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Envisioning the Future: The Role of Curriculum Materials and Learning Environments in Educational Reform

Proceedings of the Sixth International Conference on Science, Mathematics and Technology Education

Hualien, Taiwan
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Edited by

Wen-Hua Chang, Darrell Fisher, Chen-Yung Lin and Rekha Koul

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PREFACE

The Sixth International Conference on Science, Mathematics and Technology Education was held in Hualien, Taiwan in January, 2010. The theme of the conference was 'Envisioning the Future: The Role of Curriculum Materials and Learning Environments in Educational Reform'and it was organised jointly by the National Taiwan Normal University, Taiwan and the national Key Centre for School Science and Mathematics, Curtin University, Australia.

The conference provided an intellectually challenging and culturally enriching experience for science, mathematics and technology teachers, teacher educators, researchers and administrators from primary, secondary and tertiary education from around the world. Over 177 participants from 16 countries had an opportunity to interact and exchange innovative ideas, research findings and practical implications in the traditional fields of science, mathematics and technology education as well as new areas of international significance related to the conference theme.

These proceedings are a result of the conference. All papers contained in the proceedings were presented at the conference and consequently submitted to a reviewing process. Each paper was reviewed by at least two referees. The papers have been organised alphabetically in these proceedings.

This conference is now providing a supportive environment, particularly for early-career researchers, and it was noticeable that a number of these new researchers presented papers. The conference has also successfully brought together the educational areas of science, mathematics and technology.

We have continued our mode of publication as an electronic form. However, people may order a book of the proceedings by contacting one of the editors.

ACKNOWLEDGEMENTS

The conference would not have been possible without the support of the National Taiwan Normal University, Taipei, Taiwan and the Key Centre for School Science and Mathematics, Curtin University, Perth, Australia.

We would like to thank all the authors who contributed their papers to these proceedings. We would also like to thank the reviewers and particularly the members of the Editorial Board for their time and diligence.

The book represents contributions from many nations including Australia, Brunei, Hong Kong, India, Japan, Malaysia, New Zealand, Philippines, Singapore, South Korea, Taiwan, Thailand, and USA. We acknowledge the contributions of people from all these countries. The fields of science, mathematics and technology education research represent a truly international endeavour.

Wen-Huia Chang, Darrell Fisher, Chen-Yung Lin and Rekha Koul
Editors
October, 2010

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STUDENTS' MULTIPLE REPRESENTATIONS AND ATTITUDE TOWARD LEARNING UNIVERSITY PHYSICS

Yen-Ruey Kuo, David F Treagust, Marjan Zadnik and Salim Siddiqui
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ABSTRACT

This case study was conducted with first year students who were enrolled in non-major Physics units in a university in Australia. Two questionnaires on the topic of Thermal Physics and Optics, respectively, were designed for assessing students' conceptual understanding of the way in which multiple representations (description using words, diagrams, formulas and coordinate graphs) were used to explain the concepts. Students also responded to a Physics Expectation Survey, a Physics Experience Survey and a Physics Motivation Survey to gain an understanding of their attitude toward studying Physics. The Physics Expectation Survey and the Physics Experience Survey, which are pre and post test respectively, showed there was no significant difference between students' expectations and actual experience. The two surveys also showed students' expectations and experience were in upper-intermediate level. As for the Physics Motivation Survey, it revealed that on average students had a positive attitude towards learning Physics. Besides, the questionnaires that assessed students' conceptual understanding of multiple representations in Physics showed that there was a significant increase in the number of students' different representations after changing the format of the questions. However, a large number of students were unable to solve the questions effectively on the questionnaires no matter the format of the questions had been changed or not.

Key words: Physics; multiple representations; motivation; attitudes; service teaching

INTRODUCTION

Learning and assessment using multiple representations

In the recent years, there has been an increasing amount of research discussing the effects of teaching and learning with multiple representations (e.g. Schnotz & Bannert, 2003; Tytler, Peterson, & Prain, 2006; Waldrip & Prain, 2006). Although there is growing recognition that students have to understand and link different representations in learning to think and act scientifically, this task is not easily achieved. There are many factors that can influence the effect of students learning with multiple representations. For example, Cook (2006) and Seufert (2003) have argued that students' prior knowledge is a key factor in multiple representational learning. In summarizing these factors, Ainsworth (2006) provided a conceptual framework (DeFT—Design, Functions, Tasks) for considering learning with multiple representations. The research described in this chapter illustrates how the effectiveness of multiple representations can be evaluated taking into account the three phases: the design parameters of representations, the functions that representations provide for learning, and the cognitive tasks which have to be undertaken by learners. Nevertheless, before forming principles for learning with multiple representations, more research studies are needed to verify the effectiveness of multiple representations from the three phases.

A related construct to learning with multiple representations is higher-order thinking. If science courses are going to involve students in higher-order thinking, then students need to be able to construct arguments, ask questions, make comparisons, establish causal relationships, identify hidden assumptions, evaluate and interpret data, formulate hypotheses and identify and control variables (Osborne & Dillon, 2008) Earlier, Black and William (1998) suggested alternative forms of assessment which emphasize student reasoning rather than knowledge acquisition. To achieve the goal of assessing students' multiple abilities in science learning, many tasks can be designed in the process of teaching. Treagust, Jacobowitz, Gallagher, and Parker (2001, 2003) embedded different tasks such as pretests, asking questions of students, conducting experiments and activities, writing tasks, drawing diagrams in the instruction on the topic of sound to Grade 8 students. The research showed that students' understanding was more effectively assessed with multiple representations rather than one representation. In this research, we developed and used questionnaires which assess students' conceptual understanding of several physics concepts using multiple representations.

Attitude towards learning Physics

The importance of students' attitudes (e.g. motivation, expectations) towards learning Physics has been well documented by research in the past years. Frequently, students' attitude towards learning Physics usually has a positive correlation with academic achievement and conceptual understanding (Chu, Treagust, & Chandrasegaran, 2009; Minkee, 2008; Russell & Hollander, 1975) but this is not always the case. Furthermore, Nieswandt and Shanahan (2008) found that motivation can influence students' goal structure in learning and Redish, Saul, and Steinberg (1998) showed that the students' expectation and the their actual experience on a Physics course can impact what they learn from the course. As noted by Tobin, Seiler, and Walls (1999), if students lack motivation to learn, it is difficult to engage students in the instruction. Indeed, instruction in science classes should not only take care of cognitive objectives but students' attitude toward the subject (Russell & Hollander, 1975). Park (2007) stated that instructors need to think about the components of students' conceptual ecologies relating logical structure, rational process and affective aspects. Since the importance of students' attitude toward learning should not be neglected in the science classroom, the approaches used to improve students' attitude (Larkin-Hein, 2000) and more details in the relation between students' attitude and their learning (Fischer & Horstendahl, 1997) have been examined.

Since the students' attitude toward learning science is important, the issue on how to measure students' attitude has been given attention in this study. Many instruments have been developed to measure students' attitude toward science or mathematics, however, every instrument has different definition and scales about attitude (Leder, 1985). For example, in the aspect of measuring students' attitude towards learning Physics, CLASS (Adams, Perkins, Podolefsky, Dubson, Finkelstein & Wieman, 2006), MPEX (Redish, Saul & Steinberg, 1998), VASS (Halloun & Hestenes, 1998), EBAPS("EBAPS items,") are well-known instruments but they measure different aspects of students' attitudes toward Physics or learning Physics. Regardless the difference, once the instrument has high validity and reliability, it can be accepted to be used in studies. The instruments mentioned above also have been used for different research or instructional purposes in the classroom.

A more appropriate measures of attitude used in this study, was the Physics Motivation Survey revised from Science Motivation Questionnaire (Glynn, Taasoobshirazi, & Brickman, 2009) and two surveys used as a pre and a post test. The pre test is an Expectation Survey and post test is an Experience Survey (Kirkup & Mendez, 2009). Science Motivation Questionnaire was developed in recent years and is ideal for the research described in this chapter. The Expectation Survey and Experience Survey were newly developed and need more evidence to prove their validity and reliability. Based on the reasons above, the three surveys were used in this research and were expected to uncover the students' attitudes towards learning Physics.

RESEARCH METHODOLOGY

Research Questions

Two research questions guided this study:
How can the questionnaires for assessing students' Physics conceptual understanding using multiple representations be designed in the target units?
How is the students' attitude towards learning Physics in the target units?

Consequently, the two aims of the study were to:
Design and implement suitable questionnaires which can effectively assess students' Physics conceptual understanding using multiple representations (word descriptions, diagrams, formulae, coordinate graphs) in the target units.
Administer surveys to investigate students' attitude toward learning Physics.

Case study design

Merriam (1988) mentioned that although the term case study is well-known to most people, there is little agreement on what constitutes case study research. Anderson (2004) indicated that case studies are suitable for the educational situations which do not easily allow tight control or experimental manipulation. Case studies also are suitable for applying in a little known or poorly understood situation (Leedy & Ormrod, 2005).

In this case study, there was no controlled intervention or experimental manipulation. Rather all students participated in lectures, tutorials and laboratory work where physics concepts were introduced using a variety of multiple representations by lectures and tutorials (showing text, diagrams, photos, equations) and laboratory work where students conducted experiments and wrote up their findings. At the outset, the researchers had to identify those parts of the conceptual framework (Ainsworth, 2006) that actually worked. Hence, the research about students learning with multiple representations was exploratory and sought clarification. A case study was a reasonable method to be used in this research. As explained at the outset, the first aim of this research and what is reported in this paper is to determine how best to design a questionnaire to assess multiple representations using word descriptions, diagrams, formulae, coordinate graphs.

This case study was conducted in two Physics Units (Unit A and Unit B) in a university in Australia with Physics non-major students comprising 82 in Unit A and 67 in Unit B. The program for Unit A required students to take six modules, namely, Fundamental Principles, Thermal Physics, Waves and Sound, Electricity, Optics, and Atomic and Nuclear Radiation. The students in Unit B only were required to take Fundamental Principles, Thermal Physics, and Waves and Sound, The duration of the case study was three continuous semesters, which were named Phase One, Phase Two and Phase Three for each semester, sequentially. During Phase One of the study, the questionnaire assessing students' understanding of SHM (Simple Harmonic Motion) with multiple representations was designed preliminarily and given the first trial. In the first trial, problems from students' responses to the questionnaire were identified such as the definition of each representation was not clear to students.

Based on a careful examination and subsequently changing and solving the problems, a new questionnaire which assesses students' understanding of Thermal Physics and Optics using multiple representations was designed and distributed to students. This aspect is Phase Two described in this chapter. Students' low motivation in learning Physics was observed in class during Phase One and to investigate students' attitude toward learning, the Physics, Expectation and Experience Surveys (pre and post test respectively), and the Physics Motivation Survey were distributed to students in Phase Two.

Design and implementation of the Thermal and Optics Questionnaires

The Thermal Questionnaire and the Optics Questionnaire were designed and administered separately. There are two parts in each questionnaire: the first part requires personal information, including student's name, student ID, unit studying and to which year the student has previously studied Physics at school. The second part includes 12 questions in Thermal Module and also 12 questions in Optics Module. After development, three experts reviewed each question before distributing to students. Most questions are designed to be related to everyday life experience and also based on what would be /or had been taught in lectures, tutorials and laboratories. Before the questions, there is one instruction page which shows students how to answer the questions using multiple representations (recommendations being word description, diagram, formula, coordinate graph). In the formula part of the instruction page is a list of formulae were provided which may be used for answering the following questions, so students did not need to memorise the related formulas. Students were not allowed to refer any other materials (e.g., books, lecture notes) and discuss with other people while responding the questions.

Both questionnaires were distributed to students on two separate occasions as pre and posttests. Pretests were distributed during the week before the module instruction started, and posttests were distributed immediately after the module instruction had finished. There is one point which needs to be noted: the question format of Optics Questionnaire in the posttest was different from the one in pretest. The reason why the question format had been changed was from the preliminary analysis of students' responses to pre, post test in Thermal Module and pre test in Optics Module, it was found though we asked students to answer the questions using as many representations as they can, most students responded the questions just using one representation, which was with a word description. In order to approach the research aim and obtain more different kinds of students' representations, the representations which are suitable for solving each question were selected for students in the post test of Optics Questionnaire so there were separate spaces for word description, diagram, formula, coordinate graph. However, the contents of the questions were exactly the same as pre test. In addition, in order to reduce the students' workload, the Optics Questionnaire in posttest was divided to Questionnaire A and B, which were distributed to students randomly and evenly.

Administration of the Physics Motivation Survey

The Physics Motivation Survey was revised from Science Motivation Questionnaire (SMQ), which was developed by Glynn and Koballa in 2005. SMQ had been administered to 770 non-science majors and had good reliability and validity. There are 30 Likert-type items and 5 factors (intrinsic motivation and personal relevance, self-efficacy and assessment anxiety, self-determination, career motivation, grade motivation) in the SMQ and the Physics Motivation Survey keeps the same number of items and factors. What we revised from SMQ were changing the word "science" to "Physics" and some wording to meet the Australian grading system. The Physics Motivation Survey was distributed in the sixth week of the total 12 tuition weeks.

Administration of the Expectation Survey and Experience Survey

The Expectation Survey and The Experience Survey were developed from a project funded by Australian Learning and Teaching Council (ALTC). ALTC held a project workshop in which 25 academics from 12 universities attended. In this workshop, "what constitutes good service teaching" was suggested from the 25 academics. Based on the suggestions, Expectation Survey and Experience Survey were devised by the project working party. However, neither instrument had measures of validity or reliability.

In this study, the Expectation Survey was administered in the orientation week and Experience Survey was distributed in the 10th week of the total 12 tuition weeks. The goal was to determine if there were any significant differences between students' expectations and their actual experience.

RESULTS

Results from the Thermal and Optics Questionnaires

Development of the evaluation criteria. To develop an accurate procedure for evaluating the student questionnaires and to determine how many representations students used as responses, six students' questionnaires which had more representations than others were selected from each of Thermal posttest Questionnaires, Optics posttest Questionnaires A, and Optics posttest Questionnaires B. A scoring rubric was developed and confirmed by the researchers to assess the number of representations students used in every question and the mark for every student's representation (the mark was given on the basis of 0: wrong; 1: mostly wrong; 2: mostly right; 3: right). Two raters independently scored the six students' questionnaires for all questions and the inter-rater reliability for each group of six students' questionnaires reached 86% and 90% after negotiation with dissimilar ratings by two raters.

The Thermal Questionnaire (post test) contained 12 questions in total. Of six students, only one student provided three representations on 10 of 12 questions, one student provided three representations on one of 12 questions. Of six students, only one student provided two representations on six of 12 questions, two students provided two representations on five of 12 questions, one student provided two representations on two of 12 questions, two students provided two representations on two of 12 questions.

In Optics Questionnaire A (post test), there are six questions in total. Of six students, only one student provided one representation on one of six questions. In Optics Questionnaire B (post test), there are also six questions in total. Of six students, only one student provided one representation on one of six questions, one student provided no representations on one of six questions. Besides the evidence above, we also checked the remaining students' questionnaires. It was concluded that most students just used one representation as a response in Thermal Physics Questionnaire (pre and post test), and Optics Questionnaire (pre test), whilst most students used more than one representation as response in the Optics Questionnaire (post test) in which the question format had been changed.

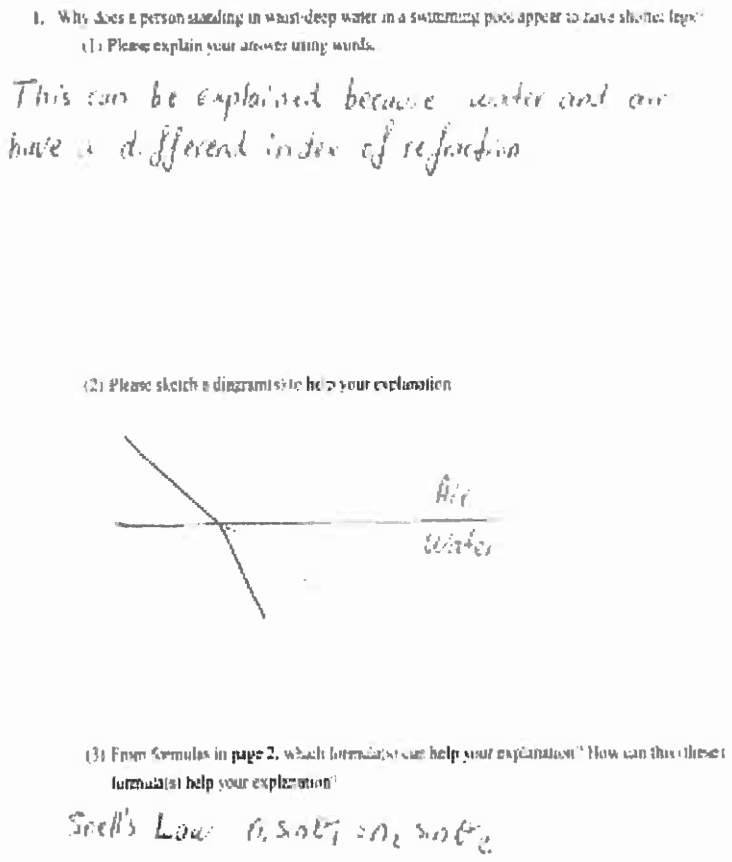

Figure 1 A student typical response to multiple representational on the Optics Questionnaire

Evaluating returned student questionnaires No matter whether the question format had been changed or not, the majority of students were not able to solve the questions effectively. For example, Figure 1 is a typical response of most students. In the part of word description, the answer does not address the main point and more details need to be described. In the diagram part, the diagram cannot present the complete situation of the question and more labels are needed to clarify the lines. In the part of formula, the variables need to be explained and to be applied to the situation of the question.

Taking another example, students' grand mean of marks in each representation in pre tests and post tests on the Thermal Physics Module are shown in Table 1. Each grand mean of mark is less than 2 (Mostly right) except the mark in the representation of graph in the posttest for Unit A (Grand mean=2.00, but just only one response). Typically even after 7 weeks of teaching that designed to provide these physics students with a wide range of representations, the tendency of students was to only respond to a question using one representation and with a maximum score possible of 3, the grand mean score was a little more than 1, mostly wrong. To sum up, students' understanding of tested concepts was not at a high level. Further as noted in table 1, not all students completed the written tests that were non-compulsory.

Table 1 Comparison of pretest and posttest in the number of students' representations and the marks in different students' representations on Thermal Physics Module

N: Number of Students who returned questionnaires; #R: Mean Number of Representations per questions; A: Mean score in Words per question (Written Description); B: Mean score in Diagrams per question; C: Mean score in Formula per question; D: Mean score in Coordinate Graph per question

Results from Physics Motivation Survey

	Unit A			Unit B		
	Pre Test Grand Mean(N=39)	Post Test Grand Mean(N=31)	Gain	Pre Test Grand Mean(N=28)	Post Test Grand Mean(N=8)	Gain
#R	1.06	1.19	0.13	1.15	1.23	0.08
A	1.07	1.27	0.20	1.20	1.20	0.00
B	0.83	0.94	0.11	0.78	0.87	0.09
C	1.69	1.67	-0.02	1.40	1.60	0.20
D	0.00	2.00	2.00	-	-	-

The mean scores of the different five factors of Physics Motivation Survey are shown in Table 2. It can be found except for the mean in the factor of self-efficacy and assessment anxiety, all means are located between 3 (sometimes) and 4 (usually). However, the mean in the factor of self-efficacy and
assessment anxiety is near 3 (sometimes). With the exception of grade motivation (GM) the Cronbach's Alpha reliability measures for each factor are acceptable: 0.86 for IMPR (N=75), 0.77 for SEAA (N=76), 0.73 for SD (N=76), 0.80 for CM (N=76), 0.47 for GM (N=76). The overall Physics motivation of students from Unit A and Unit B together was in upper-intermediate level when the survey was distributed (in the sixth week).

Table 2 Mean and standard deviation for the five factors of the Physics Motivation Survey (N=76)

	IMPR	SEAA	SD	CM	GM
Mean	3.54	2.99	3.69	3.45	3.91
Std. Deviation	0.59	0.58	0.65	0.88	0.51
Minimum	2.20	1.67	1.75	1.00	2.60
Maximum	4.90	4.22	5.00	5.00	5.00

(Five factors: IMPR: intrinsic motivation and personal relevance, SEAA: self-efficacy and assessment anxiety, SD: self-determination, CM: career motivation, GM: grade motivation)

Results from Expectation and Experience Survey

From Table 3, it is revealed that there were no statistically significant differences between students' expectations and actual experiences when we consider Unit A and Unit B as a whole. The Cronbach's Alpha reliability values for the Expectation Survey is 0.73 (N=91), and for Experience Survey is 0.57 (N=59). Besides the finding that students' experience had no statistical difference compared to their expectation, the mean of each survey was in between 3 (neutral) and 4 (agree), which means their expectation and experience were in upper-intermediate level.

Table 3. Paired samples t test for the difference between mean of Expectation Survey and mean of Experience Survey (N = 45)

Survey	Cronbach's Alpha	Mean	Standard dev	t-value
Expectation	.73	3.72	.48	.49
Experience	.57	3.69	.33	

DISCUSSION AND SUGGESTIONS

The study reported in this chapter is part of an investigation to encourage non-physics major students to present what they understand about physics topics of optics and thermal concepts using different representations and to determine how best to solicit and measure these representations. Much has been learned in Phase Two of this study. To improve students' weak performance in the multiple representational questionnaires and encourage students' self-learning, in Phase Three, students will not be prohibited from referring any other materials and discussing with other students while responding the questions. Also richer data in different representations could be obtained by doing this and help us uncover the relationships among the representations and questions.

Also, since the question format of the Optics Questionnaire posttest is likely to induce different kinds of students' representations, this format will be used in Phase Three for the third assessment of the multiple representational questionnaires. In addition, in the diagram part of the questionnaire, diagrams showing the context of the questions will be provided on the questionnaire before distribution in order to induce more diagram representations.

With regards to the motivation investigation gained from Physics Motivation Survey, Expectation Survey and Experience Survey, the results contradicted the classroom observations in Phase One. In Phase Two, Expectation Survey and Experience Survey were distributed before the beginning and near the end of the semester course, and Physics Motivation Survey was distributed in the middle of the semester course. It can be seen students' attitude towards learning Physics was positive, in upper-intermediate level in the beginning and in the mid of the semester course. Besides, from the result of Experience Survey, students' actual experience met their expectations. It can be speculated that the students' attitude towards learning Physics throughout all semester course was positive. However this findings was quite different from the classroom observations in Phase One when it was observed that students did not do homework, did not propose questions actively in tutorials, the rate of class attendance was around or less than half, and so on. The reason making the difference of students' attitudes towards learning Physics between the two phases needs to be further investigated in Phase Three.

There is another point worth mentioning. Although students' attitude towards learning Physics was positive while they responded to the multiple representational questionnaires, their conceptual understanding shown in their responses was superficial. It is quite interesting to investigate what caused the gap and the investigation will be one of the emphases in Phase Three study and will involve student interviews.

Overall in Phase Three, the multiple representational questionnaires will be revised and distributed to students for the third trial. Besides that, Expectation Survey, Experience Survey and Physics Motivation Survey will be administered again, and we will involve more non-Physics majors to fill in those surveys and questionnaires for getting more reliable results. Finally, some students will be interviewed to help us get deeper understanding of the relations within and between the multiple representations, students' conceptual understanding and students' attitude towards learning Physics.

REFERENCES

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). New instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey. Physical Review Special Topics - *Physics Education Research, 2*(Copyright (C) 2010 The American Physical Society), 010101.

Ainsworth, S. E. (2006). DeFT: A conceptual framework for learning with multiple representations. *Learning and Instruction, 16*(3), 183-198.

Anderson, G. (2004). *Fundamentals of educational research.* (2nd ed.). London and New York: RoutledgeFalmer.

Black, P., & William, D. (1998). Assessment and classroom learning. *Assessment in Education, 5*(1), 7-74.

Chu, H.-E., Treagust, D. F., & Chandrasegaran, A. L. (2009). A stratified study of students' understanding of basic optics concepts in different contexts using two-tier multiple-choice items. *Research in Science & Technological Education, 27*(3), 253-265.

. EBAPS items. from http://www2.physics.umd.edu/~elby/EBAPS/EBAPS_items.htm

Fischer, H., & Horstendahl, M. (1997). Motivation and learning physics. *Research in Science Education, 27*(3), 411-424.

Glynn, S., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching, 46*(2), 127–146.

Halloun, I., & Hestenes, D. (1998). Interpreting VASS dimensions and profiles for physics students. *Science & Education, 7*(6), 553-577.

Kirkup, L., & Mendez, A. (2009). *Forging new directions in physics education in Australian universities-- Service teaching working party report*: Australian Learning and Teaching Council.

Larkin-Hein, T. (2000). *Learning styles in introductory physics: Enhancing student motivation, interest and learning*. Paper presented at the International Conference on Engineering and Computer Education S´o Paulo, Brazil.

Leder, G. C. (1985). Measurement of Attitude to Mathematics. *For the Learning of Mathematics, 5*(3), 18-34.

Leedy, P. D., & Ormrod, J. E. (2005). *Practical research: Planning and design*. Upper Saddle River, New Jersey: Pearson Prentice Hall.

Merriam, S. B. (1988). *Case study research in education*. San Francisco: Jossey-Bass.

Minkee, K. (2008). *Causal relationships among students' attitude, interest, conceptual understanding, and school achievement in secondary physics*. Seoul National University, Seoul.

Nieswandt, M., & Shanahan, M. (2008). 'I just want the credit!' Perceived instrumentality as the main characteristic of boys' motivation in a grade 11 science course. *Research in Science Education, 38*(1), 3-29.

Park, H. J. (2007). Components of conceptual ecologies. *Research in Science Education, 37*(2), 217-237.

Redish, E., Saul, J., & Steinberg, R. (1998). Student expectations in introductory physics. *American Journal of Physics, 66*(3), 212-224.

Russell, J., & Hollander, S. (1975). A Biology attitude scale. *The American Biology Teacher, 37*(5), 270-273.

Schnotz, W., & Bannert, M. (2003). Construction and interference in learning from multiple representation. *Learning and Instruction, 13*, 141-156.

Seufert, T. (2003). Supporting coherence formation in learning from multiple representations. *Learning and Instruction, 13*, 227-237.

Tobin, K., Seiler, G., & Walls, E. (1999). Reproduction of social class in the teaching and learning of science in urban high schools. *Research in Science Education, 29*(2), 171-187.

Treagust, D. F., Jacobowitz, R., Gallagher, J. L., & Parker, J. (2001). Using Assessment as a Guide in Teaching for Understanding: A Case Study of a Middle School Science Class Learning about Sound. *Science Education, 85*, 137-157.

Treagust, D. F., Jacobowitz, R., Gallagher, J. L., & Parker, J. (2003). Embed assessment in your teaching. *Science Scope*, 36-39.

Tytler, R., Peterson, S., & Prain, V. (2006). Picturing evaporation: Learning science literacy through a particle representation. *Teaching Science, 52*(1), 12-17.

Waldrip, B., & Prain, V. (2006). Changing representations to learn primary science concepts. *Teaching Science, 52(*4), 17-21.