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THE ROLE OF GENERAL INQUIRY KNOWLEDGE IN ENHANCING STUDENTS' TRANSFORMATIVE INQUIRY PROCESSES IN A WEB-BASED LEARNING ENVIRONMENT

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Abstract. *Inquiry has been regarded internationally as an effective learning approach for science learning; however, it is still not actively used in many schools. The current study argues that one of the reasons is incompleteness of the model for inquiry. This study seeks to open inquiry from a new angle by bringing in general inquiry knowledge, which could be regarded as an important limitation in enhancing inquiry. Next, it is empirically tested if general inquiry knowledge is related to the level of students' transformative inquiry skills. General inquiry knowledge pertains to the nature of a coherent inquiry process as a whole, comprehending knowledge about transformative and regulative inquiry processes. In this study, students' general inquiry knowledge and transformative inquiry skills were evaluated in a web-based learning environment Young Researcher. The analysis of the results demonstrated that the learning environment was suitable for improving students' general inquiry knowledge, and these are related with the level of transformative inquiry skills.*

Key words: *computer-supported inquiry learning, general inquiry knowledge, inquiry learning, inquiry meta-processes, transformative and regulative inquiry processes.*

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Introduction

The European-level strategic document "Science Education Now: A renewed Pedagogy for the Future of Europe" indicates that science-teaching pedagogy should be reversed from mainly deductive to more inquiry-based methods (Rocard et al., 2007) by emphasizing the importance of the inquiry learning. It is strongly supported by the research in this area showing that inquiry is a very useful and effective learning method, helping students' better to understand the world around them (e.g., White & Frederiksen, 1998). Furtak, Seidel, Iverson, and Briggs (2012) have demonstrated in their meta-analysis that inquiry learning has an overall mean effect size of 0.50 in favour of the inquiry approach over traditional instruction. However, it has also been declared that inquiry can be too complex for learners due to the range of metacognitive and cognitive activities (Quintana, Zhang, & Krajcik, 2005). Thus, the current study offers an approach focused on developing students' general inquiry knowledge, which considers both metacognitive and cognitive activities aimed to reduce the complexity of inquiry learning.

Concept of Inquiry Learning

Inquiry learning has been described as a student-centered (Mäkitalo-Siegl, Kohnle, & Fischer, 2011) and highly self-directed constructivist form of learning (de Jong & van Joolingen, 1998). Thus, the study process requires students' active involvement and some prior knowledge about the domain that is being studied. Furthermore, research has shown that inquiry learning is focused on learning through experimenting and scientific reasoning (Kolloffel, Eysink, & de Jong, 2011). These aspects require critical thinking and reasoning processes that are characteristic of scientific work. Abstract reasoning processes are also needed to correct student misconceptions about science (Demircioğlu, Dinç & Çalık, 2013). Studies indicate that inquiry learning places students in the position of scientists (Chang, Sung, & Lee, 2003; Keselman, 2003). Like scientists, students make discoveries by carrying out experiments and observations to investigate relations between dependent and independent factors (de Jong & van Joolingen, 1998; Wilhelm & Beishuizen, 2003). De Jong and Njoo (1992) describe scientific activities through transformative processes, where the key element of the discovery is to produce new knowledge about domain information (Hulshof & de Jong, 2006). Here, the term "new knowledge" is conditional because it is usually new to the learner, but not necessarily the scientists. Nevertheless, inquiry learning helps learners construct a personal knowledge base that is scientific (McGinn & Roth, 1999) and can be used for predicting and explaining future observations or experiments (van Joolingen, de Jong, & Dimitrakopoulou, 2007). However, through scientific experimentation, not only is new knowledge acquired, but also new skills as well. Therefore, inquiry learning can be seen as both a process of acquiring new domain knowledge and of improving inquiry skills.

As a learning method, inquiry finds its roots in scientific discovery learning, and often these terms are used as synonyms. Extant research has declared that these two learning methods are merging (van Joolingen et al., 2007). Still, a distinction between inquiry and discovery learning has been indicated. If the main goal of discovery learning is to use existing knowledge in new ways to learn information (Saunders-Stewart, Gyles, & Shore, 2012), inquiry learning is more focused (besides acquiring new domain knowledge) on developing the skills needed for inquiry processes (Mäeots, Pedaste, & Sarapuu, 2009). These inquiry skills have often been improved in computer-based learning environments that are proven to be effective tools for fostering inquiry skills (Eysink et al., 2009; Plass et al., 2012), but also to lead students to deeper and more meaningful understandings of the scientific content (Manlove, Lazonder, & de Jong, 2006; Reid, Zhang, & Chen, 2003). In addition to students, these environments can also be useful to teachers, specifically, pre-service and new science teachers who need opportunities to practice how to implement inquiry in their class (Özel & Luft, 2013) and understand the entirety of scientific inquiry (Kang, Orgill & Crippen, 2008).

Computer-based environments provide learners with ample options to explore a virtual world by manipulating and finding relations between variables (Beishuizen, Wilhelm, & Schimmel, 2004). As a result of inquiry, students complement their inquiry skills and construct for themselves new knowledge about scientific content. Some authors have stated that web-based learning environments can be seen as cognitive tools (Azevedo, 2007) that support the improvement of the students' cognitive skills. In the context of inquiry learning, these skills are necessary for transformative processes.

Inquiry Processes

Inquiry learning is a complex process and, in addition to transformative processes, it also involves regulative processes (de Jong & Njoo, 1992; Njoo & de Jong, 1993). If transformative processes are primarily for improving inquiry skills, regulative processes are more focused on controlling and supporting the specific transformative process (Hulshof & de Jong, 2006). Regulative processes are related to skills like planning, monitoring, and evaluating (de Jong, Kollöffel, van de Meijden, Staarman, & Janssen, 2005). Regulative processes function to help students plan all activities for transformative processes, monitor and evaluate the success of the plan and, if necessary, make changes to the initial plan. In the case of transformative processes, there are also different suggested stages and skills related to them (Friedler, Nachmias, & Linn, 1990; Harlen & Jelly, 1997). Transformative processes involve stages sequenced as: (a) problem identification; (b) research question formulation; (c) hypotheses formulation; (d) experiment planning; (e) executing the plan; (f) analyzing data; and (g) drawing conclusions (see Pedaste & Sarapuu, 2006). However, the distinction between transformative and regulative processes does not cover all processes that characterize inquiry learning.

Kim and Chin (2011) showed that because of a lack of students' inquiry competency, it is impossible to apply inquiry learning in everyday science classrooms. This supports Quintana et al.'s (2005) suggestion that students have to know the interrelated activities that inquiry learning involves, referring to students' prior knowledge, which can be appreciated as *general inquiry knowledge*. White and

Frederiksen (2005) propose that students need to develop an understanding about how to manage their own inquiry. They describe it as metacognitive knowledge for action, involving knowledge of managing cognitive and metacognitive processes (White & Frederiksen, 2005). In the current study, it is stated as general inquiry knowledge that can be defined as knowledge, particularly pertaining to the nature of a coherent inquiry process as a whole. It is not knowledge about how to perform an inquiry activity, e.g., to formulate a hypothesis, but is, rather, knowledge about the components of the inquiry process as a whole, including knowing the sequence of transformative inquiry stages, the necessity of each stage, and the role of metacognitive processes needed for regulation of inquiry. Therefore, promoting students' general inquiry knowledge is a crucial element for successful inquiry learning. It leads to the assumption that, besides transformative and regulative processes, there exists a third type of inquiry process—*inquiry meta-processes*—where the general course of transformative and regulative processes is planned. Inquiry meta-processes can be defined as learning processes that are performed for planning and activating regulative and transformative inquiry processes in a coherent way. The relations between these three types of processes and the knowledge involved in them can be described through a theoretical model of inquiry learning.

Theoretical Model of Inquiry Learning

Recent research has often concentrated on studying inquiry learning in the context of supporting and developing transformative and regulative inquiry processes and skills (e.g., Gutwill & Allen, 2012; Manlove, Lazonder, & de Jong, 2009; Reid et al., 2003; Wu & Hsieh, 2006). Less has been investigated regarding how students' general inquiry knowledge affects the improvement of other inquiry processes and skills. Thus, considering outcomes of previous studies, where the development of transformative and regulative inquiry skills and relations between them were investigated (see Mäeots et al., 2008; Mäeots et al., 2009; Mäeots, Pedaste, & Sarapuu, 2011; Pedaste, Mäeots, Leijen, & Sarapuu, 2012), a revised theoretical model of inquiry learning was constructed (see Figure 1).

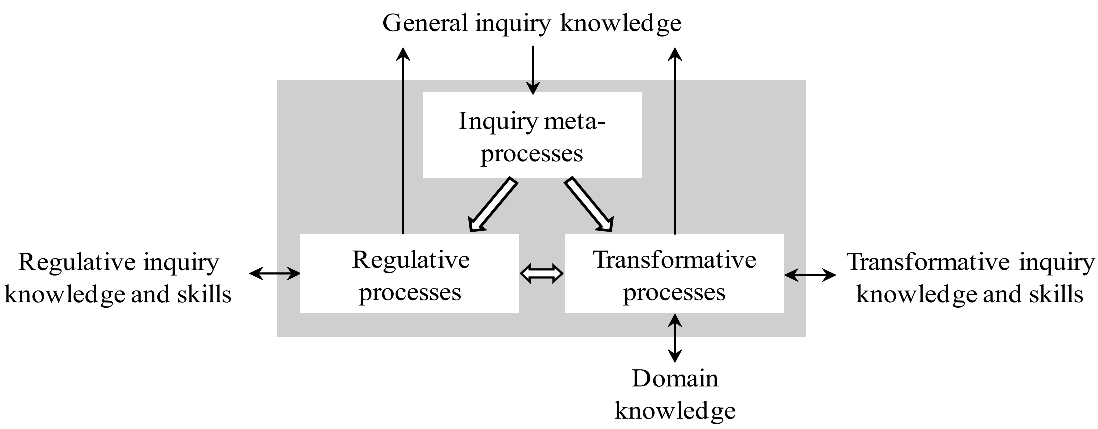

Figure 1: A revised theoretical model of inquiry learning: (a) processes involved in the inquiry process (grey area), (b) relations between processes (thick arrows), and (c) relations between knowledge and skills related to the inquiry processes (thin arrows). The direction of the arrows indicates information flows between different components of the model.

If a learner has reached a result in a particular inquiry stage, the outcome should be evaluated. This evaluation is a regulation process that emerges from the result of a transformative process. All these processes require specific knowledge and, sometimes, skills. Meta-processes assume general inquiry knowledge; regulative processes are based on regulative inquiry knowledge and skills; and

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transformative processes rely on transformative inquiry knowledge and skills. In addition, transformative processes need some input from domain-related knowledge (including procedural knowledge), while the regulative and meta-processes are more general and based on knowledge that is not domain-dependent. They can be transferred from one context to another without specific limitations. According to this model, general inquiry knowledge is a prerequisite for the acquisition of specific knowledge and skills that are necessary for transformative and regulative processes.

Regulative and transformative processes are associated with particular knowledge and skills by two-directional arrows. Consequently, these types of knowledge and skills are needed to conduct these processes, but performing the processes also improves them. An exception can be seen in the case of meta-processes; knowledge applied in these will be evaluated through regulative and transformative processes. Thus, the improvement of general inquiry knowledge can be expected while learners perform regulative or transformative processes successfully. Therefore, there are one-way arrows from general inquiry knowledge toward meta-processes, and the same from regulative and transformative processes toward general inquiry knowledge.

In the current study, evidence was collected about the improvement of student dyads' general inquiry knowledge for the purpose of describing the role of inquiry meta-processes in relation to transformative processes. This study was carried out in the web-based learning environment Young Researcher. Specifically, the following research questions were addressed:

1. How does the learning environment, Young Researcher, improve students' general inquiry knowledge?
2. Which relations appear between the general inquiry knowledge and transformative inquiry processes?

Methodology of Research

Learning Environment

Several studies have shown that web-based learning environments are efficient tools for conducting inquiries (e.g., Reid, et al., 2003; van Joolingen, de Jong, Lazonder, Savelsbergh, & Manlove, 2005). These environments enable students to observe phenomena that they cannot easily see or imagine, manipulate variables in simulated ways, and explore the targeted problem (Chang & Wang, 2009). In this study, the web-based inquiry learning environment Young Researcher (http://bio.edu.ee/teadlane) was applied. It is designed for students to learn biological topics (e.g., *"Why is it hard to catch a falling body?", "Why does our pulse and breathing rate change?"*). Such topics are associated with the Estonian science curriculum.

Each task in the learning environment is structured according to the inquiry learning stages: problem identification, research question and hypothesis formulation, experiment planning, carrying out an experiment, analysis and interpretation of results, and drawing conclusions (Mäeots et al., 2009). Inquiry learning is more successful if the learning process is guided (de Jong, Martin, Zamarro, Esquembre, Swaak & van Joolingen, 1999). Thus, to help students in their learning, different forms of supportive elements are offered by the Young Researcher learning environment. The content of these elements is designed to account for the characteristics of general inquiry knowledge, and transformative and regulative processes (see Table 1). Some of these elements are designed to support one specific type of inquiry knowledge and skills, but most of them can be flexibly applied to support different types of knowledge and skills, e.g., students' general inquiry knowledge and transformative inquiry knowledge, and the skills that are supported by *virtual professor*, *virtual teacher* and *virtual blackboard*.

Table 1. Supportive elements in the learning environment Young Researcher, and how different types of knowledge and skills are supported through them.

Supportive element	How different types of knowledge and skills are supported through elements		
	General inquiry knowledge	Transformative inquiry knowledge and skills	Regulative inquiry knowledge and skills
Guidelines given by the *Virtual professor*	*Necessity of the stage:* e.g., hypothesis is the answer to the research question, which is theoretically justified and evaluated by experiment.	*Components of the transformative process:* e.g., a research question is a question that contains independent and dependent variables.	*Evaluation of the learning process:* e.g., you have to check whether all components of the hypothesis are present and if it fits with a stated research question.
Guidelines given by the *Virtual teacher*	*Stage position in relation to other stages:* e.g., before conducting an experiment, scientists often formulate a hypothesis.		*Planning the learning process:* e.g., now you have to think how to check the correctness of the hypothesis.
Stages of inquiry presented by the *Virtual blackboard*	*Stages in pre-defined sequence*: research question formulation, hypothesis formulation, experiment planning, carrying out an experiment, analysis of data, and drawing conclusions.	*Components of a transformative process*: after each stage, the correct answers appear on the blackboard next to the name of a particular stage (e.g., the correct hypothesis).	

On the basis of the definition of general inquiry knowledge applied in this study, the following aspects of general inquiry knowledge were considered while designing the supportive elements. In order to understand the inquiry process as a whole, the presence of a pre-defined order of the inquiry stages was necessary through the learning process. This information was presented on *virtual blackboard*. Guidelines for presenting the relations between stages, and why each stage is necessary in the context of the whole inquiry, were also necessary. This was given through designing the texts of *Virtual teacher and Professor*.

Design and Procedures

Empirical data aiming to detect the development of the student dyads' general inquiry knowledge and clarify the role of general inquiry knowledge in relation to transformative processes was collected during an inquiry learning competition. This involved a three-week competition where volunteer student dyads had to solve five inquiry learning tasks in the learning environment Young Researcher. A pre- and post-test study was designed, where the first and final inquiry tasks in the learning environment were used as the pre- and post-tasks for comparing students' initial and final general inquiry knowledge and transformative inquiry skills. Three intermediate tasks with supportive elements formed a learning phase. The content of the tasks was developed based on the theoretical model described above. The students had access to the learning environment at any time, and they did not have a time-limit for completing particular assignments. In the case of technical problems and general questions about the learning environment and competition, they were supported by a person from the organizing committee of the competition. The inquiry tasks were opened for the students step by step on particular dates to avoid unreasonably rapid advancement in the competition, which has been found to be a problem when involving students in deep learning processes within applied web-based learning environments (Pedaste & Sarapuu, 2006).

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Participants

One hundred seventy dyads from 6th-9th grade (aged 10-16) participated voluntarily in an all-Estonian inquiry learning competition, which was carried out in the web-based learning environment Young Researcher. Sixty five dyads finished the competition on time, and their results were used in this study.

Pre- and Post-Tasks

The general structure of the pre- and post-tasks was designed to mirror the tasks of the learning phase. The main goal of the pre- and post-tasks was to evaluate the improvement of students' general inquiry knowledge. As a first step, students had to identify a problem based on the real-life situation. After that, they moved to the next step, where they had to plan the whole inquiry process to solve the problem. The purpose of this assignment was to explicitly perceive information about students' general inquiry knowledge in the pre- and post-tasks.

For students, a random list of six pre-defined transformative processes was provided: research question formulation, hypothesis formulation, experiment planning, carrying out an experiment, analysis of data, and drawing conclusions (presented here in the expected correct sequence). There were two assignments that measured students' general inquiry knowledge. Assignments followed the definition of the general inquiry knowledge applied in this study, containing knowledge about the sequence of transformative inquiry stages and the necessity of each stage. Thus, they first had to put transformative stages into an appropriate sequence by writing the queue number after each stage as it should be done while carrying out an inquiry. For example, students had to show that they understood that research questions should be formulated before hypotheses, and hypotheses are formed according to the research question before starting to plan experiments. This type of general inquiry knowledge is needed to plan the whole inquiry process, especially the transformative processes. Second, they were asked to explain why each transformative process is necessary in the context of inquiry and how it is related to the other stages of inquiry. For example, students had to explain why careful planning is needed before starting experimentation and data collection. This type of general inquiry knowledge is especially needed to effectively plan, monitor, and evaluate—the processes that are defined as regulative inquiry processes.

Next, after sequencing the inquiry stages, they began to solve a problem by formulating a research question and hypothesis. It was an open task, where students had to write the correct question (derived from the problem) containing the independent and dependent variables, and the correct statement indicating a hypothetical answer to the stated question. The presence of described components was also an evaluation criterion for research and hypothesis formulation.

After that, they had to plan and carry out an experiment. In the planning stage, a predetermined experimental plan was already available. However, student dyads' comprehension of the plan was evaluated by questions with multiple-choice answers. These questions were about variables that needed to be fixed for the entire experiment, the design of the experiment, and the safety aspects that needed to be taken into account. In the case of carrying out an experiment, students conducted real experiments. Their success was evaluated by the accuracy of the table filled in by the students during the experiment.

Students in the next stage could not use their own data; they were given the results of the control experiment made by authors of the environment. Hence, in the analysis stage, everyone had the same results to analyze, aiming to discover the relations among the variables. This allowed everyone to be on an equal footing, even if the experiment was unsuccessful. Finally, student dyads had to state a conclusion that accounted for the results of the study. They had to answer the formulated research question.

Conclusions were evaluated similarly to the hypothesis: there should be a statement containing independent and dependent variables, and the relation between them. According to the research questions of the current study, there were three differences implemented in the design of the pre- and post-tasks compared to the tasks in the learning phase. First, there was an additional assignment about general inquiry knowledge as described above. Second, the supportive elements were not available while solving pre- and post-tasks. In the learning phase, all supportive elements described in Table 1 were present. Third, all assignments for assessing students' inquiry skills and knowledge were in the form of open questions.

Data Analysis

Students' open-ended answers for assessing general inquiry knowledge in the pre- and post-tasks were analyzed according to a coding scheme based on the theoretical model of the study (see Table 2). Inter-rater reliability of coding was performed by two researchers and determined using Cronbach's α, which showed a relatively high score of 0.859.

Students could receive one point for each stage of inquiry that was placed appropriately in line with the stages before and after the particular stage. (It was possible to collect a maximum of six points.) Thus, if the student indicated, for example, experiment planning as the first step and placed all other stages correctly (except research question formulation and hypothesis formulation, which should be done before planning), he/she still received four points for placing the rest of the stages in the correct sequence. The evaluation followed complete correct sequence of the stages that are presented in the Young Researcher: research question formulation, hypothesis formulation, experiment planning, carrying out an experiment, analysis of data, and drawing conclusions.

Table 2. Assessment levels for analysing students' answers about general inquiry knowledge.

Level	Description of the level	Examples of students' answers
0	The answer is not given, or it is out of the assignment's context.	Research question formulation is something special.
1	The answer is in the assignment's context, but the explanation is not about particular transformative process.	Planning means collecting data.
2	Too-general explanation about necessity of particular transformative process.	Drawing conclusion is the answer to the research question.
3	Accurate explanation about necessity of particular transformative process.	Experiment planning is a base for collecting data and helps us to find answers to the research questions. For that, we need to figure out all necessary experimental instruments and the activities involved.

The improvement of the students' general inquiry knowledge was analyzed with the non-parametric Wilcoxon signed-rank test, and relations between the general inquiry knowledge and transformative processes were assessed by Spearman's correlation. Non-parametric analyses were conducted because the results were assessed on an ordinal scale and did not conform to normal distribution.

Results of Research

Improvement of Students' General Inquiry Knowledge

One of the goals of the current study was to evaluate student dyads' general inquiry knowledge by applying the web-based inquiry learning environment Young Researcher. Specifically, this meant assessing the participants' knowledge about transformative inquiry stages and their necessity for the inquiry. Sixty-five dyads who participated in the study showed a significant improvement ($Z = -2.2$; $p < 0.05$) in sequencing transformative inquiry stages as they should be passed through while conducting an inquiry (see Table 3).

Although the average score was near the maximum (4.5 out of 6.0) in the pre-task, there were still 20 dyads out of 65 who showed positive improvements in sequencing inquiry stages. There were also

10 dyads whose results in sequencing showed a negative change. The reason may be explained by the fact that it was a competition environment and their overall position in the competition might have had a negative effect on their motivation. Previous studies that have been carried out in a competitive environment have shown a similar tendency, where group of students do not concentrate completely on the tasks that must be solved to finish the competition (Mäeots et al., 2011).

The most common mistake made in the pre-task was to mix up the research question formulation with the hypothesis formulation; however, in the post-task, these were placed in the correct sequence. It also was common to start with experiment planning, which is somewhat justified because, in typical school situations, the science class students start their inquiry by planning. The main aim of the study was to broaden students' knowledge about doing inquiries by presenting the list of inquiry stages in the pre-defined order. Of course, it can be criticized because of the fact that scientists do not actually work in that way, but students must have an idea of what is involved in inquiry.

Table 3. The differences in general inquiry knowledge of the student dyads (n = 65) according to pre- and post-tasks.

Indicators of general inquiry knowledge (maximum points)	Pre-task		Post-task		Positive ranks	Negative ranks	Ties	Z-score
	Mean	SD	Mean	SD				
Sequence of the inquiry processes (6)	4.5	1.9	5.1	1.7	20	10	35	-2.2*
Necessity of research question formulation (3)	1.5	0.9	1.9	0.7	24	8	33	-3.2**
Necessity of hypothesis formulation (3)	1.5	0.7	1.9	0.7	25	9	31	-2.9*
Necessity of experiment planning (3)	1.8	0.8	2.0	0.7	19	10	36	-1.7
Necessity of carrying out an experiment (3)	1.7	0.8	1.9	0.8	18	7	40	-2.1*
Necessity of analysis of data (3)	1.6	0.9	1.9	0.8	20	8	37	-2.6*
Necessity of drawing conclusions (3)	1.6	1.0	2.0	0.7	24	4	37	-3.8**

*Significance at a level of: * < 0.05; ** < 0.001*

Under general inquiry knowledge, student dyads' knowledge about the necessity of each transformative inquiry process was also assessed. As indicated in Table 3, a significant development was detected in the students' explanations about the necessity of each transformative process. The biggest differences appeared in explaining the necessity of research question formulation ($Z = -3.2$; $p < 0.001$) and drawing conclusions ($Z = -3.8$; $p < 0.001$). Students explained that, without a question to investigate, it is impossible to start an inquiry, and the question is what needs to be answered by the inquiry. Drawing conclusions were stated in the pre-task to be just conclusions about what is done, but in the post-task, students added that it is an answer to the research question and is, therefore, also the answer to the problem. In addition, positive improvements were found in the explanations about hypothesis formulation, carrying out an experiment, and analysis of data. But no statistically significant improvement was found in the necessity of experiment planning. Here, 36 out of the 65 dyads stayed at the same level in their explanations. However, based on mean scores of the pre- and post-tasks, a slight positive change was found (from 1.8 to 2.0).

In general, the results indicate that the application of Young Researcher supported the development of the student dyads' general inquiry knowledge. In the learning environment, the dyads were put into a learning situation where there was given an appropriate sequence of transformative processes, and knowledge of the necessity of particular stages was only supported by their practice or optional guidance given by the virtual professor. There were no specific assignments supporting the development of students' general inquiry knowledge, e.g., tasks for analyzing why a research question should be formulated before formulating a hypothesis, or why a hypothesis is needed at all in the process of inquiry. However, despite the specific support, an improvement in general inquiry knowledge was demonstrated.

Relations Between General Inquiry Knowledge and Transformative Inquiry Skills

Considering that the purpose of inquiry learning is to develop inquiry skills (transformative inquiry skills in particular) and follow the structure of the revised theoretical model of inquiry learning (see Figure 1) applied in this study, the aim was to determine the relations between post-level general inquiry knowledge and transformative skills. But first, an overview of student dyads' post-level transformative skills is presented in Table 4.

Table 4. The post-level of the student dyads' (n = 65) transformative inquiry skills in the Young Researcher learning environment.

Inquiry skills (maximum points)	Mean	SD
Research question formulation (6)	4.3	1.1
Hypothesis formulation (9)	7.1	1.8
Experiment planning (6)	4.7	1.0
Carrying out an experiment (3)	2.5	0.7
Analysis of data (4)	3.4	1.5
Drawing conclusions (9)	6.6	1.8

On this basis of the study results, it can be concluded that student dyads reached an average level of inquiry skills, with 70–85% of the maximum points depending on inquiry skills. This is an expected result because previous research has shown that Young Researcher is applicable for developing students' transformative inquiry skills (Mäeots et al., 2011; Pedaste et al., 2012).

As described in the previous section, student dyads showed significant improvement of general inquiry knowledge and, thereby, a positive correlation was assumed between the level of general inquiry knowledge and the post-level transformative processes. In order to identify these relations, a Spearman correlation was executed (see Figure 2).

The results showed statistically significant positive correlations between general inquiry knowledge and research question formulation, hypothesis formulation, carrying out an experiment, and drawing conclusions. The strongest positive correlation was detected in the case of carrying out an experiment ($\rho = 0.491$; $p < 0.01$). Insignificant but positive relations appeared in correlation to the level of general inquiry knowledge of analyzing data and planning experiments. However, generally, it can be concluded that general inquiry knowledge correlates positively at a statistically significant level with most of the transformative processes. This result is in line with the theoretical model proposed in this study, where general inquiry knowledge has an important role in activating the inquiry meta-processes that should guide transformative processes of inquiry learning.

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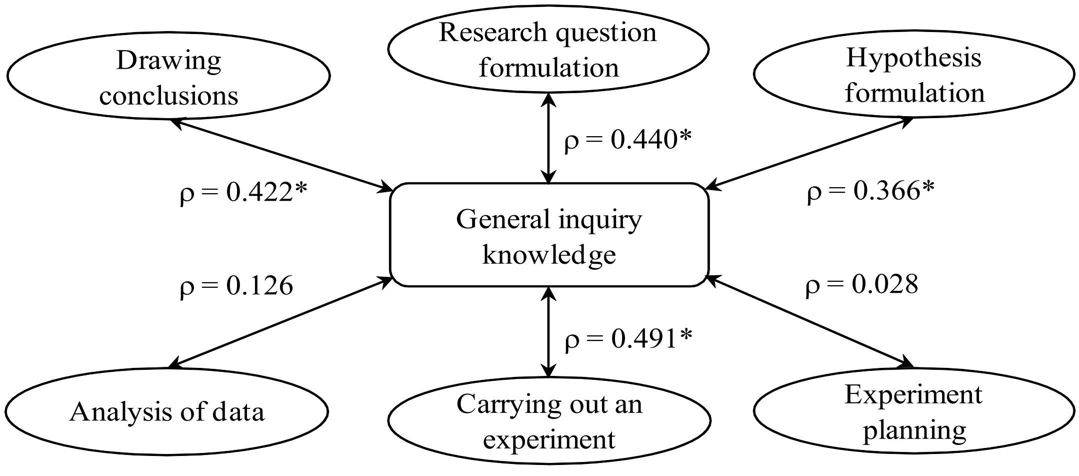

Figure 2: Correlations between learners' post-level general inquiry knowledge and post-level transformative processes (n = 65). *p < 0.01

According to this model, there are four factors influencing the quality of transformative inquiry processes, and meta-processes represent only one of those factors. The other three are regulative processes, transformative inquiry knowledge, and domain knowledge. The correlation coefficients ranging from 0.028 to 0.491 indicate that the system is multi-factorial; however, general inquiry knowledge seems to have an important role in determining the outcome of inquiry learning through inquiry meta-processes.

Discussion

The aim of the current study was to theoretically specify the role of general inquiry knowledge in the model of inquiry and investigate the improvement of students' dyads general inquiry knowledge and its relation with students' transformative inquiry skills. Specifically, empirical data was collected about students' abilities to sequence transformative inquiry processes and explain the necessity of each. This type of data allowed the acquisition of information that White and Frederiksen (2005) suggest as a students' understanding about the course of the inquiry. This cognitive outcome can be distinguished into two groups: 1) what students will be able to do; and 2) what students know about inquiry (Lederman, Lederman, & Antink, 2013). They also indicate that students, in their believing, simply have to do science, and inquiry should be addressed explicitly during science instructions (Lederman et al., 2013). However, research has shown that, due to the low level of cognitive and metacognitive knowledge, the inquiry learning process is too complicated for the students in the everyday classroom (Kim & Chinn, 2011; Quintana et al., 2005). In the current study, explicit support was used to provide students with an overview of inquiry stages and explanations about the necessity of each stage. Young Researcher did not only provide support, but, furthermore, aimed to create an atmosphere where students feel themselves "inside the inquiry". All this resulted in significant improvement in the students' abilities to sequence and explain the necessity of transformative processes. This might be valuable also to teachers who do not feel comfortable applying inquiry in their lessons. Research has indicated that teachers also lack knowledge in understanding the entirety of inquiry (Kang, Orgill & Crippen, 2008; Kidman, 2012). Therefore, it is good if teachers can use prepared materials that are scientifically tested and proven to be effective. Young Researcher is designed in accordance to offer a professionally pre-designed environment considered beneficial to students in developing their inquiry knowledge and skills.

The results of this study support the hypothesis and indicate that there are significant positive correlations between post-level transformative inquiry processes and general inquiry knowledge. For example, research question formulation, hypothesis formulation, and making conclusions all had significant positive correlations with students' levels of general inquiry knowledge. It is expected that these skills may improve in the same way because they have similar structure, containing independent and dependent variables with only one difference: the relation between variables is not expected according to the structure of a research question (Harlen & Jelly, 1997; Zachos, Hick, Doane, & Sargent, 2002). Positive correlations between developments of these skills have also been demonstrated in several earlier studies (e.g., Mäeots et al., 2009; Pedaste & Sarapuu, 2012). Still, there were also two expected correlations that did not show statistical significance in the current study. These were correlations of general inquiry knowledge with transformative processes of experiment planning and data analysis.

Conclusions

The problem of the current study was to describe an inquiry model that takes into account general inquiry knowledge that could be an important factor determining students' progress in inquiry. This model was developed based on a theoretical review of previous research. Next, there was an aim to find empirically if students' general inquiry knowledge is related with the progress of their transformative inquiry skills. Therefore, a web-based learning environment, Young Researcher, was developed in a way that supported students' general inquiry knowledge. Both general inquiry knowledge and transformative inquiry skills were analyzed in the beginning and end of the learning process.

In conclusion, this study indicates that the Young Researcher learning environment is applicable for improving students' general inquiry knowledge. The results of the study also support the theoretical model of inquiry, confirmed by positive correlations between post-level transformative processes and general inquiry knowledge. These results are significant on two levels.

First, it enriches the international discussion and understanding of the process of inquiry learning. Inquiry learning has been regarded as a key learning approach in many European-level strategic documents and national curricula (e.g., Osborn & Dilon, 2008; Tatar, 2012); however, it is still not widespread in schools (Martin et al., 2004). One of the reasons could be that the model of inquiry has not been complete. Second, the outcomes of this study could be applied by teachers who might consider the reasons for failure of the inquiry learning process. The important additional idea discovered in the current study is that general inquiry knowledge is needed to activate transformative inquiry processes. Thus, teachers who are starting inquiry with students should ensure that the students have general inquiry knowledge at a level that is sufficient to start with inquiry.

However, in this study, no relation was found between all transformative inquiry processes and general inquiry knowledge. Therefore, further studies are needed to find the minimal level of general inquiry knowledge needed for effective inquiry and if there exists a tendency that, depending on students' initial level of general inquiry knowledge, only specific skills of transformative processes will improve. Additionally, relations between regulative inquiry skills and general inquiry knowledge should be determined in future research. According to the inquiry model specified theoretically in this study, it can be hypothesized that regulative skills could have an important effect on the improvement of transformative inquiry skills; however, it cannot be explained with data collected in the current study.

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