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The effect of online argumentation of socio-scientific issues on students' scientific competencies and sustainability attitudes

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ABSTRACT

One focal point of science learning is to develop students' ability to actively participate in discussions of socio-scientific issues (SSIs) in their daily lives. This study proposed the SSIs-Online-Argumentation Pattern (SOAP) to develop a pedagogical strategy enabling students to participate in online argumentation of SSIs. Two quasi-experiments were conducted to investigate the variations in scientific competencies and sustainability attitudes of students following the SOAP strategy. The participants were 127 senior high school students and 68 undergraduates respectively. Students' scientific competencies and sustainability attitudes were assessed using quantitative methods. The results showed that the SOAP strategy led to differences in high school students' scientific competencies. The mean scientific competency of the experimental group was higher than that of the comparison group in the post-test and in the delayed test. Specifically, for the constructs 'identifying scientific issues' and 'using scientific evidence', the difference between the two groups did not reach significance in the post-test and in the delayed test. The results showed that the SOAP strategy resulted in differences in undergraduates' sustainability attitudes. In the post-test, the mean sustainability attitude of the experimental group was higher than that of the comparison group. Specifically, for the constructs of 'economic' aspect, the post-test difference between the two groups did not reach significance. Finally, this research proposed suggestions and implications for future studies related to SSIs and science education.

1. Introduction

The objective of science education is to cultivate scientifically literate citizens (Dillon, 2009; Holbrook & Rannikmae, 2009; Lin, Hong, & Huang, 2012; Sadler, 2004; Wang, 2014), and this is also the goal pursued by the reforms and standards of science education in United States (NGSS Lead States, 2013) and Taiwan (Ministry of Education, 2014). In particular, the education reform in Taiwan set the goal of constructing literacy-based curricula (Ministry of Education, 2014). In the modern era of information technology, a scientifically literate person is expected to be able to exercise independent judgment and critical thinking rather than blindly obeying authority. A scientifically literate citizen is also expected to identify scientific phenomena surrounded with filtered information and participate in public discussion (Hofstein, Eilks, & Bybee, 2011). Such a

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viewpoint emphasizes the cultivation of "participatory" scientific literacy as the objective of science education (Forbes & Davis, 2008; Hofstein et al., 2011), where the focal point of learning is to develop students' ability to actively participate in the discussions of socio-scientific issues (SSIs) as well as make prudent decisions and propose feasible solutions regarding these issues in their daily lives (Lin & Mintzes, 2010). Such socially controversial issues are related to science. They are characterized as ill-defined and open-ended structures and have multiple potential solutions (Kolstø, 2001; Ratcliffe & Grace, 2003). Recent related studies have focused on whether the application of SSIs in education has a positive effect on students' academic achievements and scientific literacy (Chin, Yang, & Tuan, 2016; Eastwood, Sadler, Sherwood, & Schlegel, 2013; Kolstø, 2001; Lin & Mintzes, 2010; Saunders & Rennie, 2013).

The Programme for International Student Assessment (PISA) organized by the Organization for Economic Co-operation and Development (OECD) has emphasized that students' scientific literacy include several aspects, namely, identifying scientific issues, explaining phenomena scientifically, and using scientific evidence (OECD, 2012). Holbrook and Rannikmae (2009) maintained that scientific literacy includes four dimensions: intellectual, attitudinal, societal, and interdisciplinary. Such a definition of literacy considers the wide-ranging aspects and links science and technology to economy, politics, culture, and society on both individual and global scales. The PISA test framework considers scientific competencies to include the scientific literacy as defined by Holbrook and Rannikmae (2009) and recognized the necessity of possessing environmental responsibility, the ability to acknowledge the importance of individual actions, and the will to adopt measures to protect natural resources. In other words, a person is expected to be responsible and conscious of the environment and resources and possess a certain degree of sustainability attitudes (Lee et al., 2013). The discussion above indicated that the essence of contemporary scientific literacy implies an individual's scientific competencies in debating SSI in a rational and reasonable way and express concerns regarding these issues.

SSIs reflect issues encountered by industrialized countries in the development of science and technology (Levinson, 2006) and integrating them into the school curriculum may promote students' scientific literacy (Chin et al., 2016; Lin & Mintzes, 2010). Contemporary research trend indicates that scientific literacy includes reading and writing (Chin et al., 2016). In the context of science education, reading refers to scientific reading (Yore & Treagust, 2006), whereas writing is most widely applied in argumentation (Tsai, 2015). Therefore, related studies (Acar, Turkmen, & Roychoudhury, 2010; Böttcher & Meisert, 2013; Lin & Mintzes, 2010; Sadler & Donnelly, 2006; Wang, 2014; Zeidler, Sadler, Simmons, & Howes, 2005) have suggested to integrate argumentation pedagogy into SSI education. Students may develop informal reasoning, argumentation ability, and higher-order thinking as a result of debate with classmates during argumentation of SSI (Lin & Mintzes, 2010; Lindahl & Folkesson, 2016; Sadler & Zeidler, 2005). The above shows students may develop argumentation ability and scientific competencies in the processes of coming up with feasible solutions to these issues. Moreover, SSIs often involve moral reasoning regarding socio-ethical dilemmas, which is lacked in traditional science education (Morris, 2014). Saunders and Rennie (2013) suggested considering the cultivation of sustainability attitudes in SSI instruction.

Related studies have proposed SSI as an important strategy to improve students' scientific literacy (Levinson, 2006; Ratcliffe & Grace, 2003; Sadler & Donnelly, 2006; Sadler & Zeidler, 2005; Sadler, 2011). However, the practical application is rare due to the difficulties in implementing SSI in classes (Hofstein et al., 2011). SSIs are merely introduced into classrooms as a formal subject (Saunders & Rennie, 2013). Sadler (2011) asserted that scholars should further contribute into the SSI research to provide suggestions for curriculum improvement, which also reveals the importance and necessity of research on SSI practice. In addition, some scholars have stressed the importance of the integration of SSIs and argumentation (Acar et al., 2010; Böttcher & Meisert, 2013; Lin & Mintzes, 2010; Sadler & Donnelly, 2006; Wang, 2014). However, few studies have proposed explicit models for guiding the instructions to be issued for SSIs and argumentation. Moreover, with regard to in-class implementation, argumentation was suggested as an SSI strategy and the Internet was stated to be an effective tool for conducting argumentation learning and activities (Choi, Hand, & Norton-Meier, 2014; Lin, Hong, & Lawrenz, 2012; Tsai, Jack, Huang, & Yang, 2012; Yu & Yore, 2013). The synergistic effect of SSI and online argumentation on students' scientific literacy should be further investigated. Thus, this study proposed the SSIs-Online-Argumentation Pattern (SOAP) and investigated the effect of this instructional strategy on students' scientific competencies and sustainability attitudes.

1.1. Socio-scientific issues

SSIs are controversial social issues which are science-related and such issues are normally interdisciplinary and related to socio-ethical dilemmas (Kolstø, 2001; Ratcliffe & Grace, 2003; Sadler & Zeidler, 2004). SSIs have an open and interdisciplinary nature and include the influence of different social factors. For example, construction of nuclear power plants in Taiwan is related to economic and political factors. Therefore, when discussing such issues, students have to evaluate the arguments from different aspects, integrate relevant information, assess feasible plans, and select an optimal solution (Eggert & Bogeholz, 2009; Liu, Lin, & Tsai, 2011; Papadouris, 2012). SSIs also involve scientific process and moral reasoning dilemmas (Kolstø, 2001; Ratcliffe & Grace, 2003; Sadler & Zeidler, 2004; Zeidler et al., 2005), one example of which is genetic engineering technologies. Disputes are a result of a value conflict among people with different standpoints regarding some issues. Consideration and judgment of merits and drawbacks of technology application and appropriateness of actions touches upon considerations of ethics and social responsibility (Zeidler et al., 2005). SSI implications involve the relationship between science and mutual influence of humankind, society, and the environment.

Integration of SSIs into the classroom can solve the problem of alienation of traditional science learning from the social reality. Traditional science learning focuses on acquirement of scientific knowledge and textbooks often fail to link the