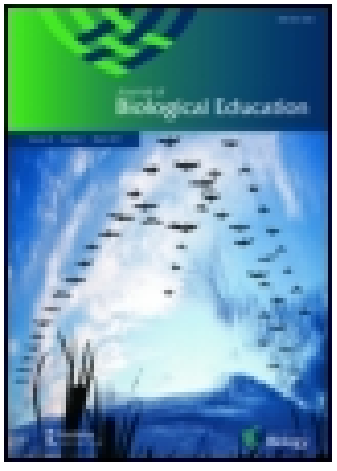

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Investigating the Effectiveness of an Inquiry-Based Intervention on Human Reproduction in Relation to Students' Gender, Prior Knowledge and Motivation for Learning in Biology

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Despite the importance of understanding how the human reproductive system works, adolescents worldwide exhibit weak conceptual understanding, which leads to serious risks, such as unwanted pregnancies and sexually transmitted diseases. Studies focusing on the development and evaluation of inquiry-based learning interventions, promoting the knowledge of human reproduction, are very few. The purpose of this study was to evaluate the effectiveness of an inquiry-based intervention on human reproduction in relation to students' gender, prior knowledge and motivation for learning in biology. Data collection methods included students' pre- and post-tests, evaluating students' conceptual understanding regarding human reproduction, and measurements of students' motivation employing the Motivational Learning Environment survey. The sample for the pre- and post-test conceptual understanding data included the whole population of the 7th graders in Cyprus ($n = 6465$). Students' motivation data were collected from a representative sample of the entire 7th graders population ($n = 946$ students). Statistical analyses indicated a statistically significant increase in students' conceptual understanding as well as in their motivation for learning in biology. However, students' gender, prior knowledge and initial motivation for learning in biology seemed to mediate the effectiveness of the inquiry-based intervention. All of these variables are deemed, therefore, as of great importance for the design, implementation and evaluation of biology teaching interventions.

Keywords: *human reproduction; conceptual understanding; motivation; socio-scientific issues; biology education*

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By the age of 11, most children have already formed some basic notions about certain aspects of human reproduction, such as are the mechanisms of sexual intercourse and understand the role of both parents, in getting sperms and eggs together, to create a new organism (Driver et al. 1994). However, several studies have indicated that adolescents possess little knowledge regarding reproductive physiology, while they also bring a number of misconceptions in the school classroom, related to the topic of human reproduction (e.g. Donati et al. 2000; Sydsjö et al. 2006). In this context, the fact that many young people find themselves in difficult situations such as unwanted pregnancies, abortions and sexually transmitted diseases, is not surprising (Blum and Nelsonmmari 2004).

These problems make abundantly clear the importance of education about human reproduction. Therefore, well-designed interventions in the course of biology are central to the vital area of educating young people regarding this crucial topic (Handa 1995). However, research has indicated that students' achievement is often mediated by a number of variables ranging from students' gender or cognitive abilities to their school location and their socio-scientific background (Soyibo and Pinnock 2005). The aim of this study was to investigate the effectiveness of an inquiry-based intervention on human reproduction in relation to students' gender, prior knowledge and initial motivation for learning in biology.

Theoretical Background

Although human reproduction is a very important socio-scientific issue (Harlen 2010), studies in relation to the development and evaluation of inquiry-based instructional interventions on this topic are few. Inquiry is the working model followed by scientists to discover new knowledge about the natural world (NRC 1996). Similarly, learning through inquiry seeks the active involvement of students in the process of discovering the natural world around them, based on the pedagogical principles of constructivism. According to the NRC (1996), learning through inquiry includes many different activities such as formulating new hypotheses, observing, experimenting, collecting and interpreting new data. Central to this approach is that, when possible, students should be engaged in an investigative process that situates the socio-scientific content in an authentic context (Sadler, Barab, and Scott 2007). Therefore, inquiry-based learning has been argued to motivate students, since it allows them to work in student-centred learning environments on issues which are important to the society as well as to their own lives (Holbrook 2003).

However, despite the promises of inquiry-based learning, previous research has indicated that the success of a learning intervention could be moderated by variables related to students' gender, motivation or prior knowledge (e.g. Baram-Tsabari et al. 2010; Cavallo, Potter, and Rozman 2004; Kragten, Admiraal, and Rijlaarsdam 2015; Randler 2009). Yenilmez, Sungur, and Tekkaya (2006) indicated, for instance, that students' achievement regarding photosynthesis and respiration in plants was related to students' prior knowledge and reasoning ability as well as to their gender. In addition, according to the gender effect, there are some learning issues which are socially or culturally considered as 'male' or 'female' and these stereotypical issues are assumed to influence students' motivation for learning (Hyde and Durik 2005). Human reproduction seems to

be included in these issues. For instance, according to Uitto et al. (2006), girls have been found to be more interested in human biology, while boys to be more interested in the basic processes of biology, such as ecological and cellular phenomena.

In this context, the aim of this study was to evaluate the effectiveness of an inquiry-based biology module about human reproduction, in relation to students' gender as well as to students' prior knowledge and initial motivation. More specifically, this study pursued the investigation of the following research questions:

- What is the impact of an inquiry-based learning intervention on students' conceptual understanding about human reproduction?
- To what extent did gender and students' prior knowledge influence their conceptual understanding about human reproduction?
- What is the effect of an inquiry-based learning intervention on students' motivation to learn science?
- To what extent did gender and students' initial motivation for learning biology affect students' motivation during the inquiry-based learning intervention?
- Is there a correlation between students' conceptual understanding and motivation?

Methodology

This study was based on a quasi-experimental methodology, employing a pre- and post-test research design. What follows is an overview of the methodology–sample, educational intervention, research tools, data collection and data analysis methods–aiming to provide the reader with an inclusive conceptualisation of the research design followed.

Sample

Given that the study took place within the context of a nationwide educational reform effort led by the Cyprus Ministry of Education and Culture (2010), the participation of all the 7th graders (12–13 years) studying in the public school of Cyprus was ensured. Thus, this study included the whole population of the 7th graders in Cyprus ($n = 6465$). A total of 3205 boys (50%) and 3260 girls (50%) made up the 7th graders' population.

Educational Intervention

An inquiry-based intervention was developed (Hadjichambis et al. 2011) during which 7th graders were asked to investigate the problem of a young couple (Artemis and Costas) related to human reproduction. The learning intervention was enacted in six 80-min sessions. During the inquiry-based intervention, students were involved in a socio-scientific investigation, since they were asked to gather, interpret and synthesize secondary information, in order to reach an evidence-based decision and to advise the young couple. According to the learning scenario, the young couple was seeking a medical advice in order to conceive a baby, while at the same time, was confronted with the dilemma on whether to proceed with In Vitro Fertilisation (IVF) or not.

The module was structured according to the following six sub-units:

(1) Learning scenario and students' mission,
(2) male reproductive system and male reproductive cell,
(3) female reproductive system and female reproductive cell,
(4) fertilisation–phases of foetus development,
(5) IVF–pros and cons,
(6) decision-making on the socio-scientific topic presented.

While students worked on these sub-units, they were asked to consider a sequence of corresponding guiding questions, such as 'What problems Costas' sperm cells may have which might account for the childbearing problem of the couple?' (for sub-unit 2) and 'Which part of Artemis's reproductive system might account for the childbearing problem and why?' (for sub-unit 3). Hence, students had the opportunity to learn both about the structure and the function of the male and the female reproductive system as well as about their potential malfunctions. Such a holistic learning approach has been indicated as more effective, instead of separating the structure from the function or focusing on each organ of a system separately (Lazarowitz and Penso 1992; Yip 1998).

In addition, in contrast to a traditional lesson, during which students receive raw and pre-scripted information followed by a number of consolidating questions, this inquiry-based intervention was based on the principles of constructivism through the investigation of a socio-scientific problem. Hence, at the stage of inquiry, students collected information needed, both from text-based sources as well as from audio-visual material (e.g. videos, animations, power point presentations, etc.). Thereafter, students organised and interpreted the information they collected, employing structured worksheets, supporting them to solve the problem as well as to take an informed decision, in terms of offering appropriate advice to Costas and Artemis. To sum up, during the learning intervention, we attempted to promote the application and use of biological knowledge in topics related to everyday life and society (see for instance Holbrook 2003), thus making biological knowledge more enjoyable and meaningful to study.

Research Tools

Two diagnostic instruments were employed, both before and after the teaching intervention. The first diagnostic instrument was an assessment test aiming to explore students' conceptual understanding about the human reproductive system. The maximum total score was equal to 20 marks. This conceptual test was developed by the research team and consisted of ten items, six of which were open-ended questions and four were closed-ended questions. The content as well as the total correct marks for each item, included in the test, is presented in Table 1. In addition, Figure 1 presents some examples from the conceptual test.

The second diagnostic test evaluated students' motivation. For this purpose, we used the Motivational Learning Environment (MoLE) survey proposed by Bolte (2012). The MoLE survey consists of two different questionnaire versions, namely the REAL and the TODAY version (Bolte 2000). The REAL version investigates the actual characteristics of the biology lessons in general, while the TODAY version investigates how effective a

Table 1. Items included in the conceptual understanding test

Item	Content	Total marks (out of 20)
# 1	Naming of basic cells, organs and processes of human reproduction	3
# 2	Basic function of the main organs of male and female reproductive system	2.5
# 3	Differences between sperm cell and egg cell	2
# 4	Changes in girls' body during puberty	2
# 5	Organs responsible for the transport of nutrients and oxygen to the foetus	1
# 6	Calculation of the number of egg cells that a woman will release during her lifetime	0.5
# 7	Male and female reproductive system anatomy	4
# 8a	Calculation of fertile time	1
# 8b	Calculation of next normal menstrual period	1
# 9a	Succession of stages from fertilisation to birth	0.5
# 9b	Description of stages from fertilisation to birth	1.5
# 10	Argumentation against and in favour of *in vitro* fertilisation	1

specific lesson has been regarding the motivation of the students. In this study, the REAL version was administered to the students before the inquiry-based enactment, aiming to evaluate students' initial motivation. On the other hand, the TODAY version was administered immediately after the enactment, aiming to evaluate the effectiveness of the inquiry-based lessons in motivating the students.

Both versions of the MoLE instrument addressed as follows: (1) comprehensibility of the taught material, (2) opportunities to participate, (3) relevance to everyday life provided by the socio-scientific contexts, (4) class collaboration, (5) students' willingness to participate and (6) student satisfaction. A seven point rating scale (where one was the minimum and seven was the maximum) was employed, and students were asked to evaluate the aforementioned scales in the two different conditions ('Real: Traditional biology lessons' and 'Today: Inquiry-based biology lessons about reproduction').

Data Collection

The diagnostic tests were administered to the students both before and after the learning intervention and were completed in the presence of their biology teachers, within a period of 40 min. The conceptual test was completed by all the 7th graders who participated in this study ($n = 6465$). The MoLE survey was completed by a representative sample of the 7th graders, which included 946 students, namely 433 boys (46%) and 513 girls (54%), chosen according to the method of random stratified sampling.

Data Analysis

The pre- and post-tests were subjected to statistical analysis. The statistical analysis involved the investigation of the differences between pre- and post-test scores on

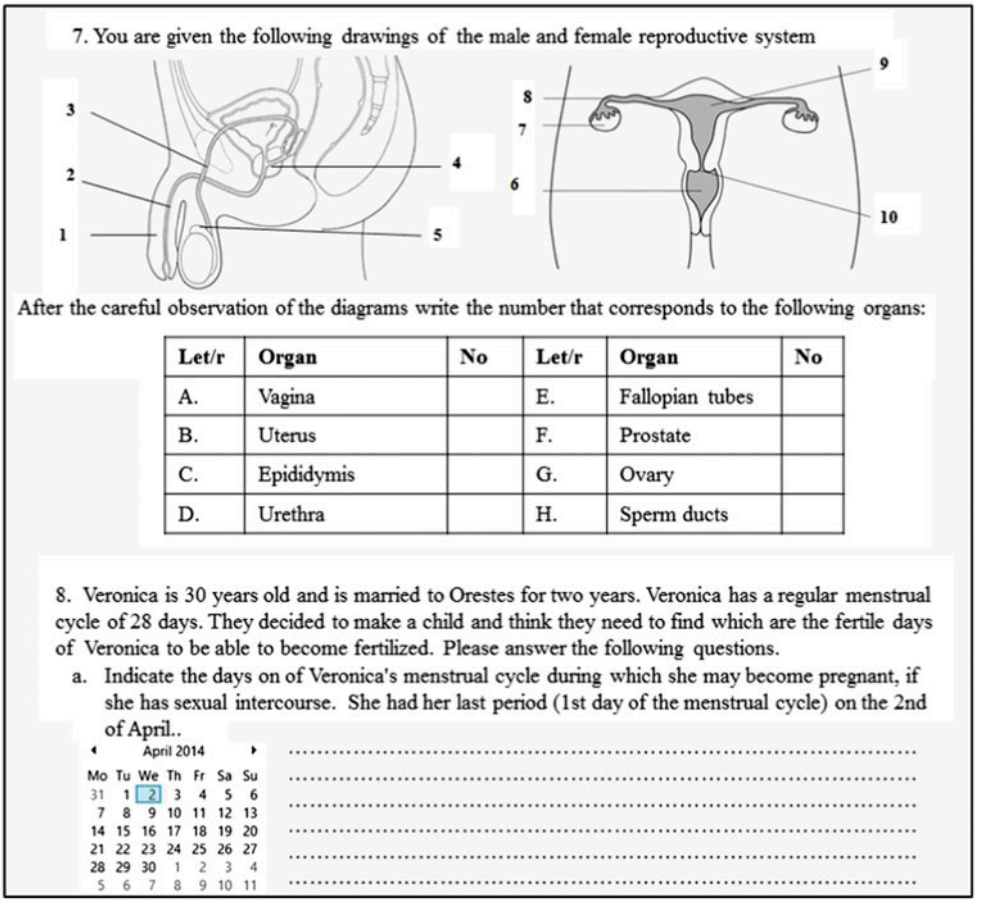

Figure 1. Sample items from the diagnostic test on conceptual understanding (translated from Greek)

students' learning scores and motivation, employing *t*-tests for dependent means, both overall as well as per gender. Furthermore, aiming to investigate whether students' gender, prior knowledge as well as the interaction of these two variables, had an effect on students' learning gains, a two-way ANOVA statistical test was employed, using the post-test learning scores as the dependent variable, while the students' gender (boys, girls) and prior knowledge (very low, low, medium, high and very high performance), as two nominal, independent variables. Respectively, in an effort to investigate whether students' initial motivation, gender as well as the interaction of these two variables, had an effect on students' post-motivational gains, a two-way ANOVA statistical test was employed, using the post-test motivation as the dependent variable, while the students' gender (boys, girls) and initial motivation (low, medium, high motivation), as two nominal, independent variables. Finally, the correlation between students' learning scores and motivation in biology was also investigated through the Pearson correlation coefficient.

Findings

What follows are the main findings derived from the data analysis regarding the effectiveness of the learning intervention, in terms of students' conceptual understanding and students' motivation, as well as of students' achievement in relation to their gender, prior knowledge and initial motivation.

Conceptual Understanding

The comparison of students' scores, before and after the intervention, in terms of students' conceptual understanding, indicated a statistically significant increase after the inquiry-based intervention, both overall, as well as per gender (Table 2). Overall, according to our findings, the mean value of students' conceptual understanding before the learning intervention was $\bar{x} = 5.61$ (SD = 2.99), while the mean value after the intervention increased to $\bar{x} = 14.30$, (SD = 4.68), $t(6464) = -163.91$, $p < 0.01$. In addition, as presented in Table 2, despite the fact that there was a statistically significant increase both in the case of boys and girls regarding their conceptual understanding, girls begun and ended the teaching intervention with a higher mean value in comparison with boys.

The means, standard deviations, results of the *t*-tests and effects sizes for each item are shown in Table 3. A statistically significant increase was found in students' conceptual understanding for all of the items included. In addition, the effect size was consistently large (e.g. *d* scores around 0.80 or over; Cohen 1988) for most of the items evaluated. Taking into consideration the effect size, it seems that the magnitude of the conceptual change was greater in items related to the structure and the anatomy of the reproductive system (Item 7) as well as to the naming of basic cells and organs of the system (Item 1). In contrast, the magnitude of the conceptual change was lesser in items related to the succession of stages from fertilisation to birth (Item 9a), the description of stages from fertilisation to birth (Item 9b) or the calculation of the next normal menstrual period (Item 8b).

A two-way ANOVA test was run to determine the main effects of gender, students' prior knowledge and their interaction, on students' conceptual understanding by the end of the inquiry-based intervention. According to the findings, students' prior knowledge had a statistically significant effect on students' learning gains $F(4, 6455) = 314.41$, $p < 0.01$ since the mean value of students' conceptual understanding after the inquiry-based lessons was significantly higher for students of increased prior knowledge.

Table 2. Comparison of students' conceptual understanding before and after the learning intervention overall and per gender

		Pre-test		Post-test		
	N	$\bar{x}$	SD	$\bar{x}$	SD	*t*-test
Boys	3205	5.10	2.97	13.68	4.85	−109.92**
Girls	3260	6.12	2.93	14.93	4.91	−122.47**
Total	6465	5.61	2.99	14.30	4.68	−163.91**

**$p < 0.01$.

Table 3. Pre- and post-tests scores regarding students' conceptual understanding

	Pre-test		Post-test			
	M	SD	*M*	SD	*t*-test	*d*
Total	5.61	2.99	14.30	4.68	−167.34**	2.21
Item 1	1.14	0.69	2.17	0.82	−119.10**	1.36
Item 2	0.83	0.78	1.98	0.79	−91.81**	1.46
Item 3	0.24	0.51	1.40	0.78	−109.25**	1.76
Item 4	1.30	0.84	1.81	0.48	−48.08**	0.75
Item 5	0.42	0.36	0.79	0.32	−67.51**	1.09
Item 6	0.10	0.20	0.26	0.25	−40.17**	0.71
Item 7	0.61	0.74	3.00	1.27	−143.94**	2.29
Item 8a	0.05	0.19	0.44	0.46	−65.69**	1.11
Item 8b	0.17	0.36	0.49	0.49	−46.24**	0.74
Item 9a	0.33	0.23	0.45	0.15	−34.02**	0.62
Item 9b	0.27	0.43	0.47	0.15	−70.45**	0.62
Item 10	0.15	0.30	0.72	0.40	−103.69**	1.61

**$p < 0.01$.

However, gender did not have a significantly statistical effect on students' final conceptual understanding ($F(1, 6455) = 1.92$, $p > 0.05$). The same finding was true regarding the interaction of the two independent variables, namely the gender and students' prior knowledge ($F(4, 6455) = 0.34$, $p > 0.05$).

Motivation

The analysis of students' motivation indicated a statistically significant increase of students' motivation in the context of the inquiry-based module, in comparison with students' motivation in the context of traditional biology lessons (Table 4). Overall, according to our findings, before the learning intervention, the mean value for students' motivation was $\bar{x} = 5.47$ (SD = 0.85), while after the intervention the mean value for students' motivation increased to $\bar{x} = 5.57$ (SD = 0.91), $t(945) = -4.23$, $p < 0.01$. As shown in Table 4, this comparison revealed that students were more motivated, since they understood the inquiry-based lesson more (comprehensibility), were more eager to participate (willingness), they collaborated more (collaboration), they enjoyed the inquiry-based lesson to a greater degree (satisfaction) and felt that they were taught about more relevant issues to their lives (relevance).

While there was an increase in motivation for both boys and girls, this difference was statistically significant only in the case of girls ($t(512) = 4.32$, $p < 0.01$). In addition, based on the data analysis, girls seemed to enter and leave the teaching intervention with a higher mean value in motivation in comparison with boys (see Table 5).

A two-way ANOVA was run to determine the main effects of gender, students' initial motivation for biology and their interaction, on students' motivation during the inquiry-based module employed. According to the findings of the two-way ANOVA test, students' initial motivation had a statistically significant effect on students' motivation

Table 4. Pre- and post-tests scores regarding students' motivation

	Pre-test		Post-test		
	M	SD	*M*	SD	*t*-test
Total	5.47	0.85	5.57	0.91	−4.23**
Comprehensibility	5.61	1.15	5.72	1.13	−3.19**
Participation	5.19	1.43	5.17	1.42	0.57
Willingness	6.04	1.03	6.13	1.04	−3.14**
Satisfaction	5.21	1.46	5.34	1.49	−2.93**
Collaboration	5.08	1.10	5.17	1.24	−2.47*
Relevance	5.58	1.22	5.78	1.27	−4.57**

**$p < 0.01$.
*$p < 0.05$.

during the inquiry-based intervention $F(2, 940) = 198.62$, $p < 0.001$. In addition, gender also had a statistically significant effect on students' motivation during the intervention $F(1, 940) = 198.62$, $p < 0.01$. Finally, the examination of the interaction of the two independent, nominal variables (gender and initial motivation) also yielded a statistically significant effect on students' motivation during the inquiry-based lessons $F(2, 940) = 198.62$, $p < 0.01$. This indicates that girls, who initially had higher motivation, were also more motivated to participate in the inquiry-based module on human reproduction as compared to boys of higher initial motivation. Furthermore, girls of medium initial motivation outperformed the boys of initial medium motivation.

Investigation of the Correlation between Students' Conceptual Understanding and Motivation

The correlation between students' conceptual understanding and motivation was also investigated. The Pearson correlation coefficient indicated a positive correlation between students' motivation about the inquiry-based learning environment employed and the students' learning gains derived from the inquiry-based implementation ($r = 0.33$, $p < 0.01$). This correlation was statistically significant, indicating a positive relation between students' motivation during the inquiry-based learning intervention and their final learning outcomes.

Table 5. Comparison of students' motivation before and after the learning intervention overall as well as per gender

		Pre-test		Post-test		
	N	$\bar{x}$	SD	$\bar{x}$	SD	*t*-test
Boys	433	5.38	0.91	5.46	1.02	−1.88
Girls	513	5.55	0.79	5.67	0.80	−4.32**
Total	946	5.47	0.85	5.57	0.91	−4.23**

**$p < 0.01$.

Discussion and Conclusions

The purpose of the present study was to investigate the effectiveness of an inquiry-based intervention on human reproduction, in terms of students' conceptual understanding and motivation. At the same time, the present study made an effort to explore students' achievement in relation to gender, prior knowledge and initial motivation. In this section, we discuss our findings organised around these two areas of interest.

Effectiveness of the Inquiry-Based Intervention on Human Reproduction

This study documented the low level of 7th graders' prior knowledge regarding human reproduction, highlighting, as previous studies did, the importance of learning interventions for promoting students' conceptual understanding of this topic (e.g. Donati et al. 2000; Handa 1995; Sydsjö et al. 2006). In this context, the findings of the present study indicate that inquiry-based learning interventions can have significant contribution to students' conceptual understanding as well to students' motivation.

Focusing on conceptual understanding, students in our study demonstrated a statistically significant increase in content knowledge regarding human reproduction, indicating the positive impact of the intervention. The magnitude of this conceptual change was greater in items related to the structure and the anatomy of the reproductive system rather than to its function. This finding is in agreement with previous studies, indicating that students tend to understand concepts related to the structure of cells, organs and systems easier rather than the function of biological units (e.g. Yip 1998). Based on these findings, it seems that an inquiry-based learning intervention should examine both the structure as well as the function of each organ of the reproductive system, as it was the case in the learning intervention employed. A holistic approach is necessary, since if it is not employed students may come to assume that each organ may stand on its own (Lazarowitz and Penso 1992). Further research is required to investigate how to best address this challenge and particularly how to support students in understanding issues relating to the function of biological systems.

In addition, data analyses indicated a statistically significant increase in students' motivation during the inquiry-based intervention. According to the MoLE motivation instrument, students' responses highlighted that the inquiry-based intervention resulted in a more student-centred and thus motivating learning environment. These findings are aligned with previous studies supporting that an inquiry-based approach for the investigation of socio-scientific issues can contribute to motivating students for learning (Holbrook 2003; Sadler, Barab, and Scott 2007).

Finally, taking into consideration the positive correlation between students' learning gains and motivation, it seems that both of these aspects should be emphasised during the design and implementation of such learning interventions. According to Kochhar (1992) students' motivation is one of the most important factors in the learning process, since without this students' learning could be limited. Based on these premises, the effectiveness of the inquiry-based learning intervention employed, both in terms of students' conceptual understanding as well as of students' motivation, seems to be of great importance. However, these findings should be treated with a cautious optimism given that a

control group was not included in the present study, and hence, there are no adequate data supporting that the proposed teaching approach could have a more positive effect when compared to other teaching approaches.

Students' Achievement in Relation to Gender, Prior Knowledge and Initial Motivation

Despite the effectiveness of the inquiry-based learning intervention employed, students' achievement seemed to be mediated by a number of variables related to students' gender, prior knowledge and initial motivation. This finding is not surprising, given that such variables have often been linked with students' science understanding and overall performance (Soyibo and Pinnock 2005).

In the context of the present study, students' prior knowledge as well as students' initial motivation seemed to affect students' conceptual understanding as well as students' motivation during the inquiry-based learning intervention. More specifically, students with higher prior knowledge and their initial motivation seemed to reach higher levels of conceptual understanding and motivation accordingly. These findings echoed and reinforced several existing studies in the field of biology education (e.g. Baram-Tsabari et al. 2010; Cavallo, Potter, and Rozman 2004; Hyde and Durik 2005; Kragten, Admiraal, and Rijlaarsdam 2015; Randler 2009; Soyibo and Pinnock 2005; Yenilmez, Sungur, and Tekkaya 2006), documenting that such factors could mediate the impact of a learning intervention.

In its essence, the present study provides empirical support on that students' starting point, in terms of their existing knowledge and motivation, seems to affect both students' conceptual and affective learning gains. Hence, given that girls entered the learning intervention with higher levels of motivation and prior knowledge, girls achieved greater learning gains by the end of the learning intervention, in comparison with boys. In fact, girls not only outperformed boys in terms of conceptual understanding, but at the same time, students' motivational gains were statistically significant only in the case of girls. These results are of great importance if we consider that according to international exams such as PISA revealed that the greatest hurdle among girls is in reaching the top (OECD 2014).

This gender effect has often been detected in the frame of biology education, and thus, researchers have even described biology as the only science subject that has escaped a masculine image, emerging as a 'feminine niche' in science (Ayalon 1996). For instance, according to Baram-Tsabari and Yarden (2008), gender is an important factor relating to students' interests and attitudes towards science, with boys more interested in physics and girls in biology. Besides, in some studies, differences were also found even between sub-domains within biology: i.e. girls are reported to be more interested in human biology and topics dealing with human health and well-being, while boys seem more interested in zoology or in the basic processes of biology (Baram-Tsabari et al. 2010; Uitto et al. 2006).

Educational Implications

The findings of the present study have several educational implications. Firstly, at the level of designing biology education learning materials regarding human reproduction,

we should attend to how to engage boys more. Secondly, biology teachers should anticipate that boys may need additional support and scaffolding in order to attain similar learning as girls in the specific biology topic. More specifically, boys need greater scaffolding to increase their motivation, given that girls had a more positive attitude towards biology education initially, and higher motivation during the inquiry-based implementation. According to Makenzius et al. (2009), boys need greater support in order to participate as responsible partners towards the improvement and protection both of their own sexual health and that of others. These findings suggest that the design of motivating, inquiry-based learning environments can support learning about human health and illustrate challenges that still remain to be addressed.

Finally, we would like to bring the reader's attention to the fact that this study focused on a few but not all aspects of sex education; the latter, also requires attending to the psychological and social aspects, which were not systematically investigated in our study. According to Kirby, Laris, and Rolleri (2007), knowledge, awareness of risk, values and attitudes, self-efficacy and intentions are factors specified by many psychosocial theories as being the determinants of sexual behaviour. Since these aspects are very important parts of a holistic sex education they should also be investigated in future studies.

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Disclosure statement

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