Mevlana International Journal of Education (MIJE) Vol. 2(3)
Special Issue: Inquiry in Science Education & Argumentation Based Science Inquiry,
pp. 53-61 , 30 December, 2012 Available online at http://mije.mevlana.edu.tr/

INVITED ARICLE

# Supporting Students' Interest through Inquiry-Based Learning in the Context of Fuel Cells

Maija Aksela*
*The Unit of Chemistry Teacher Education Department of Chemistry, University of Helsinki, Finland*

Matleena Boström
*The Unit of Chemistry Teacher Education Department of Chemistry, University of Helsinki, Finland*

**Article history**

**Received:**
20.09. 2012

**Received in revised form:**
11. 11. 2012

**Accepted:**
25.12. 2012

**Key words:**
students, inquiry-based learning, fuel cells, chemistry education, junior high school level, contextual learning

The main aim of this research is to understand how inquiry-based learning in the context of fuel cells support the interest of 14 to 15-year-old male and female junior high school students. In total, 18 student groups (N=159) were involved in the case study in which a learning material with inquiry-based laboratory work in the context of fuel cells, designed based on previous research, was used. According to the survey conducted as a part of this research, the majority of youth liked inquiry-based chemistry experiments. The tangible stages of the work, i.e. compiling the miniature fuel cell car and operating it in practice, interested the youth the most. Boys were significantly more interested than girls in the applications of fuel cells related to the studied subject. Girls were interested in hydrogen energy economy, and that the issue is topical at the moment. Girls were also significantly more interested in the stages of inquiry-based learning – reporting the results and answering the questions that required reasoning. It seems that the model of inquiry-based learning used here and the learning materials give good opportunities for increasing the interests in chemistry among girls and boys alike, and thus provide a solution for the biggest challenge in chemistry education – increasing the youth's interest in chemistry.

## Introduction

Motivating and supporting the students' interest is one of the biggest challenges in chemistry teaching. The pedagogical methods used and the meaningful contexts from the students' perspective have an influence on interest and maintaining it (e.g. Byman, 2002; Karjalainen & Aksela, 2008; Lavonen & al., 2005). Different themes induce gender-specific interest in different ways (e.g. Jones & al., 2000). The main aim of this research is to understand how inquiry-based learning including laboratory work and assignments with multiple stages related to fuel cells support the interest of 14 to 15-year-old male and female junior high school students. In addition, the research focuses on the gender-specific differences between girls and boys with regard to interest. A topical issue of green chemistry, i.e. fuel cells, was chosen as the context of this study.

### *Theoretical framework*

In contextual learning, the students are instructed to encounter concepts of chemistry in situations and contexts that are known or believed to showcase the importance of chemistry in

* Correspondence: The Unit of Chemistry Teacher Education Department of Chemistry, University of Helsinki, Finland
maija.aksela@helsinki.fi

everyday life, further studies, or working life (Bennett, Hogarth and Lubben 2003; Gilbert, 2006). Fuel cells are electrochemical equipment that convert chemical energy of the fuel into electricity and heat through electrochemical reaction of oxidation and reduction (U.S. Department of Energy, 2004). The development of fuel cells is reinforced by the requirements of sustainable development: the depletion of fossil fuels, strict emission restrictions, and the goals to improve energy efficiency. The benefits of fuel cells are high fuel economy and environmental aspects.

One aim of chemistry education is to teach the student to use chemical knowledge as a consumer and citizen in promoting sustainable development, and in participating to discussions and decision making related to nature, environment, and technology (Finnish National Board of Education, 2003).

In teaching about fuel cells in chemistry education, the human–technology relations can be brought up to help the student to see the significance of technology in the everyday life through different fuel cell applications. In addition, the teaching can encourage the students to ponder the connection of society and technology and discuss the possibilities of fuel cells and green chemistry for sustainable development and energy production. Also, the significance of fuel cells as clean energy source and the status of hydrogen used in them as safe and pollution-free fuel of the future can be discussed in chemistry teaching.

The open inquiry-based learning used in this research combines first-hands-on inquiry, student-centered learning, and perceiving the concepts of chemistry in practice (Gordon, 1990). Inquiry-based learning can be implemented into teaching through many ways. The ways differ from one another with regard to openness, that is, how much the teacher instructs the work and how independently the students conduct the work (DeBoer, 2004). During inquiry-based learning, the students practice critical thinking by observing, making questions, forming hypotheses, making predictions, planning inquiries to solve the problem, doing precise measurements, interpreting the results, making conclusions, generalizations and assumptions, and understanding the limitations of scientific research and how the gained knowledge can be applied to different situations (Gordon, 1990; Minner & al., 2010).

It has been pointed out that inquiry-based learning is an efficient way to increase the students' interest towards natural sciences. In their research, Zachos & al. (2000) showed that within a short period of time, junior high school students are capable of forming notions of the laws of natural sciences and testing them experimentally through inquiry-based learning. It has been noted that this working method increases the interest towards natural sciences especially among girls (Rocard & al., 2007). Learning and understanding the concepts of chemistry through inquiry-based learning is also more efficient than traditional experimental methods of teaching (Minner & al., 2010). However, the teacher has to know how to instruct and support the student creatively throughout the inquiry, and be able to ask open-ended questions from them (DeBoer, 2004; Gordon, 1990).

In this research, a learning material designed based on research literature was used in teaching junior high school students. The small-scale inquiry was conducted in small groups using miniature fuel cell cars with regenerated PEM (Proton Exchange Membrane) type fuel cell that produces energy for the electric engine of the car. The aim of inquiry-based laboratory work was to teach the chemistry of fuel cells, hydrogen energy economy, and to support the students' interest by motivating them to study chemistry.

The aspects that motivate interest in girls as well as boys were taken into consideration in the design of the material. According to research literature, boys are more interested in technology whereas girls are more interested in themes related to humans and biology (Kotte, 1992). The themes related to climate change and alternative energy sources motivate interest especially in boys (Christidou, 2006). The chosen theme can be seen to be related to biology through environmental aspects that could, according to previous studies, support also girls' interest (Osborne&Collins,2001). The designed learning material was made to be open in that the student could manage the work according to written instructions without much help from the teacher. The designed material includes an illustrative manual with instructions on how to compile the car and complete different stages of inquiry. In addition, the material included questions regarding forming hypotheses and making conclusions, and a form for the results to be handed out to the students. The aim of it was to help them perceive the integral parts of doing research and the significance of different stages. The learning material was designed in a way that it supports the active role of the student according to the theories on interest and inquiry-based learning (e.g. Minner & al., 2010). The learning material (.pdf files) can be found in Finnish from the following web addresses:

- http://www.kemianluokka.fi/files/tulevaisuuden_auto_ohjekirja.pdf
- http://www.kemianluokka.fi/files/tulevaisuuden_auto_kalvot.pdf
- http://www.kemianluokka.fi/files/huhti10_oppilas.pdf.

How the inquiry-based learning was implemented can be seen in Figure 1. The starting point for the study was climate change and the emissions produced by traffic and it was presented in the frame narrative of the learning material. The aim of the frame narrative was to encourage the students to take responsibility over their own learning and increase their interest towards the subject (Gilbert, 2006). After that, the students pondered in small groups the possible sources of energy that could substitute for fossil fuels in the future. After brainstorming, inquiries were made using miniature fuel cell car. First, a solar panel inquiry was conducted the goal of which was to study whether a solar panel could produce enough current power for the electric engine of a fuel cell car. Next, the electrolysis of water and hydrogen was examined as the fuel of the future. Using PEM electrolysis cell, hydrogen and oxygen gases were produced into the car's tank from water through an electrolytic method. After fueling the car, the functions of fuel cells as energy producers were studied. The inquiry included hypothesis, reporting results, and discussing conclusions, just like in an authentic science inquiry. The students worked together in small groups,justlike researchers in research groups.

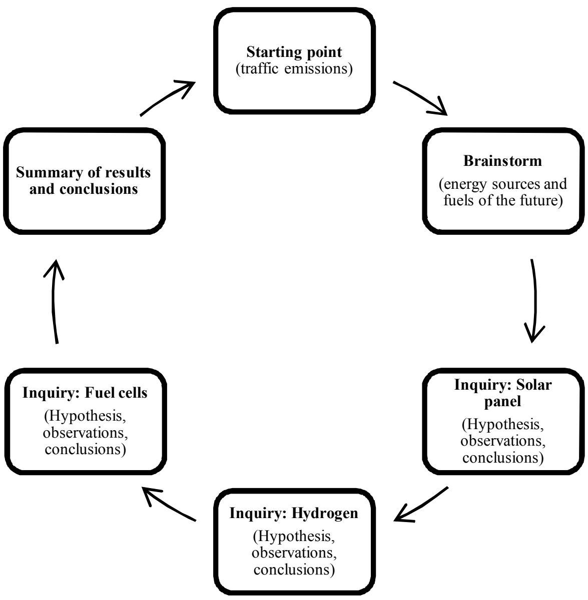


**Figure 1:** Inquiry-based learning in the context of fuel cells

## *Methodology*

*Participants*

159 junior high school 8th grade students were involved in the case study, 72 of them were boys and 87 girls. All in all, 18 groups of students participated in the study. According to a background survey, the youth in this study considered chemistry as a quite interesting school subject (only 37% of them considered chemistry as slightly or very interesting).

### *Data collection and analysis*

The case study was conducted as a survey, which had been tested and found adequate in a pilot study among students of the same age (N=34). In the Results section of this paper, the survey will be analyzed according to four categories: (I) background information (gender, interest in experimental work and chemistry), (II) interest in the inquiry-based learning material (laboratory work and assignments: studying how solar panels work, compiling a fuel cell car, fueling the fuel cell car with hydrogen, and driving the car) and different stages of the study (reporting the results, answering the questions), (III) interest in the studied topics (hydrogen energy economy, fuel cells and its applications and topicality), and (IV) other feedback. In sections I to III the respondents evaluated the given topics according to five-point Likert scale (1 = not at all interesting, 2 = slightly interesting, 3 = neutral, 4 = quite interesting, 5 = very interesting). In the survey, there was also the option to choose 0 from the scale, meaning “cannot say”.

The research was carried out in two consecutive days during technology theme week. Each workshop of inquiry-based learning lasted 60 minutes. There were altogether four guides, two for each workshop. After the workshop, students had five minutes to answer the survey (1 A4 sheet). The survey was answered anonymously.

For the analysis, the survey forms were numbered 1 to 159. The analysis was done quantitatively using SPSS 15.1 (Statistical Package for Social Science) statistical analysis software. Frequencies, modes, means, and standard deviations were calculated from the data. In addition, t-tests were done and p-values determined (the significance of gender-specific differences in interest). Some answers had been left blank. The option 0 “cannot say” was taken into the examination of frequencies, but not taken into determining means.

The open-ended question in section IV was analyzed using content analysis based on grounded theory. The answers (N=49) were classified into categories based on the data. The categorization was repeated several times.

## Results

The youth involved in this research liked experimental laboratory work; as much as 68% of them evaluated it as quite or very interesting. The youth were the most interested in the tangible results: does the fuel cell work in practice (see Table 1: Driving the fuel cell car). Also compiling the car was interesting to the youth. Fueling the car with hydrogen was considered quite interesting. Investigating the operations of a solar panel linked to the fueling part interested the youth the least.

**Table 1:** Student's interest in the different stages of laboratory work based on inquiry-based learning (N=159).

| Area of interest | Frequency | | | | | | Mean | Standard deviation |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 0 | | |
| Investigating the operation of solar panel | 16 | 41 | 58 | 24 | 6 | 14 | 2,7 | 1,0 |
| Compiling fuel cell car | 6 | 16 | 34 | 63 | 35 | 5 | 3,7 | 1,1 |
| Fueling the fuel cell car with hydrogen * | 10 | 24 | 43 | 56 | 18 | 7 | 3,3 | 1,1 |
| Driving the fuel cell car ** | 6 | 9 | 24 | 55 | 58 | 4 | 4,0 | 1,1 |

* (N=158), ** (N=156)

Of the different stages of laboratory work, the boys were more interested than girls to investigate how solar panels work and to compile the fuel cell car (see Table 2). Girls, however, were more interested than boys in fueling the fuel cell car and driving it. However, the differences between genders were not statistically significant.

**Table 2:** The interest of boys and girls in the laboratory works of the learning material (N=159).

| Area of interest | Mean | | t | p< |
|---|---|---|---|---|
| | Boy | Girl (N=87) | | |
| Investigating solar cells | 2,8 | 2,7 | 0,6 | 0,5 |
| Compiling fuel cell car | 3,7 | 3,7 | 0,3 | 0,8 |
| Fueling fuel cell car with hydrogen | 3,3 | 3,4 | – 0,4 | 0,7 |
| Driving fuel cell car | 3,9 | 4,0 | – 0,6 | 0,5 |

Girls were more interested than boys in areas related to inquiry-based learning and reporting the results and answering questions that required reasoning (see Table 3). This result is statistically significant.

**Table 3:** The interest of girls and boys in the assignments related to laboratory work (N=159).

| Area of interest | Mean | | T | p< |
|---|---|---|---|---|
| | Boy | Girl | | |
| Reporting the results | 2,2 | 2,6 | – 2,2 | 0,03* |
| Answering questions requiring reasoning | 2,4 | 2,6 | – 1,6 | 0,11 |

*p < 0,05

The interest of students in the topics of laboratory work, hydrogen energy economy and fuel cells was relatively neutral (see Table 4). The topical nature of the issue interested the youth.

**Table 4:** Students' interest in the topics of laboratory work (N=158).

| Area of interest | Frequency | | | | | | Mean | Standard |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 0 | | deviation |
| Hydrogen energy economy | 15 | 35 | 51 | 31 | 9 | 17 | 2,9 | 1,1 |
| Fuel cells and their applications* | 17 | 31 | 47 | 43 | 6 | 13 | 2,9 | 1,1 |
| Topicality of the issue | 15 | 28 | 46 | 41 | 14 | 14 | 3,1 | 1,1 |

*(N=157)

Of the topics in the learning material, boys were more interested than girls in the applications of fuel cells (see Table 5). The result is statistically significant. Girls were more interested in hydrogen energy economy and the topicality of the fuel cell issue.

**Table 5:** The interest of girls and boys in the topics of the laboratory work (N= 159).

| Area of interest | Mean | | T | p< |
|---|---|---|---|---|
| | Boy | Girl | | |
| Hydrogen energy economy | 2,8 | 3,0 | – 0,9 | 0,37 |
| Fuel cells and their applications | 3.2 | 2.7 | 2.3 | * 0.02 |
| Topicality of the issue | 2,9 | 3,2 | – 1,8 | 0,07 |

* p < 0,05

In the open-ended answers the following aspects related to inquiry-based learning and material for laboratory work were brought up: (i) the instructions for fuel cell work were clear and good (N=22), and the entire laboratory work was good (N=7), (ii) the work was interesting (N=4), and the standard of chemistry was of suitable level (N=4). Two respondents hoped that the material would have been more illustrative.

*"The work was easy to do because the instructions were good"* (Respondent 26)
*"Good, it was nice to do something different than normally"* (Respondent 40)
*"Everything was good and understandable"* (Respondent 153)
*"It was nicer than regular 8th grade chemistry…"* (Respondent 6)

### *Discussion and conclusion*

Based on the case study, inquiry-based laboratory work material in the context of fuel cells supported students' interest well. These results are similar with those of Berg's &. al. study made in Sweden (2003). On the other hand, it has to be borne in mind that there are youth whose areas of interest differ significantly from the "average student".

Tangible areas of inquiry-based laboratory work were the most interesting: compiling the fuel car and operating it (driving it). The notion that tangible topics and working methods are interesting is also supported by previous research (Osborne & Collins, 2001). The interest in the different areas of laboratory work was gender-specific. Boys were more interested in the applications of fuel cells. This is supported by previous research in which boys were noted to be more interested in the technical issues than girls (Kotte, 1992). Also Jones & al. (2000) have gotten similar results: the themes in chemistry interest different genders in different ways. According to their study, boys were more interested in technical applications such as cars than girls. A suggestion for the development of solar panel inquiry, that was the least interesting according to this study, would be to measure the current from solar cells in different light sources with multimeters. This way the students could be demonstrated how solar panels work in different settings. Although there are some gender-specific areas of interest in laboratory activities, assignments and topics, the presented results are approximate.

Based on the results, it can be said that students are not particularly interested in reporting the results and answering to the questions that require reasoning. Girls are significantly more interested in these areas than boys. By comparison though, Palmer (2009) investigated student interest during an inquiry skills lesson. It was indicated that copying notes during the lesson was least interesting. Furthermore, when copying notes the mean for girls was higher than the mean for boys.

Of the topics of laboratory work, hydrogen energy economy and the topicality of fuel cell issue support girls' interest more than that of boys'. Hydrogen energy economy can be linked to the environment and nature. According to research literature, girls are more interested than boys in the phenomena related to biology (Kotte, 1992). On the other hand, boys are more interested than girls in sources of energy, current innovations and greenhouse effect (Christidou, 2006). Osborne and Collins (2001) have stated in their research that if girls are interested in something boys will often be interested in the same thing. Saying that and according to the results of this study, especially hydrogen energy economy and the topicality of the issue should be brought up when teaching about fuel cells through experiments.

According to the case study, the students described the work as good, interesting and deviating from normal. Similar positive results that support learning have been noted in studies that use inquiry-based learning as the working method (Hodson, 1990). According to research literature, the text of an interesting learning material has to be consistent, coherent, and easy to understand (Mitchell, 1993; Schraw & Lehman, 2001).

The method used in teaching has a great significance in motivating and supporting interest (Lavonen & al., 2005). According to this research, there is a link between inquiry-based learning and interest in the chemistry of fuel cells. For the teachers to be able to use inquiry-based learning at schools, it is important that there are suitable learning materials available for them. Therefore, it is important to continue with the design of materials for inquiry-based learning. In addition, there has to be in-service training for teachers on how to implement inquiry-based learning into teaching, so that the threshold to use this method is made lower. Inquiry-based learning is often regarded as time consuming and that implementing it requires special skills from the teacher (DeBoer, 2004). Therefore, implementing inquiry-based learning should be discussed at pre-service level teacher training. The present research gives evidence that the newly designed learning material using inquiry-based learning in teaching about the chemistry of fuel cells gives good opportunities to support interest and answer the biggest challenge in chemistry education – motivating youths' interest.

In the future, it is important to study whether the laboratory work and materials designed for this research affect the study results of the students. According to research literature, inquiry-based learning based on experiments supports the learning of chemistry concepts (Minner & al., 2010), thus it would be justified to investigate what students learn from the laboratory work in the context of fuel cells. It would be also interesting to study the usefulness of the designed material when it is used by teachers as a classroom activity.

## References

Bennett, J., Hogarth, S. & Lubben, F. (2005). A systematic review of the effects of context- based and Science-Technology-Society (STS) approaches in the teaching of secondary science.

Educational Studies: University of York. http://www.york.ac.uk/depts/educ/research/ResearchPaperSeries/SciTTA1a.pdf

Berg, A., Bergendahl, C., Lundberg & Lundberg, b. (2003). Benefiting from an open-ended experiment? A comparison of attitudes to, and outcomes of, an expository versus an open-inquiry version of the same experiment. *International Journal of Science Education*, 25(3), 351–372. DOI 10.1002/tea.20263

Byman, R. (2002). Voiko motivaatiota opettaa? [Can you teach motivation?] In. Kansanen P. & Uusikylä K. *Luovuutta, motivaatiota, tunteita. Opetuksen tutkimuksen uusia suuntia [Creativity, motivation, emotions. New aspects in pedagogy]* (p. 25–41). PS- kustannus 2002. Opetus.

Christidou, V. (2006). Greek Students' Science-related Interest and Experiences: Gender differences and correlations. *International Journal of Science Education*, 28(10). 1181-1199. DOI: 10.1080/09500690500439389

DeBoer, G. E. (2004). Historical perspective on inquiry teaching in schools. In. Flick, L. B. & Ledean, N. G. *Scientific inquiry and nature of science: Implications for teaching, lerning, and teacher eduction,* (p.17-34) Dordrecht: Kluwer Academic Publishers.

Finnish National Board of Education (2003). *National core curriculum for upper secondary schools 2003.* Helsinki: Finnish National Board of Education.

Gilbert, J. K. (2006). On the Nature of "Context" in Chemical Education. *International Journal of Science Education, 28*(9), 957-976. DOI: 10.1080/09500690600702470

Gordon, E. U. (1990). Inquiry in classroom. *BioScience,* 40(11), 841–843. URL: http://www.jstor.org/stable/i256130

Jones, G., Howe, A. & Rua, M. J. (2000). Gender Differences in Students' Experiences, Interests, and Attitudes towards Science and Scientists. *Science Education*, 180(84). 180–192. DOI: 10.1002/(SICI)1098-237X(200003)84:2<180::AID-SCE3>3.0.CO;2-X

Karjalainen, V. & Aksela, M. (2008). *Kemian opetus tänään*: *Nykytila ja haasteet Suomessa. [Chemistry teaching today: current state and challenges in Finland]* Chemistry Education Centre. Department of Chemistry: University of Helsinki, University printing.

Kotte, D. (1992). *Gender differences in science achievement in 10 countries*. Frankfurt: Peter Lang.

Lavonen, J., Juuri, K., Meisalo, V., Uitto, A. & Byman, R. (2005). *Luonnontieteiden opetuksen kiinnostavuus peruskoulussa. [Interest in Science Teaching in basic education].* Department of Applied Education: University of Helsinki. p. 5-30.

Minner, D. D., Levy, A. J. & Century, J. (2010). Inquiry-Based Science Instruction – What Is It and Does it Matter? Results from a Research Synthesis Year 1984 to 2002. *Journal of Research in Science Teaching,* 47(4). 474-496. DOI: 10.1002/tea.20347

Mitchell, M. (1993). Situational interest: Its multifaceted structure in the secondary school mathematics classroom. *Journal of Educational Psychology*, *85*(3), 424–436. DIO: 10.1037/0022-0663.85.3.424

Osborne, J. & Collins, S. (2001). Pupils' views of the role and value of the science curriculum: A focus group study. *International Journal of Science Education,* 23(5), 441-467. DOI:10.1080/09500690010006518

Palmer, D. H. (2009). Student Interest Generated During an Inquiry Skills Lesson. *Journal of research in science teaching*. 46(2), 147–165. DOI 10.1002/tea.20263

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Welberg-Henrikson, H. & Hemmo, V. (2007). European Commission Community research: Science Education Now: A Renewed Pedagogy for the Future of Europe. Directorate-General for research Science, Economy and Society.

Schraw, G. & Lehman, S. (2001). Situational Interest: A Review of the Literature and Directions for Future Research**.** *Educational Psychology Review,* 13(1), 23-52. DOI:10.1023/A:1009004801455

US Department of Energy. (2004). *Fuel Cell Handbook*, 7. Edition. US Department of energy: Washington, DC.

Zachos, P., Hick, T., Doane, W. & Sargent, C. (2000). Setting Theoretical and Empirical Foundation for Assessing Scientific Inquiry and Discovery in Educational Programs. *Journal of Research in Science teaching,* 37(9), 938–962. DOI: 10.1002/1098-2736(200011)37:9<938::AID-TEA5>3.0.CO;2-S