PROMOTING SCIENTIFIC LITERACY THROUGH THE ONLINE ARGUMENTATION SYSTEM

Chun-Yen Tsai

Department of Information Management, Cheng Shiu University
No.840, Chengcing Rd., Niaosong Dist., Kaohsiung City 83347, Taiwan

ABSTRACT

This study investigated how the scientific competencies advocated by the Programme for International Student Assessment (PISA) could be improved by using online argumentation. An online argumentation system served as an aid for argumentation instruction and activities among students during the experiment. Seventy-one 10th grade high school students took part in this study. A quasi-experimental design was adopted and qualitative and quantitative analyses were used. The results showed that using the online argumentation system to conduct argumentation instruction and activities could improve the students' PISA scientific competencies. The experimental group students outperformed their counterparts in terms of mean scientific competencies. Finally, this study proposed suggestions related to argumentation research and science instruction.

KEYWORDS

Argumentation, online argumentation system, PISA, scientific competencies, scientific literacy

1. INTRODUCTION

The Programme for International Student Assessment (PISA) sponsored by the Organization for Economic Co-operation and Development (OECD) measures students' competencies in reading literacy, mathematics literacy, and science literacy every 3 years. Each survey focuses on a single subject, with the other two as supplementary subjects. The objective of the PISA is to understand how 15-year-old students from the participating countries apply knowledge and abilities in their handling of daily issues before completing their compulsory education (Bybee, 2008; Bybee & MaCrae, 2011; Fensham, 2009; Lin, Hong, & Huang, 2012a; Olsen & Lie, 2011; Sadler & Zeidler, 2009). Not only does the PISA measure the students' understanding of school curricula, it also measures the important knowledge and abilities required in civic society for their future (Bybee, 2008; Bybee & McCrae, 2011; Lin et al., 2012a; Yeh & She, 2010). Nowadays, public debates about governmental policies on socio-scientific issues also rely on the scientific literacy of citizens to make informed decisions (Lin et al., 2012a).

The PISA focuses on the students' competencies in applying their acquired knowledge in daily scenarios (Bybee, 2008). The ability to probe is emphasized in their scientific literacy, including interest, support, and responsibility (OECD, 2009). Likewise, Taiwan's nine-year integrated curriculum for the science and technology domain is similar to the principles of the PISA in terms of cultivating the required competencies in students. However, the global rankings of Taiwanese students in scientific literacy fell from 4th place in 2006 (total score of 534) to 12th in 2009 (total score of 520) (TWPISA National Center, 2012a). The students' performance scores are related to complex factors such as teaching practice, school culture, and family values. Although stating that the international evaluation results such as those of the PISA are due to education performances is controversial (Wang & Lin, 2005), it is still feasible to implement relevant teaching strategies in the classroom for promoting such performance. The enhancement of PISA scientific competencies has become an important issue in the reforming of school curricula by Taiwan's science educators.

Recent studies on the PISA have focused on the effects of demographic variables or transnational culture (e.g., Basl, 2011; Bybee & McCrae, 2011; Kjarnsli & Lie, 2004; Olsen, 2005; Olsen & Lie, 2011; Nentwig, Roennebeck, Schoeps, Rumann, & Carstensen, 2009). Few studies (e.g., Lavonen & Laaksonen, 2009) have

proposed relevant teaching strategies for improving students' PISA scientific competencies. Researchers need to provide more experimental data in terms of PISA scientific competencies in order to contribute to educational policies. Some researchers (e.g., Lee, 2009) have recommended the improvement of argumentation skills in light of the relationship between PISA scientific competencies and argumentation, whereby it is thought that students would cultivate their scientific competencies. In addition, the internet is an effective tool for conducting argumentation instruction and activities (Bell & Linn 2000; Clark & Sampson, 2008; Lin, Hong, & Lawrenz, 2012b; Yeh & She, 2010) and new generation has been used to contact in the social networking service, such as Facebook. The present study considered the use of internet tools and argumentation as a medium to explore the improvement of students' scientific literacy.

1.1 Scientific Literacy

The OECD (2009) has illustrated the definition of scientific literacy and its framework for the PISA science assessment. In this framework, the term scientific literacy denotes an overarching competency comprising a set of specific scientific competencies. Scientific competencies include the abilities to mobilize cognitive and non-cognitive resources in any given context. These competencies are regulated by the individual's appreciation, interest, values, and actions relative to scientific matters, and are characterized as crossing through three interrelated aspects, including context, knowledge, and attitudes (as shown in Fig. 1).
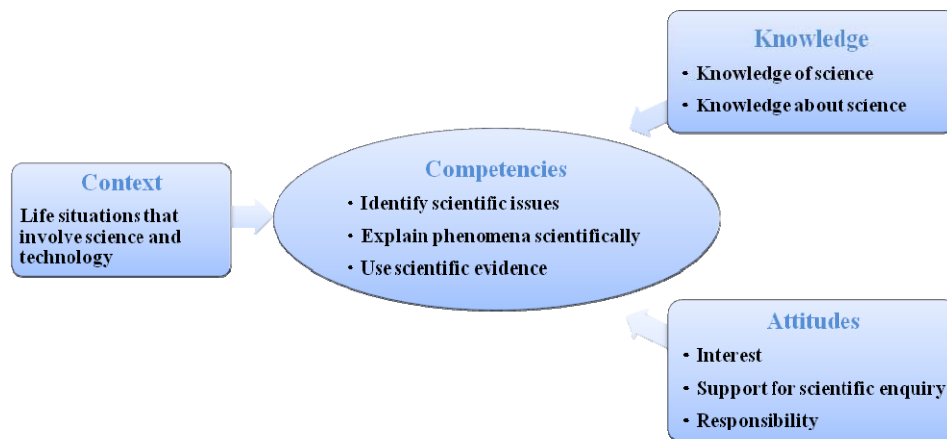

Figure 1. Framework for the PISA science assessment (OECD, 2009)

Scientific competencies comprise a set of three specific constructs (OECD, 2009):

1. Identifying scientific issues: This construct includes recognizing issues that are open to scientific investigation; identifying keywords to use in searching for scientific information; and recognizing the key features of a scientific investigation.
2. Explaining phenomena scientifically: This construct includes application of scientific knowledge in a given situation; describing or interpreting phenomena scientifically and predicting changes; and identifying appropriate descriptions, explanations, and predictions.
3. Using scientific evidence: This construct includes interpreting scientific evidence, making and communicating conclusions; identifying the assumptions, evidence, and reasoning behind conclusions; and reflecting on the societal implications of science and technological developments.

In the dimension of "context" in Fig. 1, the assessment is built around life situations including five aspects: health, natural resources, environment, hazard, and frontiers of science and technology, with each context spanning personal, social, and global scales. The dimension of "knowledge" includes "knowledge of science" and "knowledge about science". The former refers to knowledge of the natural world while the latter entails knowledge of scientific inquiry. The dimension of "attitudes" includes interest in science, support for scientific inquiry, and motivation to act responsibly towards, for example, natural resources and environments.

1.2 Argumentation and Online Argumentation

Argumentation in scientific learning can be defined as a process of connecting claims and data through justification or through the evaluation of knowledge claims in light of empirical or theoretical evidence (Clark & Sampson, 2009; Jimenex-Aleixandre & Erduran, 2008; Osborne, Erduran, & Simon, 2004). Arguments are the artifacts of argumentation and consist of either assertions or conclusions, including their justifications, reasons, or supporting factors (Zohar & Nemet, 2002). In science education, argumentation is seen as entailing three overlapping goals: making sense of the phenomenon under study (i.e., constructing claims and explanations), articulating those understandings (presenting arguments), and persuading others to adopt one's ideas (critiquing and evaluating counter ideas while defending one's own) (Berland & Reiser, 2009, 2011).

Discourse is an essential component of argumentation, and social interaction plays a critical role in knowledge construction. Such social interaction forms an environment for discussion which allows individual thinking to move from implicit to explicit, and this can result in group reflection to reach a common consensus. However, students are often not able to propose evidence or reasons supporting their arguments (Nussbaum, 2002). Argumentation should be imparted to students through appropriate teaching, learning tasks, assisting, and other processes (Kuhn, 1991). It would achieve such teaching objectives more easily by complementing them with scaffolding (Bell & Linn, 2000; Nussbaum, 2002; Osborne et al., 2004).

Argumentation activities require specific steps and thinking processes, of which and information technology can assist in building (Bell & Linn, 2000; Yeh & She, 2010). Computer tools can assist students in becoming researchers and reviewers, helping them to actively evaluate scientific thinking (Linn, 1998). Joiner and Jones (2003) believe that asynchronous computer-mediated communication is much more advantageous than face-to-face communication and is suitable to become the cultivation tool of argumentation skills. For example, the characteristic of asynchronous online discussion is the extension of answering time for students (Joiner & Jones, 2003). High level questions can stimulate more accurate and definite answers from students when given a more sufficient waiting time. Moreover, the context of argumentation requires equality amongst the participants, which cannot be easily established in traditional classrooms (Duschl & Osborne, 2002; Joiner & Jones, 2003). Online discussion is free from the traditional classroom constraints whereby the discussion is led by a few dominant students, and low-achieving students can express their own opinions asynchronously. Therefore, this study hoped to complement argumentation instruction and activities with the advantages of an online environment, and observe how this process might promote students' scientific literacy.

1.3 Argumentation and Fostering of Scientific Literacy

Argumentation is the coordination of evidence and theory to support or refute an explanatory conclusion, model, or prediction (Clark & Sampson, 2009; Osborne et al., 2004). Such a process requires PISA scientific competencies in using scientific evidence and explaining phenomena scientifically. The competency in using scientific evidence involves accessing scientific information and producing arguments and conclusions based on scientific evidence. The competency in explaining phenomena scientifically includes describing, interpreting phenomena, and predicting changes, and may involve recognizing or identifying appropriate descriptions, explanations, and predictions (OECD, 2009). The above comparison shows the potential relationship between argumentation and PISA scientific competencies. Therefore, conducting argumentation instruction and activities may promote the students' scientific literacy.

The improvement of PISA scientific competencies also requires students to go through the scientific learning process in the scientific context. Previous science learning studies have viewed individual learning as a form of conceptual change (Posner, Strike, Hewson, & Gertzog, 1982), and relevant researchers (Dole & Sinatra, 1998; Nussbaum & Sinatra, 2003; Yeh & She, 2010) believe that argumentation can effectively promote students' conceptual change. The process of argumentation allows students to compare and contrast arguments through in depth thinking (Dole & Sinatra, 1998), essentially triggering a cognitive conflict in an individual by giving him/her new information that varies from his/her prior knowledge. This is the first condition proposed by Posner et al. (1982) for conceptual change: the learner has to feel dissatisfaction on a current concept. A cognitive conflict triggered by in-depth thinking can then lead to learning and conceptual change (Nussbaum & Sinatra, 2003).

1.4 Research Question

Based on the above literature discussion, this research used an online argumentation system to complement the argumentation instruction and discussion of PISA issues. This study investigated the improvement of PISA scientific competencies throughout these online argumentation processes. The research question was as follows: Were there any differences in scientific competencies between students who participated in online argumentation instruction and activities and those who did not?

2. METHODOLOGY

2.1 Participants

The subjects of the PISA are primarily 15-year-old students worldwide who have completed compulsory education. Therefore, this study selected 10th grade high school students (15 years old) from a senior high school situated on the edge of the Kaohsiung city center in southern Taiwan. This study was conducted during the students' first summer vacation when they had just finished their junior high school education. A total of 79 students were chosen from two out of six classes. Due to eight students applying for leave during the experiment process, a total of 71 students participated fully in the research throughout, with 36 of them in the experimental group and 35 in the control group. These students had similar academic achievements, having being promoted to senior high school from junior high through the national entrance examinations.

2.2 Experimental Design

The study adopted a quasi-experimental design (as shown in Table 1). A PISA science assessment was conducted on both groups before the experiment. The students in the experimental group then went through argumentation instruction and activity using an online argumentation system for a total of 4 hours. After the experiment, both groups conducted the same PISA science assessment.

Table 1. Experimental design of this study

Group	Pre-test	Treatment	Post-test
Experimental group	O_1	X	O_3
Control group	O_2		O_4

Note: O_1, O_2, O_3, and O_4 were the PISA science assessments; X was the online argumentation

2.3 The Online Argumentation System

The argumentation system is shown in Fig. 2. The upper portion shows the argumentation topic, for which the teacher can set up two opposing viewpoints. The lower left portion is the column for the tree directory of students' arguments titles. This directory provides a way for both the teacher and students to view the arguments of all the students in the class by means of hyperlinking to their saved location in a database. In addition, this column records the thought process of all the students, helping individuals to reflect on their thoughts. The lower right portion shows the argument of an individual student. Students are able to understand the perspectives of other students and achieve the objective of mutual interaction.

As shown in Fig. 3, the interface for students to construct their arguments was designed based on the Toulmin (1958) Argument Pattern (TAP). It provides the scaffold to assist students in formulating their arguments. To ensure that students are not affected by specific terms of the TAP, Nussbaum (2002) suggested that changes to spoken language should be made. Students are given partial statements with textboxes next to them where they can type information to complete the TAP structure. Separate scaffolding provides prompt buttons marked with a question mark for the students, which prompt the students according to the missing or incorrect components of their previous arguments. If a student's information did not adequately complete the statement, the button remains visible and indicates that the information was not adequately complete. Should the preceding argument encompass all five components, then the buttons would not appear to achieve the "fading out" strategy.
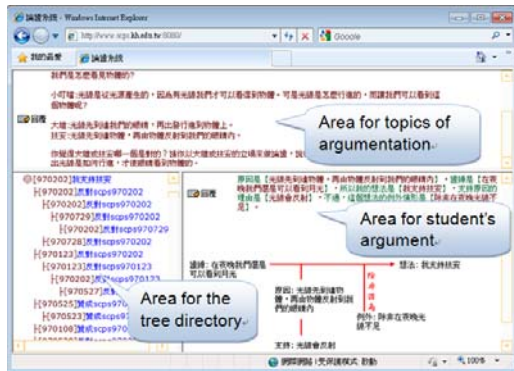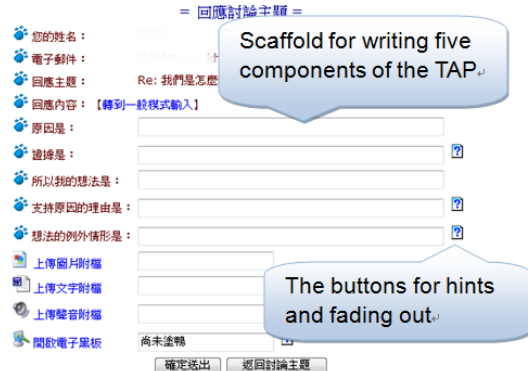
Figure 2. The system overview   Figure 3. The scaffold for argumentation

2.4 The PISA Science Assessment

The released items of the PISA science assessment can be downloaded from the TWPISA National Center (TWPISA National Center, 2012b). These sample items were constructed or translated by experts and researchers from various fields in the past when Taiwan participated in the PISA. The most items are the same as the OECD released items, which can be downloaded from the PISA official website (OECD, 2006). Five teachers in the research team from the biological, life sciences, physics, chemistry, and earth sciences field were tasked to select items, the constructs of which were then reviewed and verified by two science educators. To achieve construct validity, the Rasch model (Rasch, 1960) was applied for analysis and the infit mean square error (MNSQ) of each item was calculated to be between 0.95 and 1.18. In terms of reliability, the item separation reliability of the whole test was 0.95. The validity and reliability were both within acceptable range. The answering formats of the assessment items included multiple choice questions, true or false questions, and short answer questions. There were a total of 15 items, with each item having a full score of 10, a partial score of 5, and a score of zero for a wrong answer. The full score for the entire assessment was thus 150.

2.5 The Argumentation Instruction and Activities

Students in the experimental group went through online argumentation instruction and activities. Argumentation instruction focused on how to use the argumentation system and the TAP for constructing individual arguments. During the instruction, the researcher tried to allow individual students to construct the arguments that best suited their logical thinking by following the teacher's argument example. The teaching strategy enabled students' learning to progress from simplicity to complexity and from single to diversity (Collins, Brown, & Newman, 1989) in terms of argument construction.

The three lessons of argumentation instruction were conducted, in order, using a three components argumentation pattern (claim-data-warrant), a four components argumentation pattern (claim-data-warrant-backing), and a five components argumentation pattern (claim-data-warrant-backing-rebuttal). The templates used for student practice in argumentation instruction were based on examples in Toulmin's book (Toulmin, 1958). For example, "All three sisters of Ming have red hairs (warrant). As Hua is the fourth sister of Ming (data), she might have red hair as well (claim). The supporting reason is that their family members have red hair genetically (backing). The exception is that Hua's hair turns white during aging (rebuttal)." These examples include deductive reasoning and inductive reasoning. The researcher explained the difference between these two forms of reasoning in the argumentation instruction.

Students experienced difficulties mostly in responding PISA items of identifying scientific issues, especially when they are required to describe specifically about the treatment and dependent variable of a contextual investigation (Lin et al., 2012a). The final lesson of current study conducted argumentation activities based on two topics, including the scientific process encompassing experimental design and control variables. Both topics are related to "identifying scientific issues", to compensate PISA-related competencies for the lack of training in this area for argumentation instruction. During the argumentation, the teacher did not provide any correct answer, just guiding the activities instead.

3. RESULTS

The tests of homogeneity conducted before ANCOVA obtained the following results for "identifying scientific issues", "explaining phenomena scientifically", "using scientific evidence", and "overall score", respectively: $F_{(1, 67)}=.02$ ($p=.870>.05$), $F_{(1, 67)}=.15$ ($p=.695>.05$), $F_{(1, 67)}=.14$ ($p=.704>.05$), and $F_{(1, 67)}=.30$ ($p=.583>.05$). These results, in which all the tests did not reach significance, matched the basic assumption of regression analyses. Therefore, ANCOVA was conducted as illustrated below.

The ANCOVA results for the various scientific competencies are shown in Table 2. Under the construct of "identifying scientific issues", the post-test difference between groups achieved significance ($F_{(1, 68)}=7.40$, $p<.01$) with an effect size of 0.098. According to Cohen's (1988) definition, the small, medium, and large effect sizes are 0.10, 0.25, and 0.40, respectively. This shows that the experimental treatment had a medium effect on the competency in "identifying scientific issues". The comparison in Table 2 shows an adjusted mean post-test score of 26.85 for the experimental group, higher than the 21.81 obtained for the control group.

Table 2. The ANCOVA of scientific competencies

Competencies	Group	Pre-test Mean(SD)	Post-test Mean(SD)	Post-test Mean'(SE)	F	η^2	Cohen' f
Identifying scientific issues	Experimental	26.19(6.81)	27.41(7.36)	26.85(1.28)	7.40**	0.098	0.330
	Control	23.25(8.61)	21.22(8.95)	21.81(1.30)			
Explaining phenomena scientifically	Experimental	30.88(9.14)	33.83(7.38)	33.18(1.10)	1.47	0.020	0.143
	Control	28.17(8.32)	30.62(8.22)	31.29(1.12)			
Using scientific evidence	Experimental	55.69(5.49)	56.52(6.74)	55.92(1.09)	4.84*	0.066	0.266
	Control	53.57(9.59)	51.85(8.91)	52.47(1.11)			
Overall score	Experimental	112.50(12.96)	117.92(14.01)	116.04(2.40)	10.00**	0.128	0.383
	Control	105.00(20.51)	103.14(18.91)	105.06(2.44)			

Note: * $p<.05$; ** $p<.01$; *SD*=standard deviation; *SE*=standard error; Cohen's $f^2= \eta^2/(1-\eta^2)$

Under the construct of "explaining phenomena scientifically", the post-test difference between groups did not achieve significance ($F_{(1, 68)}=1.47$, $p>.05$) with a small effect size of 0.143. The adjusted mean post-test score of the experimental group was 33.18, compared to 31.29 for the control group.

Under the construct of "using scientific evidence", the post-test difference between groups achieved significance ($F_{(1, 68)}=4.84$, $p<.05$) with an medium effect size of 0.266. This shows that the experimental treatment had a medium effect on the competency in "using scientific evidence". The comparison in Table 2 shows the adjusted mean post-test score of 55.92 for the experimental group, which is higher than the 52.47 obtained for the control group.

Finally under "overall score", the post-test difference between groups achieved significance ($F_{(1, 68)}=10.00$, $p<.01$) with an effect size of 0.383. This showed that the experimental treatment had a medium to large effect on the overall scientific competencies. The comparison in Table 2 shows an adjusted mean post-test score of 116.04 for the experimental group, which is higher than the 105.06 obtained for the control group.

4. DISCUSSIONS

In the post-test, the mean overall scientific competencies of the experimental group was higher than that of control group, as is the case with the competencies in "using scientific evidence" and "identifying scientific issues". However, the experimental group students did not outperform their counterparts in terms of competency in "explaining phenomena scientifically". The nature of argumentation is to produce scientific evidence to support conclusions, and the process of argumentation instruction appeared to promote the abilities of students to raise scientific evidence, such as answering questions based on data given in a diagram. The argumentation topics in the current study were based upon identifying scientific issues, and the argumentation process appeared to promote the students' abilities to identify scientific topics, such as understanding control variables and experimental designs. The above two forms of competencies do not require much basic background knowledge from the students as compared to the competency in "explaining

phenomena scientifically". Nevertheless, some items of the "explaining phenomena scientifically" in PISA require students to have basic background knowledge. For example, there is a question under "Acid Rain" that states: "Where do these sulfur oxides and nitrogen oxides in the air come from?" The official answer from PISA is: "Any one answer referring to car exhausts, factory emissions, burning fossil fuels such as oil and coal, gases from volcanoes, or other similar things." The scoring of such questions still requires students to have background knowledge, in order to allow students to answer questions effectively by applying the competency in "explaining phenomena scientifically".

5. CONCLUSION

In summary, argumentation instruction comprising a specific process, online scaffolding assistance, and argumentation conflict scenarios may help to promote students' PISA scientific competencies. Therefore, using the online environment to complement argumentation instruction and organizing argumentation activities focused on related topics is a potential direction to consider in the future for improving students' scientific literacy.

REFERENCES

Basl. J. (2011). Effect of school on interest in natural sciences: A comparison of the Czech Republic, Germany, Finland, and Norway based on PISA 2006. *International Journal of Science Education, 33*(1), 145–157.

Bell, P., & Linn, M. C. (2000). Scientific arguments as learning artifacts: designing for learning from the web with KIE. *International Journal of Science Education, 22*(8), 797-817.

Berland, L. K., & Reiser, B. J. (2009). Making sense of argumentation and explanation. *Science Education, 93*(1), 26 – 55.

Berland, L. K., & Reiser, B. J. (2011). Classroom communities' adaptations of the practice of scientific argumentation. *Science Education, 95*(2), 191-216.

Bybee, R. W. (2008). Scientific literacy, environmental issues, and PISA 2006: The 2008 Paul F-Brandwein lecture. *Journal of Science Education and Technology, 17*(6), 566–585.

Bybee, R., & McCrae, B. (2011). Scientific literacy and student attitudes: Perspectives from PISA 2006 science. *International Journal of Science Education, 33*(1), 7–26.

Chin, C. C., Yang, W. C., & Tuan, H. L. (2010). Exploring the impact of guided Tapping scientific reading-writing activity on sixth graders. *Chinese Journal of Science Education, 18*(5), 443-467.

Clark, D. B., & Sampson, V. D. (2008). Assessing dialogic argumentation in online environments to relate structure, grounds, and conceptual quality. *Journal of Research in Science Teaching, 45*(3), 293-321.

Clark, D. B., & Sampson, V. D. (2009). The impact of collaboration on the outcomes of scientific argumentation. *Science Education, 93*(3), 448-484.

Cohen. J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Eribaum.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick(Ed.), *Knowing, Learning, and instruction: Essays in Honor of Robert Glaser* (pp.453-494). Hillsdale, NJ: Lawrence Erlbaum Associates.

Dole, J. A., & Sinatra, G. M. (1998). Reconceptalizing change in the cognitive construction of knowledge. *Educational Psychologist, 33*, 109-128.

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education, 38*(1), 39–72.

Fensham, P. J. (2009). Real world contexts in PISA science: Implications for context-based science education. *Journal of Research in Science Teaching, 46*(8), 884–896.

Joiner, R., & Jones, S. (2003). The effects of communication medium on argumentation and the development of critical thinking. *International Journal of Educational Research, 39*, 861-871.

Kjarnsli, M., & Lie, S. (2004). PISA and scientific literacy: Similarities and differences between the Nordic countries. *Scandinavian Journal of Educational Research, 48*(3), 271–286.

Kuhn, D. (1991). *The skills of arguments*. Cambridge, England: Cambridge University Press.

Lavonen, J., & Laaksonen, S. (2009). Context of teaching and learning school science in Finland: Reflections on PISA 2006 results. *Journal of Research in Science Teaching, 46*(8), 922–944.

Lee, C. T. (2009). Implications on TIMSS & PISA scientific achievement among junior high school students in Taiwan. *Study Information, 26*(6), 73-88.

Lin, H. S., Hong, Z. R., & Huang, T. C. (2012a). The role of emotional factors in building public scientific literacy and engagement with science. *International Journal of Science Education, 34*(1), 25–42.

Lin, H. S., Hong, Z. R., & Lawrenz, F. (2012b). Promoting and scaffolding argumentation through reflective asynchronous discussions. *Computers & Education, 59*(2), 378–384.

Linn, M. C. (1998). The impact of technology on science instruction: historical trends and current opportunities. In B. J. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education* (pp. 265-294). Boston: Kulwer Academic Publishers.

Nentwig, P., Roennebeck, S., Schoeps, K., Rumann, S., & Carstensen, C. (2009). Performance and levels of contextualization in a selection of OECD countries in PISA 2006. *Journal of Research in Science Teaching, 46*(8), 897–908.

Nussbaum, E. M. (2002). Scaffolding argumentation in the social studies classroom. *Social Studies, 93*(3), 79-84.

Nussbaum, E. M., & Sinatra, G. M. (2003). Argument and conceptual engagement. *Contemporary Educational Psychology, 28*, 384-395.

OECD. (2006). *PISA released items: Science*. http://www.oecd.org/pisa/testquestions-pisa2006.htm

OECD. (2009). *PISA 2009 assessment framework: Key competencies in reading, mathematics and science*. Paris: OECD Publishing.

Olsen, R. V. (2005). An exploration of cluster structure in scientific literacy in PISA: Evidence for a Nordic dimension? *Nordina, 1*(1), 81–94.

Olsen, R. V., & Lie, S. (2011). Profiles of students' interest in science issues around the world: Analysis of data from PISA 2006. *International Journal of Science Education, 33*(1), 97-120.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching, 41*(10), 994-1020.

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

Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching, 46*(8), 909–921.

Toulmin, S. (1958). *The uses of argument*. Cambridge, England: Cambridge University Press.(Reprinted 2005)

TWPISA National Center (2012a). *Rankings in PISA*. http://pisa.nutn.edu.tw/ link_rank_en.htm

TWPISA National Center (2012b). *PISA released items: Science.* http://pisa.nutn.edu.tw/sample_tw.htm

Wang, J & Lin, E. (2005). Comparative Studies on U.S. and Chinese mathematics learning and the implications for Standards-based mathematics teaching reform. *Educational Researcher, 34*(5), 3-13.

Yeh, K.H., & She, H.C. (2010). On-line synchronous scientific argumentation learning: Nurturing students' argumentation ability and conceptual change in science context. *Computers & Education, 55*(2), 586-602.

Zohar, A, & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching, 39*(1), 35-62.