International Education Journal, 2007, 8(2), 204-212.
ISSN 1443-1475 © 2007 *Shannon Research Press*.
http://iej.com.au

Learning content, physics self-efficacy, and female students' physics course-taking

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A review of literature reveals that self-efficacy (SE) has been shown as a successful predictor of students' course-taking. Many factors have been reported to have influences on physics self-efficacy (PSE), but most of them are contextual variables. This article suggests that learning content is also an influencing factor. Physics learning content in high schools is far from being congruent with girls' development of cognitive psychology and social cognition. This incongruence contributes to the lower PSE of girls, and consequentially leads to their less course-taking in physics. The relationship is examined with respect to the author's personal schooling experiences in China. Appropriate interventions to promote female students' physics course- taking need to be emphasised.

Learning content, physics learning, self-efficacy, course-taking, gender issues

Although the number of females has continuously increased in science fields in the past few decades, data (for example, NSF, 2005a, 2005b; DEST, 2005) has shown that a significant gender difference still exists in the number of students who decide to pursue a male-dominated physics major[1] after finishing secondary education. For example, statistics from National Science Foundation (NSF) (2005a, 2005b) showed that in 2004, 26 per cent of female students in the United States intended to major in science and engineering fields, compared to 41 per cent of male students. In the same year, female students were only about 22 per cent of all physics bachelor's degree awarded students in the United States, significantly less than male students.

Studies have shown that self-efficacy (SE), which is defined as the beliefs about ones' capabilities to accomplish a given task (Bandura, 1994), is a major predictor of students' academic achievement, career interest and course-taking (for example, Britner and Pajares, 2001; Hackett, 1985; Schunk, 1985; Zeldin and Pajares, 2000; Zimmerman, Bandura, and Martinez-Pons, 1992). Deficits in physics self-efficacy (PSE) of female students would appear to contribute to their less course-taking in the field of physics.

Many factors have been reported to have an influence on girl's PSE, such as parental emotional support (Scott and Mallinckxodt, 2005); classroom variables such as teaching strategies and classroom climates (Fencl and Scheel, 2005); prior performance (Hackett, 1985; Lent, Lopez and Bieschke, 1991, 1993), and the link between SE and career interests (Philips, 2002). However, SE is not only context but also content dependent (Shaw, 2004). Besides these context factors, physics learning content would also play a role in girl's development of PSE. Physics learning content in high school classrooms would not only be related to the textbooks and materials used in classrooms, but would also be embodied in the knowledge structure, the ways the knowledge was presented, as well as being strongly associated with classroom activities and classroom teaching strategies. Contextual and content factors are likely to interact with each other to have a

[1] The physics-related area where significant gender difference in course-tanking was found includes physics science, computer science and engineering.

combined influence on students' learning motivation and career interests, which in turn jointly have an influence on learning experiences, and hence, the development of PSE. However, little research has been conducted at the high-school educational level with respect to considering the relationship between physics learning content and PSE.

The following sections discuss the effects of physics learning content on girls' physics course-taking in the high school context from both psychological and sociological perspectives. The relationships are examined in terms of my personal schooling experiences. On the basis of these discussions, the final section summarises my points of view of the relationship between learning content and female students' physics course taking, and gives suggestions for further investigation.

PHYSICS SELF-EFFICACY AND GIRLS' COURSE-TAKING

According to Bandura's (1994) social cognitive theory, SE is defined as "people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives" (Bandura, 1994, p.71). Bandura (1994) hypothesised four main factors as the sources of SE: Mastery experience (experience of success), vicarious experience (learning from watching others succeed), social persuasion (feedback from other people), and physiological arousal (feelings involved with pursuing a task). People construct their SE through the interpretation and integration of information from these four sources.

Among the four main factors, mastery experience is regarded as the most effective source fostering people's SE: the experience of success in performing a task is likely to promote SE related to that task (Bandura, 1994; Britner and Pajares, 2006). But some researchers suggest that girls' learning is influenced more by social persuasions and vicarious experiences (Zeldin and Pajares, 2000). No matter what the arguments are with respect to the causes, they all suggest that higher SE is a strong predictor of academic success and course-taking when compared with academic talent (Bandura, 1986; Zeldin and Pajares, 2000). In the case of physics, female students who have higher PSE are more likely to take physics courses.

However, it is generally reported that females have lower physics self-efficacy (PSE) than males. Educators have long been concerned about how to promote girls' PSE and then to increase their physics course-taking. Their concerns have given rise to numerous attempts to improve girls' PSE through collegiate interventions. However, no amount of effort has thus far produced a successful solution. Is it because collegiate interventions have not worked effectively? The answer is "no". The critical damage to girls' participation rates in physics has happened much earlier. A proof here is that "attrition rates in postsecondary education are very similar for men and women" (Leslie, McClure, and Oaxaca, 1998, p.31). Most of the attrition of girls in physics occurs well prior to university entrance. For example, the ACER (in Lyons, 2005) studies showed a consistent gender difference in physics enrolments of Year 12 Australian students in 1993, 1998, 2001, with females only making up between 35 per cent and 38 per cent of all physical science students. Thus, earlier interventions based on examining a wide range of factors that affect girls' PSE and thus course-taking, must be implemented during girls' adolescent years.

COGNITIVE PSYCHOGLOGY AND GIRLS' PSE

Learning content in high school physics classrooms can greatly influence girls' PSE through affecting girls' mastery experience and physiological arousals. This can be understood in terms of Piaget's learning theory. This learning theory is generally attributed to Jean Piaget and can be used to explain the importance of learning in promoting PSE of adolescents. According to Piaget (in Huitt & Hummel, 2003), individuals construct new knowledge from their experiences through processes of accommodation and assimilation. Assimilation allows the learner to fit their new experiences into an already existing cognitive framework; while accommodation urges the learner to change the pre-existent cognitive structure to make sense of the environment. This theory suggests that teachers should engage students in meaningful learning to allow them develop knowledge by matching new information against their prior experiences. Therefore, the learning content in classrooms has strong effects on students' learning: by facilitating students' learning if it is linked with students' experiences or retarding students' learning if it is far beyond students' experiences.

Piaget (in Huitt & Hummel, 2003) identified four stages in cognitive development: sensor-motor stage; pre-operational stage; concrete operational stage, when intellectual development relates to concrete objects; and formal operational stage, when the development of intelligence relates to abstract concepts. He believed that in adolescence (13-18 years old), intellectual abilities develop to a formal operational stage. However, maturation does not mean that students can automatically think formally. For example, Callahan, Clark, and Kellough (1998) reported that most junior and middle high school students have not reached the formal operations stage. Since the formal operational stage is a prerequisite for much physics learning, it is essential to engage students in advancing their level of learning, that can successfully help the students to work through the concrete stage to the abstract stage of mental processing required for learning of physics concepts. Physics learning content must link to students' prior experience to be meaningful and involve students in learning tasks successfully.

However, learning content in junior high school science classrooms was generally regarded as irrelevant, difficult and uninteresting by Australian students (Lyons. 2005). Woolnough and Cameron (1991) found that senior high school students (in ACT) tended to have a very negative approach to physics. Students especially girls, who decided to enrol in physics course at the Year 12 level, normally had some very vague utilitarian reasons but with little interest. Under such situations, many girls who tended to find the content difficult and uninteresting would be more likely to employ rote strategies to learn physics compared to boys (Ridley and Novak, 1983). A typical rote strategy would involve copying formula and duplicating working steps to answer questions instead of making the effort to understand the meanings behind the formula to solve the problems. This kind of learning strategies would promote girls' lack of interest in learning and retard the development of their scientific reasoning abilities which are believed to be very important for understanding physics. For example, Williams and Cavallo's study (1995) found that scientific reasoning ability would best predict students' understanding of Newtonian physics. Since learning interest was essential to engage students in learning tasks and gain successful experience, girls with rote learning strategies would be at a substantial disadvantage in developing their SEP.

One possible explanation for this gender difference is possibly that female students and male students have different learning styles. Males show a greater preference than females for the abstract conceptualisation mode of learning (Severiens and Ten Dam's, 1994). Girls preferred to learn physics in a conversational style and collaborative activity, and work with concrete objects. Boys, on the contrary, liked to learn through argument and individual activity, and tended to use more abstract thinking. However, most classroom activities were organised to accommodate male learning styles (Ong, 1981). Females were therefore more likely to be disinterested in physics learning than their male counterparts.

Physics learning content in high school, as exhibited by the physics section in science curriculum, commonly fails to consider such differences in learning patterns. It promotes competitive learning approaches which put boys at an advantage over girls and which satisfy their respect for the strength of the abstract contents of physics. As the educational level progresses, physics textbooks become increasingly abstract and disconnected from the world that physics attempts to describe. Experiments become rushed by the increasing amounts of material to be presented. Classroom activities become full of practising, testing and lectures. This situation creates an environment where teachers only have time to present information in an abstract manner, generally devoid of any relationship with the world around them. This situation creates an environment where many girls develop a more negative attitude than boys to learning physics and do not dare to express their frustration due to diffidence with respect to their abilities. Evidence (Simpson and Oliver, 1985, 1990) has shown that students' especially girls' attitudes toward science became less positive throughout each school year from Grades 6 to 10. But unfortunately it is still believed by some old experienced physics teachers, that this kind of formal learning content is the so-called 'essence' of this discipline, the strength of learning physics.

SOCIAL COGNITIVE DEVELOPMENT AND GIRLS' PSE

Learning content also has an impact on girls' PSE by significantly affecting their vicarious experiences and social experiences. Bussey and Bandura (1999) have addressed gender development and differentiation. They proposed that

> …gender conceptions are constructed from the complex mix of experiences… (They) operate in concert with motivational and self-regulatory mechanisms to guide gender-linked conduct throughout the life course…Conceptions of gender and (gender) roles are the products of social influences operating interdependently in a variety of social subsystems... People contribute to their self-development and bring about social changes that define and structure gender relationships through their agentic (agential?) actions within the interrelated systems of influence. (p 676)

This theory suggested that the modelling of gender roles could greatly influence conceptions of gender. When applied to analysing physics learning content in high school, it had significant implications.

Learning content in physics classrooms, as a reflection of social activities and human experience, accompanying students from their very young age, had a great potential to foster conceptions of gender, especially nowadays when the availability of role models is greatly multiplied with the rapid development of ICT. Several studies (see Gray, 2005) found that repeated viewing of the symbolic modelling of equal roles for men and women significantly reduced gender role stereotyping in children. However, the available role models for young girls in physics learning, that is involved in the content of traditional textbooks, materials used, and classroom activities, were often stereotypical and offer relatively more male models of perceived confidence, and also, more models of males in physics careers. Lacking successful female role models in physics careers and having many female role models in house-works, physics leaning content subtly communicates the message that physics is a hard subject for girls to learn. This could result in girls' difficulties in seeing physics as a scholarly and professional pursuit.

Another noteworthy fact is that during females' development of gender identity they frequently link their important life goals to the desires of others. An example is that high school girls start thinking about how to balance career and family roles. "Women are socialised to seek intimate relationships and these relationships are more important concerns for female adolescents" (Ginn, 2003). In the case of physics learning, girls like to learn knowledge in a collaborative way, generate their thoughts based on group consensus, and contribute to group's interrelationship. It is not surprising that most girls tend to be interested in careers emphasising human interaction and tend to pursue social science careers after secondary education. However, physics learning content, focusing more on competitive activities and individual exercises, drives girls away from social interaction. Most examples and topics in physics textbooks and materials used in classrooms are regarded by girls as lacking interaction and having quite tenuous links to their daily life. Learning activities rarely encourage social interactions and feedback from peers and teachers. Girls' curiosity, interests and questions are often not taken seriously by teachers when designing the learning activities and assessment tasks. Teachers' attitudes can in turn influence girls' and boys' attitudes. They also develop their gender roles by imitating the social behaviors of the teachers. If teachers, girls and boys all hold such ambiguous beliefs that girls can not learn physics as well as boys, this kind of belief can be strengthened by social influences in classrooms where teachers hold traditional beliefs of gender roles.

In addition, physics learning content always links to other disciplines such as geography and chemistry. It also needs mathematical methods to solve problems. But traditional physics learning content generally tends to neglect the interactions between physics and other disciplines, and tends to treat mathematics as an isolated tool. It is hard for girls to obtain more social experience to construct their PSE by stretching physics learning content to a more meaningful world.

THE IMPLICATIONS FOR TEACHERS

It is generally reported that female students have lower PSE than male students. Kahle and Meece (1994) have found that this difference is not evident until late adolescence. Adolescence is the critical period, a time when SE forms, thus the primary foci must be on early and appropriate interventions aiming at improving females' PSE. An unsatisfying example might be such a story referred to by Riesz, McNabb & Stephen (1997), who reported that one intervention program, that was designed to enhance girls' science SE among high school students by inviting women scientists and engineers to make presentations in high school science classes, failed to promote more interest of the high school girls, who still showed significantly less interest in science learning than did the high school boys.

As I have mentioned before, besides those contextual factors, lower PSE in girls also result from the impact of learning content in high school physics classrooms. From this angle, I suggest that there are many things educators can do to improve girls' PSE. First, treating girls and boys without difference is not enough to allow girls to make sense of the learning content of physics. Also, treating girls as the weaker sex is no favour to them. Teachers should interact with female students and create conditions such as collaborative activities to motivate them to interact with male peers, challenge them seriously, engage them in learning content rigorously and actively, and expect a high performance of them as they do their male students. Educators should also manage learning content such as restructuring knowledge and presentation and changing materials used in classroom activities to meet the needs of psychological and social cognitive development of female students. However, how to make interventions appropriately and effectively is very complex and requires the combined efforts from the educators and the educational administration department. The impact of the content of physics learning together with influences of other factors in high school should be considered deliberately and thoroughly at the system level.

Analysing My Schooling Experiences in China

My physics learning experience in a Chinese high school in1986 to1991

Physics is a compulsory subject for Year 8 to Year 11 students in China. The students need to spend four school years on learning physics. Due to the long learning period, learning content covers a very broad range of physics concepts, which become more abstract in the senior high-school years.

I did not learn physics very well in junior high school. It is not because I did not have the ability to learn physics; on the contrary, I did very good work in mathematics and other science subjects like biology and geography. Moreover I also wanted to achieve a higher academic level in physics. The only reason was that I did not make sense of physics. Many of my female classmates also had the same problem.

The textbooks were very boring. Few pictures and diagrams, they were filled with great quantities of texts and a lot of abstract concepts, formula and calculation. Examples focused more on applying formula to calculating rather than explaining the rationale. Schoolwork emphasised format rather than logical thinking. At the same time, there were almost no female role models related to the content of learning and role models of females in physics careers. Except from Madame Curie, I could not find any other female scientists in the textbooks.

Teachers used to teach physics through lectures and seldom used concrete materials like videos, stories and pictures to help students to understand the content to be learnt. Although sometimes there were some teacher demonstrations and student hand-on activities in classroom, it was not really helpful to me because the data recorded by experiments rarely linked to concepts I learned in the textbooks and rarely linked to my daily-life experiences. We used the recorded data to fill in the formula (not to derive the formula) in order to examine its accuracy, and if we found that the data did not match the formula, the teacher would tell us that it was due to measurement error. In such a situation, I found that physics was a very boring subject.

On the other hand, every time when I reviewed the textbook, I always found that I did too many exercises. But every time when I took a test, I always found that I got a low mark. I began to lose interests in learning physics and doubted whether I could learn it well.

However, when I stepped into the senior high school, the situation changed, even the content became more abstract. There were several factors contributing to this change. First, my intellectual levels increased due to maturation and academic training. I tried to understand abstract concepts by linking to the prior knowledge and I found that kind of approach worked effectively. The second reason was that the new physics teacher used more concrete materials and designed more meaningful activities to help students to understand physics concepts. He encouraged girls to participate in learning activities and challenged girls seriously. For example, he often required girls as well boys to demonstrate their understanding about one phenomenon or to illustrate their working steps on the blackboard. He also tended to use less competitive and more collaborative activities in the classroom and promoted collaborative relationships between boys and girls.

My increasing academic performance and confidence showed that these strategies, that considered the psychological and sociological characteristics of female students, did work for me. Ultimately I chose physics as my university major. However, there are very few female students among my classmates who selected physics as their university major.

My physics teaching experience in Chinese high schools in 1995 to 2003

When I worked as a physics teacher in Chinese high schools, I found that content of learning have changed a great deal when compared to my time at school.

The knowledge involved was always in changing. It changed several times during the ten years period, moving to a clearer and more understandable structure. Textbooks tended to be more colourful, employing more diagrams and pictures, more examples and less abstract descriptions. Some abstract concepts were deleted, some content became elective, and some content was made more concrete (equipped with examples or diagrams or pictures). Especially, with the development of ICT, the textbooks began to be accompanied by videos and CDs. In Shanghai, some traditional experiments were even accompanied by complementary ICT experiments in the new textbooks. Although female role models in physics careers in these textbooks were more than before, I still found that there were very few. They were rarely linked to females' social experiences and still showed respect for the strength of this discipline especially in senior high schools textbook. They were abstract and disconnected from the real world.

As a physics teacher with professional ICT background, I always tried to make learning content more concrete by using ICT and I tended to use more concrete materials to help students understand abstract physics concepts. The concrete materials and animations I used in my classroom sometimes made the physics learning funny and relaxing. Students liked to use computer software to simulate the movement of objects. They also liked to use instruments to design their own experimental systems. But these materials and information that I presented in physics classrooms, though concrete, still were far away from girls' daily life and the real world. Another strategy that I used was inviting a student to be a temporary teacher. Student must take the responsibility to communicate effectively with me and other students, to let us make sense of content that she or he talked about. This was the favourite activity of students.

Generally, students in my classrooms showed a higher level of academic achievement than those in other classrooms. However, I could not change the physics curriculum that prescribed what students must learn in China. I could not treat girls differently either due to the heavy academic pressure in China. I gave them the same academic treatment as I did to boys. I did not look after their psychological needs very much. Sometimes I did not give enough feedback to the girls' questions because of lack of time or other consideration. Sometimes I had to carry out competitive activities to fit in to the heavy academic pressure. All of these reinforced the male-dominated nature of physics learning. The content thus failed to arouse more girls' interests in learning physics and therefore in their course-taking in Year 12 level and beyond.

CONCLUSIONS

The forgoing sections discuss the relationship between the content of physics learning and female students' course-taking by referring Piagetian learning theory and Bandura's social cognitive theory and the findings from the relevant literature. The content of physics learning in high schools is far from being congruent with girls' development in cognitive psychology and social cognition. This incongruence contributes to lower PSE of girls, and as consequence leads to their less physics course-taking. This relationship is confirmed by my schooling experiences in China. I advance the suggestions that, on one hand interactions among learning content, students and teachers in physics classrooms can play a significant role in girls' development of PSE, on the other hand leaders in school should think critically about the foundations of the content to be learnt, such as the stereotypical gender models in textbooks and materials used in classroom, the knowledge structure, and the organisation and presentation of that knowledge to identify the gender biases that exclude female students from learning physics effectively. Since very few empirical studies were found to support these suggestions, future investigation need to focus on examining the relationships between the content of leaning, girls' PSE and their physics course-taking by employing more vigorous methods of investigation.

Educators must develop more appropriate interventions for the adolescent years. Strategies must include examining the influences of a wide range of factors including the content of learning through different perspectives. These solutions should be considered at a systematical level in order to promote female students' taking course in science and physics before university entrance. Special efforts to expose female students to elective science courses in their senior high school years are important in order to enhance both their skills and the physics self-efficacy necessary to making physics a meaningful choice for a college major.

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