between hands-on science learning and science achievement. For example, although hands-on science has been proposed as a means to increase student achievement in science education, many educators have argued that hands-on science may reduce student achievement as well as improve it (Burkham, Lee & Smerdon, 1997; Glynn & Duit, 1995; Hodson, 1996; Peng & Hill, 1995).

Similar inconclusive results have recently been found in the relationships between computer use and mathematics and science achievement in various countries (Papanastasiou, 2003; Papanastasiou & Ferdig, 2003; Papanastasiou, Zembylas & Vrasidas, 2003). Although the usefulness and importance of educational technology is reflected through the rapid increase in the placement of computers in schools, there are still occasions where computer use is associated with lower levels of achievement.

Thus inconclusive and different results might be due to the complexities of these relationships (e.g. House, 2000; Zady, 2003) and the importance of investigating their "locality" (Papanastasiou & Zembylas, 2002), that is, the local influence of variables on student learning in science (Schibeci, 1989). Thus, this study examines the instructional activities that underlie achievement in science in the context of Cyprus.

METHODS

The results of this study are based on the repeat of the TIMSS that took place in 1999 (TIMSS-R). The sample of the study included 3116 Cypriot students who were in eighth grade at the time of the study. Of the whole sample, 49.1% were girls, while the average age of the sample was 13.8 years old. The main sources for these analyses were the TIMSS student questionnaires and student science achievement tests. The student questionnaires included items where the students had to report information about their mathematics and science classrooms, their backgrounds and activities, and instructional techniques used by their teachers.

For the purpose of this study, in addition to student's achievement, the only other variables explored were the activities related to the science teacher's teaching methods (as reported by the students). For the purpose of this study, the dependent variable was the students' science scores. The Rasch scale was selected for these analyses since it allowed for the scores of all students to be equated and placed on the same scale, regardless of which TIMSS booklet was assigned. The analyses performed in this study were based on correlational-based analyses (e.g., factor analysis) that were performed with SPSS 10.1.

RESULTS

The first analysis that was performed in this study was a Pearson correlation, to determine which types of science activities were positively and negatively correlated with science achievement on the TIMSS. Activities that were associated with high levels of science achievement in Cyprus were: using everyday things to solve science problems ($p = 0.155$, $p = 0.00$), giving homework ($p = 0.170$, $p = 0.00$), having the teacher check homework ($p = 0.093$, $p = 0.00$), having the teacher give demonstrations ($p = 0.100$, $p = 0.00$), having the teacher use the board ($p = 0.087$, $p = 0.00$), and having the students do experiments in class ($p = 0.049$, $p = 0.07$). These results are presented in Table 1.

Activities that were associated with lower levels of achievement were: copying notes from the board ($p = -0.058$, $p = 0.01$), working on projects ($p = -0.129$, $p = 0.00$), using calculators ($p = -0.126$, $p = 0.00$), students using computers ($p = -0.161$, $p = 0.00$), the students using the overhead ($p = -0.201$, $p = 0.00$), beginning homework in class ($p = -0.105$, $p = 0.00$), checking each other's homework ($p = -0.118$, $p = 0.00$), and the teacher using the computer ($p = -0.167$, $p = 0.00$). These results are also presented in Table 1.

Table 1: Correlation coefficient between science activities and science Rasch scores

	Pearson Correlation	*Sig. (2-tailed)*
Activities correlated *positively* with achievement	**Science Rasch score**	
Teacher shows how to do problems	.027	.129
Have a quiz or test	.012	.507
Work from worksheets on their own	.003	.881
Solve with everyday things	.155**	.000
Work in pairs or small groups	.024	.184
Teacher gives homework	.170**	.000
Teacher checks homework	.093**	.000
Teacher gives demonstrations	.100**	.000
Students do experiment in class	.049**	.007
Teacher uses board	.087**	.000
Students use board	.007	.698
Activities correlated *negatively* with achievement		
Copy notes from the board	-.058**	.001
Work on projects	-.129**	.000
Use calculators	-.126**	.000
Use computers	-.161**	.000
Begin homework in class	-.105**	.000
Check each other's homework	-.118**	.000
Discuss completed homework	-.005	.788
Teacher uses overhead	-.019	.316
Students use overhead	-.201**	.000
Teacher uses computer	-.167**	.000
New topic\teacher explains rules	-.011	.543

** significant at p = 0.01

In order to categorize these science activities, a principal components factor analysis was performed with a varimax rotation to create new factors. The factor analysis produced three overall factors. Factor 1 explained 13% of the total variance, Factor 2 explained 11.84% of the variance, while the third factor explained 11% of the variance. A close examination of the activities that fall into Factor 1 revealed that they could be separated into two broad categories, namely, use of technology (computers, calculators, and overhead projectors), and homework (begin homework in class, check each other's homework).

A similar examination of the seven activities that fall into Factor 2 included seven activities that fall into two broad categories: use of the board by the student and/or the teacher (copy notes from the board, teacher uses board, students use board), paper and pencil activities and demonstrations (teacher shows how to do problems, have a quiz or test).

Finally, Factor 3 activities could be separated into two broad categories: teaching strategies (teacher gives homework, teacher checks homework, discussion of completed homework, teacher gives demonstration, students do experiment in class, work in pairs or small groups) and group interactive activities (work in pairs, do experiments).

Table 2: Factor analysis results.

	Factor		
	1 *Technology, and homework*	*2* *Board and paper activities*	*3* *Teaching strategies and interactive activities*
Use computers	**0.749**	0.014	-0.016
Students use overhead	**0.677**	-0.030	0.085
Use calculators	**0.666**	0.072	0.020
Teacher uses computer	**0.665**	-0.054	0.048
Check each other's homework	**0.418**	0.221	0.188
Begin homework in class	**0.393**	0.330	0.057
Teacher uses overhead	**0.363**	-0.027	0.247
Work on projects	**0.327**	0.324	0.235
Copy notes from the board	0.121	**0.714**	-0.110
Teacher uses board	-0.196	**0.665**	0.069
Students use board	0.137	**0.547**	0.165
Teacher shows how to do problems	0.098	**0.505**	0.270
New topic\teacher explains rules	0.064	**-0.466**	-0.280
Teacher gives homework	-0.223	**0.411**	0.407
Have a quiz or test	0.152	**0.289**	0.287
Students do experiment in class	0.305	-0.046	**0.588**
Work in pairs or small groups	0.252	-0.012	**0.586**
Teacher gives demonstration	-0.177	0.195	**0.529**
Teacher checks homework	-0.015	0.356	**0.521**
Solve with everyday things	0.085	0.109	**0.505**
Work from worksheets on their own	0.162	0.274	**0.429**
Discuss completed homework	0.103	0.321	**0.363**

After the factors were identified, student scores for each factor were calculated and saved in the dataset. Student scores on these factors were then correlated with their science achievement. The results of these correlations are presented in Table 3. All three factors were significantly correlated with the science achievement of the students. However, Factors 1 and 2 were negatively correlated, while Factor 3 was positively correlated with the student's science achievement. However, the correlation of Factor 2 with science achievement was quite small in magnitude ($r = -0.05$, $p = 0.012$) although it was significant.

Table 3: Correlations of factors with Rasch science scores

	Pearson Correlation	*Sig. (2-tailed)*
Rasch science score	1	–
Factor 1. Technology and Homework	-.225	.000
Factor 2. Board and paper activities	-.053	.012
Factor 3. Teaching strategies and interactive activities	.185	.000

DISCUSSION

Findings from this study demonstrated that when students use technology (computers, calculators, and overhead projectors), begin homework in class, check their classmates' homework, and interrupt their teacher, their achievement in science is negatively affected. It is surprising that the use of technology had a negative effect on Cypriot students' achievement. Earlier studies in science education have reported that the use of technology, and especially the use of computers, is highly and positively correlated to science achievement (Zacharia & Anderson, 2003; Beichner et al., 1999; Goldberg, 1997; Van Heuvelen, 1997; Eylon, Ronen, & Ganiel, 1996; Grayson & McDermott, 1996). One possible explanation for this surprising result is that teachers in Cyprus are not adequately trained to be able to use such technology. Researchers have argued that when teachers are not well trained to use science-related learning/teaching tools, they are reluctant to put in the time and effort to use them (Hounshell & Hill, 1989). The findings of this study, in conjunction with a number of other studies in recent years, suggest that student learning would be enhanced by teachers who are more knowledgeable in their field and are skillful at teaching it to others. Substantial evidence from prior reform efforts indicates that changes in course taking, curriculum content, testing, or textbooks make little difference if teachers do not know how to use these tools well and are unable to diagnose their students' learning needs (Darling-Hammond, 1997).

Other findings in this study that had a negative effect on achievement (begin homework in class, check their classmates' homework) comply with results from previous research work (Brookhart, 1997). It has been found that any homework assignment that is not well designed (structured guidelines, time for students to study her/his homework, hands-on projects and cooperative learning are important parameters that should be considered when homework is designed) and not interactive in terms of levels of family and teacher involvement, negatively affects not only students' achievement but also students' cognitive and attitudinal domain (Farrow, Tymms & Henderson, 1999; House 2000; Van Voorhis 2001). According to Van Voorhis (2001) any diversion from this model, such as the ones found in this study (begin homework in class, check their classmates' homework), should be avoided in order to eliminate any possible negative impact on students' achievement.

Two additional findings emerged from this investigation. First, it is obvious that working on projects and approaching them based on everyday experience, has a significantly positive effect on achievement. According to the National Research Council (1996), relating science to everyday activities creates a learning environment where students are motivated and actively engaged because as teaching progresses toward increasingly familiar ideas, students' experiences relevant to what is to be learned increase significantly. Posner et al. (1982) point out that students hold strong opinions about how the world operates because their conceptual knowledge has been constructed over many years of experience in the everyday world. Thus, a meaningful learning experience requires science instruction that embraces students' worldviews in a way that promotes assimilation of the scientifically accurate conceptions (American Association for the Advancement of Science, 1993; Haladyna, Olsen, & Shaughnessy, 1982, 1983; Myers & Fouts, 1992; Roth & Lucas 199; Simpson & Oliver, 1990).

Another major finding of this study was that specific teaching strategies can affect the students' achievement in science. Specifically, it was found that when a teacher assigns homework, checks students' homework, and uses demonstrations, students' achievement is positively affected. This finding complies with the work of Stefanich and Kelsey (1989) and Hewson, Kerby, and Cook (1995), who have found that teachers' practices and strategies were shown to have a strong influence on students' science achievement and learning. Arguably, the efforts of the science education community should focus on research issues related to the development of effective teaching strategies because of their strong link to classroom activities.

CONCLUSIONS AND IMPLICATIONS

Several implications may be drawn from this study. The most important, though, is that some of our findings contradict the results of previous research studies. This is an indication that teaching methods and strategies that work well in experimental research settings might not always work well in practice. It is also possible that teaching strategies employed in one culture might not work as well in other cultures; this is something that deserves further investigation. A cross-cultural comparison of science achievement in conjunction with effective teaching strategies would be valuable both for researchers and practitioners.

Most importantly though, it is likely that many teachers in Cyprus are not adequately prepared to use such teaching methods appropriately in order for their students to profit from them. One way to overcome this problem is to understand that there is a need to target science educators to detect possible sources of ineffective practices and thus to enhance teaching behaviors (Tobin, Tippins, & Gallard, 1994). Therefore, such results might also indicate the need for continuous teacher training, accountability and professional development in the educational system in Cyprus. Many studies show that professional development that enhances teachers' subject matter knowledge and expands their range of teaching practices are likely to enhance student achievement. For example, Monk (1994) has found that additional coursework in specific areas (e.g., number and types of science courses) has a positive effect on student learning. In addition, advanced coursework in science (e.g., graduate courses) as well as high teacher achievement in those courses have been related to improved student achievement. Thus, professional development for Cypriot teachers should provide opportunities so that teachers have experiences to test, discuss, and analyze new teaching strategies. Professional development not only improves teachers' knowledge but also positively influences their attitudes towards science. It is expected that teachers equipped with expanded content knowledge, positive attitudes toward science, models of technology integration, and effective teaching strategies will make significant impacts in Cypriot classrooms and on students' learning.

However, it should be emphasized that this study can only be considered as the first step in a series of future studies that should examine these relationships more specifically and in depth. This current study is purely exploratory in nature, so it has only descriptively identified the types of teaching methods and activities that work and do not work well in relation to science achievement in Cyprus. In order to reach conclusive results, each of these activities must be examined closely in practice to determine the specific reasons that have contributed to the directions and magnitudes of these relationships. For this purpose, a future study that combines qualitative and quantitative methodologies could be useful in investigating this issue.

References

American Association for the Advancement of Science. (AAAS). (1993). *Benchmarks of science literacy*. New York, NY: Oxford University Press.

Beichner, R., Bernold, L., Burniston, E., Dail, P., Felder, R., Gastineau, J., Gjersten, M., & Risley, J. (1999). Case study of the physics component of an integrated curriculum. Physics Education Research, *American Journal of Physics Supplement, 67*, 16-24.

Burkham, D. T., Lee, V. E., & Smerdon, B. A. (1997). Gender and science learning early in high school: Subject matter and laboratory experiences. *American Educational Research Journal, 34*, 297-331.

Brookhart, S. (1997). Effects of the Classroom Assessment Environment on Mathematics and Science Achievement. *Journal of Educational Research, 90*(6), 323-330.

Darling-Hammond, L. (1997). *The right to learn: A blueprint for creating schools that work*. San Francisco: Jossey Bass.

Eylon, B.S., Ronen, M., & Ganiel, U. (1996). Computer simulations as tools for teaching and learning: Using a simulation environment in optics. *Journal of Science Education and Technology, 5* (2), 93-110.

Farrow, S., Tymms, P., & Henderson, B. (1999). Homework and Attainment in Primary Schools. *British Educational Research Journal, 25*(3), 323-341.

Geban, O., Askar, P., & Ozkan, I. (1992). Effects of computer simulations and problem-solving approaches on high school students. *Journal of Educational Research, 86*, 5-10.

Glynn, S. M., & Duit, R. (1995). Learning science meaningfully: Constructing conceptual models. In S. M. Glynn and R. Duit (Eds.), *Learning science in the schools: Research reforming practice* (pp. 3-33). Mahwah, NJ: Erlbaum.

Goldberg, F. (1997). Constructing physics understanding in a computer-supported learning environment. *AIP Conference Proceedings*, *399*, 903-911.

Grayson, D. & McDermott, L. (1996). Use of the computer for research on student thinking in physics. *American Journal of Physics, 64*, 557-565.

Haladyna, T., Olsen, R., & Shaughnessy, J. (1982). Relations of student, teacher, and learning environment variables to attitudes toward science. *Science Education*, *66*, 671-687.

Haladyna, T., Olsen, R., & Shaughnessy, J. (1983). Correlates of class attitude toward science. *Journal of Research in Science Teaching, 20*, 311-324.

Haury, L., & Rillero, P. (1992). *Hands-On Approaches to Science Teaching: Questions and Answers from the Field and Research.* ERIC Document (ED349185).

Hewson, P. W., Kerby, H. W., & Cook P. A. (1995) Determining the conceptions of teaching science held by experience high school science teachers. *Journal of Research in Science Teaching, 32*, 503-520.

Hodson, D. (1996). Laboratory work as scientific method: Three decades of confusion and distortion. *Journal of Curriculum Studies, 28*, 115-135.

Hounshell, P. B., & Hill, S. R. (1989). The microcomputer and achievement and attitudes in high school biology. *Journal of Research in Science Teaching, 26*(6), 543-49.

House, J. D. (2000). Relationship between instructional activities and science achievement of adolescent students in Hong Kong: Findings from the Third International Mathematics and Science Study (TIMSS). *International Journal of Instructional Media, 27*, 275-288.

Lemke, M., Lippman, L., Bairu, G., Calsyn, C., Kruger, T., Jocelyn, L., Kastberg, D., Liu, Y. Y., Roey, S., & Williams, T. (2000). *Outcomes of learning. Results from the 2000 Program for International Student Assessment of 15-year-olds in reading, science and science literacy.* National Center for Educational Statistics, Washington, D.C.: NCES 2002-115.

Martin, M. O., Mullis, I. V.S., Gonzalez, E. J., Gregory, K. D., Smith, T. A., Chrostowski, S. J., Garden, R. A., & O'Connor, K. M. (1999). *TIMSS 1999*

International Science Report: Findings from IEA's Repeat of the Third International Science and Science Study at the Eighth Grade. Boston, MA: Boston College, International Study Center.

Monk, D.H. (1994). Subject area preparation of secondary mathematics and science teachers and student achievement. *Economics of Education Review, 13*, 125-145

Myers, R. E., & Fouts, J. T. (1992). A cluster analysis of classroom environments and attitude toward science. *Journal of Research in Science Teaching, 29*, 929-937.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

Papanastasiou, E. C. (2003). Science literacy by technology by country; USA, Finland and Mexico. Making sense of it all. *Research in science and technology education, 21*(2), 229-241.

Papanastasiou, E. C., & Ferdig, R. E. (2003). Computer use and mathematical literacy. An analysis of existing and potential relationships. *Proceedings of the third Mediterranean conference on mathematical education* (pp.335-342). Athens, Greece: Hellenic Mathematical Society.

Papanastasiou, E., & Zembylas, M. (2002). The relationship between science attitudes and achievement at the senior high school year in Cyprus. *International Review of Education, 48* (6), 469-484.

Papanastasiou, E. C. & Zembylas, M. (2004). Differential effects of science attitudes and science achievement in Australia, Cyprus, and the USA. *International Journal of Science education, 26*(3), 259-280.

Papanastasiou, E. C., Zembylas, M., & Vrasidas, C. (2003). Can computer use hurt science achievement? The USA results from PISA. *Journal of science education and technology, 12*(3), 325-332.

Peng, S. S., Wright, D. A., & Hill, S. T. (1995). *Understanding racial-ethnic differences in secondary school science and mathematics achievement* (NCES 95-710). Washington, DC: U.S. Department of Education, NCES.

Posner, G.J., Strike, K.A., Hewson, P.W., & Gertzog, W.A. (1982). Accommodation of scientific conception: Toward a theory of conceptual change. *Science Education, 66*, 211-227.

Roth W. M. and Lucas K. (1997). "From 'Truth' to 'Invented Reality': A Discourse Analysis of High School Physics Students' Talk about Scientific Knowledge," *Journal of Research in Science Teaching, 34*, 145-179.

Schibeci, R.A. (1989). Home, school, and peer group influences on student attitudes and achievement in science. *Science Education, 73*, 13-24.

Simpson, D., & Oliver, S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education, 74*, 1-18.

Stefanich, G., & Kelsey, K. (1989). Improving science attitudes of preservice elementary teachers. *Science Education, 73*, 187-194.

Suárez, M., Pías, R., Membiela, P., & Dapía, D. (1998). Classroom environment in the implementation of an innovative curriculum project in science education. *Journal of Research in Science Teaching*, *35*, 655-671.

Van Heuvelen, A. (1997). Using interactive simulations to enhance conceptual development and problem solving skills. *AIP Conference Proceedings*, *399*, 1119-1135.

Van Voorhis, F. (2001). Teachers' Use of Interactive Homework and Its Effects on Family Involvement and Science Achievement of Middle Grade Students. Paper presented at the Annual Meeting of the American Educational Research Association (Seattle, WA, April 10-14).

Zacharia, Z., & Anderson, R. (2003). The Effects of an Interactive Computer-Based Simulation Prior to Performing a Laboratory Inquiry-Based Experiment on Students' Conceptual Understanding of Physics. *American Journal of Physics*, *71*(6), 618-629.

Zady, M. F., Portes, P. R., & Ochs,V. D. (2003). Examining classroom interactions related to difference in students' science achievement. *Science-Education, 87*, 40-63.