

# MODEL FOR GUIDING REFLECTION IN THE CONTEXT OF INQUIRY- BASED SCIENCE EDUCATION

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## Introduction

The publication of the 'Science Education Now: A renewed Pedagogy for the Future of Europe' report (Rocard, Csermely, Jorde, Lenzen, Walberg-Henrikson, & Hemmo, 2007) brings science and mathematics education as the top of priority for the schools. The authors argue that school science teaching needs to become more engaging, based on inquiry and problem solving methods, and designed to meet the interests of young people. The teaching of science subjects in school also plays an important role in promoting the development of a range of skills and values (Holbrook & Rannikmäe, 2002) that are important for enhancing scientific literacy (Holbrook & Rannikmäe, 2007). Scientific literacy includes knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity (National Science Education Standards, 1996). According to Özdem, Çavas, P., Çavaş, B., Çakiroğlu, and Ertepinar (2010) scientific literacy should be thought of as the combination of science and scientific knowledge, as well as skills such as critical thinking, problem-solving, decision-making, and inquiry. The Rocard report (Rocard et al., 2007) indicates that these changes of young people should be achieved through inquiry-based science education (IBSE) approach. Inquiry learning has shown its effectiveness in learning science in several studies (e.g. Pedaste & Sarapuu, 2006; De Jong et al., 2012). Some recent studies have demonstrated how inquiry learning can be enhanced through reflection supported by technology (Pedaste, Mäeots, Leijen, & Sarapuu, 2012).

Inquiry learning can be applied in many different conditions and technology enhanced learning is one of them. In this context, computers permit the provision of complex information in verbal or visual form (Jonassen, 1996; Lajoie, 2000). Generally, inquiry helps students through planning and conducting experiments to understand what science is about and what they are doing (see Pedaste & Sarapuu, 2012). Using web-based learning environments enable the demonstration and teaching of natural processes that



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**Abstract.** *Only a limited number of studies have focused on guiding students' reflection in the context of inquiry learning in science education. In this study, a review of literature about reflection, reflection skills, and reflection levels was conducted in order to develop a new model for guided reflection in the context of science education using the advantages of technology-enhanced learning. The outcomes of the literature review suggest that in the context of science education reflection should be seen as a metacognitive activity that supports the integration of theory and one's own experiences to learn from experience. It contains active reviewing and conceptualization of regulative and inquiry activities. The main activities of reflection in this context are describing, justifying, evaluating, and discussing. According to the theoretical model, describing can be guided by writing a diary or narrative, justifying by explanation guidance, or evaluating and discussing by role play. Guiding questions can be applied in supporting all activities of reflection.*

**Key words:** *guidance of reflection, inquiry learning, instructional models, science education, technology-enhanced learning.*

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cannot be presented in the classroom or cannot be understood due to their scale or progression rate (Alessi & Trollip, 1985). In general, computers allow the wide use of inquiry learning because they allow the presentation of models and simulations (Veermans, 2002). Computer-based inquiry learning develops learners' metacognitive regulative skills, which are planning, monitoring, and reflection (Quintana, Zhang, & Krajcik, 2005). Planning and monitoring as regulative activities in inquiry learning have been one of the interests of several former studies (Mäeots, Pedaste, & Sarapuu, 2009; Mäeots, Pedaste, & Sarapuu, 2011; Pedaste et al., 2012). However, reflective activities that are also components of inquiry learning, have gained less attention (see e.g. Pedaste et al., 2012) in previous studies and it is important to elaborate on reflection and reflection skills in the context of inquiry learning (Ifenthaler & Lehmann, 2012).

Several studies have shown that science teachers consider reflection to be very important in achieving learning outcomes (Gunstone, 1999; Zembal-Saul, Blumenfeld, & Krajcik, 2000; Davis, 2003). Exploiting it enhances the effectiveness of further learning processes, integrating knowledge (Davis, 2003), and the development of flexible thinking and effective problem-solving skills (Lin, Hmelo, Kinzer, & Secules, 1999). According to various publications (e.g., Davis, 2003; Baird & White, 1996; Dewey, 1933), reflection is a very important activity for successful learning processes. For example, Davis (2003) pointed out that using reflection improves the effectiveness of the learning process and helps to create new connections between initial and acquired knowledge. Reflection can be tied to a wide variety of different learning methods, including inquiry learning. In their studies, Baird and White (1996) and Davis (2003) have found that, by using inquiry learning, reflection skills can be developed. White and Frederiksen (2005) pointed out three metacognitive reflective skills, planning, monitoring, and reflection, which, in their interpretation, resemble the regulative inquiry skills introduced by De Jong and Njoo (1992): planning, monitoring, evaluating. Several studies (De Jong & Njoo, 1992; Wilhelm, 2001) have shown that pupils' regulative skills can be improved by applying inquiry learning. Therefore, the reflection skill, which is one of the inquiry skills, can also be developed through using inquiry learning. Regardless of that, reflection is not widely used in lessons, and it causes difficulties for teachers in applying it effectively (Griffiths 2000; Leijen, Lam, Wildschut, & Simons, 2009a; Woodward, 1998).

### The Concept of Reflection

Reflection has been defined by several authors in a way that is relevant to inquiry learning (e.g., Dewey, 1933; Boud, Keogh, & Walker, 1985; Davis, 2003; Lin et al., 1999). Dewey (1933) saw reflective thinking as a way to understand situations, particularly puzzling ones, by making observations to clarify what is happening and by perceiving, considering, and testing various possibilities. It can be viewed in the context of inquiry learning because, similarly to Dewey (1933), outlining observation and testing as part of reflective thinking, observing (Friedler, Nachmias, & Linn, 1990), and experimenting (Padilla, 1990) have also been introduced as transformative stages of inquiry learning.

Boud et al. (1985) aptly defined reflection in the context of learning and focused more on one's personal experience as the object of reflection, referring to "those intellectual and affective activities that individuals engage in to explore their experience, which leads to new understanding and appreciations" (Boud et al., 1985, p. 3). Reflection helps students to integrate the theory of professional practice with their own experiences to develop their own practice. Boud's definition has been taken under examination as it focuses on learning from experience.

Davis (2003) added to the concept of reflection one more important dimension – the desire to improve the learning process. According to this, reflection is deliberate thinking about a learning experience to improve it. In a broader context, reflection is important in facilitating knowledge integration (Davis, 2003), and reflection on one's own cognition is a feature of flexible thinking and effective problem-solving (Lin et al., 1999). Additionally, reflection helps to integrate knowledge and solve problems more efficiently (Wilhelm, 2001).

Based on the three aforementioned definitions, it can be argued that in the context of inquiry learning, reflection is a metacognitive activity that supports the integration of theory and one's own experiences to learn from experience. It contains active reviewing and conceptualization about regulative and inquiry activities.



The assessment of learners' improvement in reflection skills can be determined by the levels that characterize its quality. There are several studies where levels of learners' reflection have been described (Bain, Ballantyne, & Packer, 1999; Bradley, 1995; Tsangaridou & O'Sullivan, 1994; McCollum, 1997; Moon, 1999, 2004; Leijen, Valtna, Leijen, & Pedaste, 2012). These levels are defined through specific activities. However, it is not clear how in the context of science education these activities could be facilitated to improve students' skills of reflection that have a positive effect on inquiry learning. Owing that only limited studies have focused on guiding students' reflection in the context of inquiry learning in science education (e.g. Pedaste et al., 2012; Ifenthaler & Lehmann, 2012) and a common framework for guiding reflection in this context is missing, a theoretical study with an aim of exploring guiding of students' reflection in various contexts of education was conducted. This theoretical study is based on a synthesis of the outcomes presented in several articles to provide a model of guided reflection in a technology-enhanced inquiry-learning context. This model would support learners in achieving a higher level of reflection. Consequently, it is aimed to answer two questions:

- Which activities of reflection are relevant in the technology-enhanced inquiry learning context?
- What guiding methods should be applied to support students' reflection in the context of technology-enhanced inquiry?

### Activities of Reflection

In order to provide an answer to the first question of the study, an analysis of literature was conducted. The analysis was mainly based on the information found about the levels (Bradley, 1995; Tsangaridou & O'Sullivan, 1994; McCollum, 1997; Moon, 1999, 2004; Leijen et al., 2012), phases (Korthagen, 1985, 1999; Korthagen, Kessels, Koster, Lagerwerf, & Wubbels, 2001), and thinking activities (Dekker-Groen, van der Schaaf, & Stokking, 2010) of reflection suggested by different authors, which all could be viewed as activities for improving reflection skills.

In Table 1, the reflection levels and phases, as well as reflection-related thinking activities of four groups of several authors (Bradley, 1995; Leijen et al., 2012; Korthagen 1985, 1999; Korthagen et al., 2001; Dekker-Groen et al., 2010) have been compared. Based on these, a list of reflection activities has been proposed.

**Table 1. Comparison of activities, levels, and phases of reflection.**

Levels according to Bradley (1995)	Levels according to Leijen, Valtna, Leijen, & Pedaste (2012)	Phases according to Korthagen (1985, 1999), Korthagen, Kessels, Koster, Lagerwerf, & Wubbels (2001)	Thinking activities according to Dekker-Groen, van der Schaaf, & Stokking (2010)	Reflection activities applied in the model developed in the current study
<b>Action</b>				
Gives examples of observed behaviours or characteristics	Description	Looking at or looking back	Describing	Describing
	Justification		Analysing	Justifying
Structuring				
			Explaining	



Levels according to Bradley (1995)	Levels according to Leijen, Valtna, Leijen, & Pedaste (2012)	Phases according to Korthagen (1985, 1999), Korthagen, Kessels, Koster, Lagerwerf, & Wubbels (2001)	Thinking activities according to Dekker-Groen, van der Schaaf, & Stokking (2010)	Reflection activities applied in the model developed in the current study
<b>Action</b>				
Provides a cogent critique from one perspective	Critique	Awareness of essential aspects	Evaluating	Evaluating
Views things from multiple perspectives	Discussion	Creation of alternative solutions or methods of action	Concluding	Discussing
			Attributing	
			Formulating intentions	
Trial				

Bradley (1995) divided the levels of reflection into three main types: 1) giving examples of observed behaviours or characteristics, 2) providing a cogent critique from one perspective, and 3) viewing things from multiple perspectives. He also used specific criteria for assessing those levels.

On the first level, the person tends to focus on just one aspect of the situation and uses unsupported personal beliefs as frequently as “hard” evidence. He also may acknowledge differences in perspectives but do not differentiate effectively among them. In addition, the person at this level gives examples of the observed characteristics of the setting but provides no insight into the reasons behind the observation; observations tend to become dimensional and conventional or unassimilated repetitions of what has been heard in class or from peers.

On the second level, the observations are fairly thorough and nuanced, although they tend not to be placed in a broader context. The person reflecting provides a cogent critique from one perspective but fails to see the broader system in which the aspect is embedded and other factors that may cause changes in the system. They use both unsupported personal beliefs and evidence, but in the beginning, they are not always able to differentiate between them. Additionally, the person at this level perceives legitimate differences of different viewpoints and demonstrates a preliminary ability to interpret evidence.

On the third and final level, the learner has the ability to view things from multiple perspectives, to observe several aspects of the situation, and to place them into particular context. The conflicting goals are perceived within and among the individuals involved in a situation, and it is recognized that the differences can be evaluated. It is also recognized that actions must be situation-dependent, and many of the factors that affect their choice are understood. The person can also make appropriate judgments based on reasoning and evidence.

Leijen et al. (2012) distinguished four hierarchical levels of reflection, which are shown in Figure 1. The reflection levels found are cumulative; therefore, the higher levels cannot be reached without passing the lower levels first. This work is a follow-up from Tsangaridou and O’Sullivan’s (1994) and McCollum’s (1997) classification of three reflection levels: describing, justification, and critique. Leijen et al. (2012) added to them the level of discussion that brings into focus the conceptualization of the experiences to plan future activities. This way of thinking can also be defined as one of the highest reflection levels.

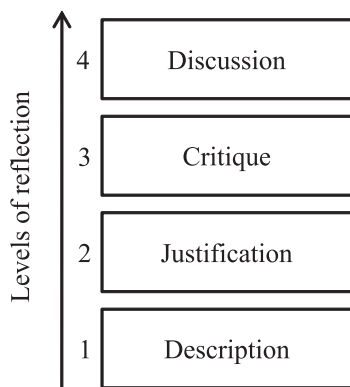
In Figure 1, the lowest level of reflection is description. From a pedagogical aspect, describing the learning experience is important in reflection. For example, during that learned phenomena, processes, their scale, their direction, and their speed of flow are characterized. Description also allows the bringing out of feelings and thoughts associated with learning experience.



The second level of reflection is justification, during which logic and justification skills are used. Using logic helps to derive previously unknown knowledge and organize thinking to create systems and relations and to reach conclusions.

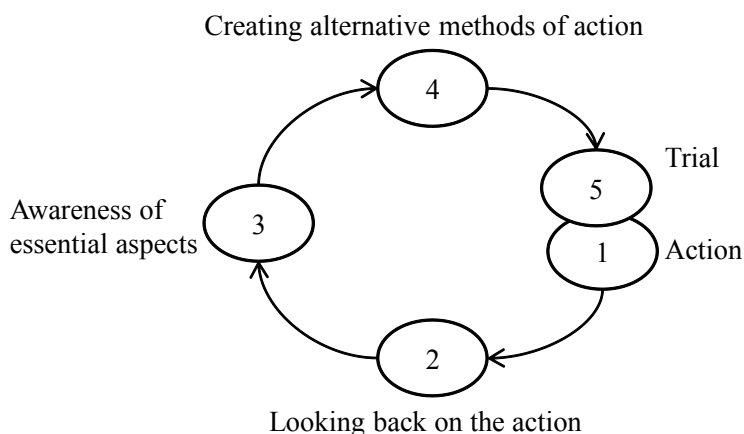
The third level of reflection is critique, which entails a comparison of experiences according to certain criteria. One possible way to do it is to let the pupils to compare the tasks they have completed with the correct solutions. This method helps pupils to clarify for themselves which mistakes they have made so they will not make them the next time.

The fourth and highest level of reflection, discussion, is future-oriented. On this level, an inner discussion with oneself takes place, during which appropriate methods and ways are found that can be used in similar situation in the future to reach the goal better.



**Figure 1: Levels of reflection (based on Leijen et al., 2012).**

Figure 2 depicts the spiral ALACT model developed by Korthagen (1985, 1999; Korthagen et al., 2001). The model distinguishes five phases of reflection: 1) action, 2) looking at or looking back, 3) awareness of essential aspects, 4) creation of alternative solutions or methods of action, and 5) trial. The last phase also forms the first phase of a new cycle. The model is derived from a framework for experimental learning and evaluated in studies (Korthagen, 1999), and it guides students through a succession of questions to give structure to their thinking process when they are reflecting on their experience (Bulman & Schutz, 2004).



**Figure 2: The ALACT model describing a process of reflection (Korthagen, 1985, 1999; Korthagen et al., 2001).**



According to Dekker-Groen et al. (2010), thinking activities that take place during students' reflection processes can be divided into eight different categories: describing, analysing, structuring, explaining, evaluating, concluding, attributing, and formulating intentions. Describing consists of precisely, systematically, and selectively telling or writing about a situation, experience, reasoning, or emotion that gives rise to the reflection. Analysing is checking and clarifying relevant aspects of the description, for instance, what the student and other persons did, thought, wanted, or felt. Structuring includes developing some structure to discover patterns or connections, for instance, by making categories or ordering things chronologically. Explaining embodies giving reasons for or causes of what happened or what the student did, thought, wanted, or felt in reaction to the situation or a personal drive or based on a reflex. Evaluating incorporates valuing or assessing a situation, experience, reasoning, or emotion by using certain criteria and norms or goals. Concluding is drawing conclusions about a situation, experience, reasoning, or emotion in relation to the students' own future thinking and/or acting. Attributing consists of attributing aspects or effects to yourself (internal attribution) and/or to things outside yourself (external attribution) and making it meaningful for other situations. Finally, formulating intentions involves considering what can be learned from the reflection and how it can be used in a new situation.

Based on the aforementioned, it can be said that the first activity of reflection is *describing* (see Table 1), during which looking back at the learning process and describing it occurs. A similar concept was used by McCollum (1997) and Tsangaridou and O'Sullivan (1994) as the first reflection level and in the study of Dekker-Groen et al. (2010) as the first thinking ability. Bradley's (1995) first level of reflection is *giving examples*, which resembles description since giving examples is one part of describing. Korthagen's (1985, 1999; Korthagen et al., 2001) model of reflection phases has *looking at or looking back* as the second phase, during which past actions are reviewed and which is also a part of describing.

The second activity of reflection is *justifying*, which includes explaining the flow of the learning process and looking for its causes. In addition, McCollum (1997) and Tsangaridou and O'Sullivan (1994) listed *justification* as their second level of reflection, during which an attempt is made to explain the flow of the learning process. As for the thinking activities of Dekker-Groen et al. (2010), the same level includes *analysing*, *structuring*, and *explaining*, all of which can be observed as parts of justification. Korthagen's second phase of reflection, *looking at or looking back*, does not necessarily need to be limited to descriptive review, but, during it, the causes of an activity can also be explained; thus, it is also tied to *justifying*.

Based on the comparison presented in Table 1, the third reflection activity is *evaluating*, during which the covered learning process is evaluated and looked at critically. Dekker-Groen et al. (2010) also had *evaluating* for their thinking activities at the same level. Bradley's (1995) second level of reflection was *providing a cogent critique from one perspective*, which is comparable to *critique*, the third level of reflection according to Tsangaridou and O'Sullivan (1994) and McCollum (1997). Both levels include critical thinking and, therefore, fit well with *evaluating*, the third activity of reflection that has been proposed for the model of the current study.

The last reflection activity is *discussing* (see Table 1), during which there is an attempt to improve the past learning process being learned from and learning strategies through thinking of the future. Korthagen's (1985, 1999) and Korthagen et al.'s (2001) fourth phase of reflection, *creation of alternative solutions or methods of action*, are also future-oriented activities, during which the understanding of what should be done differently next time to reach the goal is formed. Bradley's (1995) third level of reflection, *viewing things from multiple perspectives*, also guides the student to perceive the past learning process more widely and understand that there are additional methods to reach the goal. As for Dekker-Groen's thinking activities, *concluding*, *attributing*, and *formulating intentions*, all of which can be viewed as parts of discussion, are on the same level.

Korthagen (1985, 1999) and Korthagen et al. (2001) had two additional phases of reflection – *action* and *trial* – that should be not treated as reflection activities since, in these phases, looking back does not occur, but these activities are learning processes that will be reflected on later.





## Methods for Guiding Reflection

Effective reflection does not happen by itself, and, to make it happen, the pupils should be guided through different activities (e.g. Bain et al., 1999; Leijen et al., 2009a; White & Frederiksen, 2005). Of the various methods used for guiding, five are described in Table 2. These selected methods can also be applied in the context of technology-enhanced inquiry learning.

**Table 2. Different methods of guidance for reflection.**

Author(s)	Method of guidance for reflection	Short description
White & Frederiksen (2005)	Role-play	Pupils were embodied in different types of advisors (cognitive, social, metacognitive) and employed their metacognitive regulative skills through it, including the reflection skill.
Bain, Ballantyne, & Packer (1999)	Writing a diary	During an 11-week practice, students were asked to keep a diary, where they had to reflect on how their beliefs and practical experience changed with teaching.
De Vries (2004)	Writing a narrative	After learning, pupils had to describe their learning experience through a narrative, which is a way to present the past and previous experiences (Wertsch, 1998).
Aleven & Koedinger (2002)	Explanation	A computer programme was used, which guided pupils to explain how they solved the problem.
Smits, Sluijsmans, & Jochems (2009); Sööt & Leijen (2012)	Guiding questions	Questions were used that guided pupils through the five phases of the ALACT model (Korthagen 1985, 1999; Korthagen et al., 2001).

White and Frederiksen (2005) developed and studied pupils' reflection through the use of inquiry learning software. They used the program "Inquiry Island," which involved three types of advisors – cognitive, social, and metacognitive. The cognitive advisors were the theory manager, evidence manager, synthesis manager, and application manager. The social advisors were the collaboration manager, communication manager, and mediation manager. The metacognitive advisors were the planning manager, revision manager, and reflection manager. Pupils had the opportunity to embody different advisors and thereby give advice to others. Cognitive roles, among the easier ones, were picked first. Later, social roles were chosen, and, finally, pupils also had to try the roles of metacognitive advisors. In the roles of the planning manager, revision manager, or reflection manager, pupils had to use their metacognitive regulative skills, which White and Frederiksen (2005) listed as planning, observing, and reflection.

Reflection was also studied and developed by Bain et al. (1999) through the method of writing a diary. Similarly, De Vries (2004) employed a method of writing narratives. After completing a learning task, in her study, pupils had to describe their learning experience through a narrative, which is a way to present the past and previous experiences (Wertsch, 1998).

In addition, Aleven and Koedinger (2002) developed reflection through the explanation skill. To do that, they used a computer programme that guided pupils to explain how they solved the problem. They found that pupils who better described their activities for solving problems could also solve problems better.

Smits et al. (2009) and Sööt & Leijen (2012) guided students to reflect through different tasks and guiding questions. They used the ALACT model (Korthagen, 1985, 1999; Korthagen et al., 2001), which included five reflection phases: 1) acting and experiencing, 2) looking back on this action or experience, 3) awareness of essential aspects of the situation, 4) creating alternative methods of action, and 5) trial based on new alternatives. The task in the first phase was to analyse an action or experience. The students were asked what had happened, what they had wanted to pay particular attention to, and what they had wanted to try out. In the second phase, pupils had to specify an action or experience by asking



for the context, thinking, feeling, doing. Next, in the third phase, the students were to concretize learning goals by making them explicit. The guiding questions asked about the connections between the answers to the previous questions, the influence of the context as a whole, and what all of that meant to them. The fourth phase was about support through the development of alternatives and choices by answering questions about what alternatives they saw, what the advantages and disadvantages of those alternatives were, and what would they resolve the next time. In the fifth and final phase, the task was the selection of an appropriate context for the trial of the newly chosen learning goal together with the student. The guiding question of the final phase was to specify the context in which the pupils had to try out their newly chosen learning goal.

All the methods referred to here are applicable in guiding students toward better reflection in the context of technology-enhanced inquiry learning. However, the applicability of particular methods is often limited to specific activities of reflection. Therefore, there is a need for a model of guiding reflection for designing technology-enhanced learning environments for inquiry learning.

### Theoretical Model for Guiding Reflection

Reflection as a whole and its specific activities need guidance, as shown in the previous section. It can be argued that, to support particular activities, specific guiding methods (see e.g. Leijen, Lam, Wildschut, Simons, & Admiraal, 2009b) are more relevant due to the particular challenges related to certain activities. In the first reflection activity, pupils need to observe and describe their experiences from an objective perspective, as though they were the actions of another. Reaching this aim is challenging owing to the fact that pupils' perception of their own experience is often influenced by implicit and explicit knowledge and by feelings associated with a concrete experience. What pupils think or feel about an experience can differ from the actual practice, as already pointed out by Argyris & Schön (1974). Therefore, it seems insufficient to ask pupils to keep a diary or be engaged with narrative writing without detailed guiding questions that support pupils to take a more objective perspective on their experience.

The second reflection activity requires pupils to present analytical explanations for their actions. Similarly to the first activity, it can be challenging due to feelings associated with concrete experience or due to implicitly or explicitly kept preconceptions. Detailed guiding questions can be used to direct pupils' focus in the course of explaining and reasoning.

A major difficulty associated with the third reflection activity, evaluation, is that pupils tend to wait for the teacher to present evaluations instead of evaluating their experiences themselves (see e.g. Leijen et al., 2009b; Mountford & Rogers, 1996). In order to support self-assessment, pupils need to comprehend evaluation standards and the criteria representing these standards. Pupils can be provided with these criteria by their teachers. Another option is to implement peer-feedback activities for evaluation. Another difficulty associated with evaluation is that pupils tend to focus on the aspects that went wrong and ignore positive aspects. Guided questions for establishing the evaluation criteria and a role-play method that involve peer-feedback activities could be implemented to support this process of reflection.

In the course of the final activity of reflection, pupils should go beyond self-evaluation and discuss alternative solutions for changing their practice. Out-of-the-box thinking about one's experiences, and seeing alternatives, is a challenging task. To address this challenge, several authors have pointed out the potential of interaction with others (see e.g. Dewey, 1933; Moon, 1999; Moon, 2004; Leijen et al., 2012). Feedback enables individuals to share and learn from the perspectives of others on experiences and ideas, and (re)interpret and develop their own perspectives further. Therefore, peer feedback can help students move beyond the evaluation and explanation of an experience and consider alternatives, as also indicated by Moon (1999):

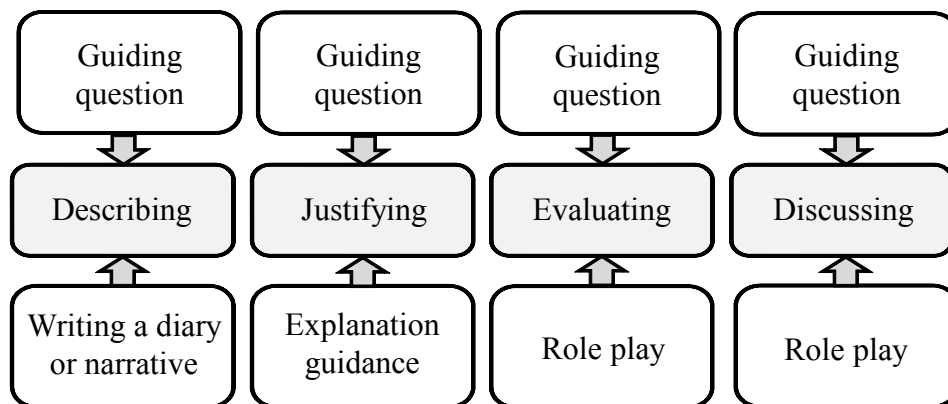
Working with others can facilitate learners to reflect and can deepen and broaden the quality of reflection so long as all the learners are engaged in the process. Another person can provide the free attention that facilitates reflection, ask challenging questions, notice and challenge blocks and emotional barriers in reflection. (p 172)





Based on the above, it can be suggested that the role-play method where students take different roles to provide alternative perspectives on a certain issue can be a useful method for guiding this activity of reflection. Similarly to other activities, guiding questions should be incorporated to the instruction in order to provide further support for students.

According to the above described review, a new model for guiding reflection and developing skills related to it can be proposed for the context of technology enhanced science education (see Figure 3).



**Figure 3: Theoretical model for guiding reflection activities in the context of science learning.**

In designing guidance on inquiry-related reflection activities in applying technology-enhanced learning in the context of science education, it can be presumed that adaptive guidance is more effective than guidance that applies all methods of reflection support in the case of all activities of reflection while the same has been the case in the context of inquiry learning (see Veermans, 2002). First, it can be assumed that each student should be provided with guidance for only one activity of reflection – it depends on the student's initial level of reflection (see the levels in Figure 1). For example, a student whose initial level of reflection is at the level of description (the first level) should be guided with methods that can train his/her skills of justifying (to achieve the second level of reflection – justification). In addition, the guidance should be adapted through the selection of appropriate guidance methods. For all activities, there are two available methods in the proposed model, and it should be clarified which students would benefit more from each of them. For example, one learner should be supported by guiding questions but another by explanation guidance. Furthermore, some learners may need two methods of guidance. However, in both cases, when selecting either the activities that will be guided or the method of guidance, the adaptive selection should decrease learners' cognitive load and help to achieve better learning outcomes due to the provision of more relevant guidance. The students' initial level of reflection can be clarified with guiding questions, which are associated with all activities of reflection.

## Conclusions

It can be concluded that in the context of technology-enhanced inquiry in science education, based on findings from different authors (Dewey, 1933; Boud et al., 1985; Davis, 2003; Lin et al., 1999), reflection can be defined as a metacognitive activity that supports the integration of theory and one's own experiences to learn from experience. In line with the definition, the general activities of reflection for inquiry-based and technology-enhanced science education are 1) describing, 2) justifying, 3) evaluating, and 4) discussing as derived from different studies (Bradley, 1995; Leijen



et al., 2012; Korthagen, 1985, 1999; Korthagen et al., 2001; Dekker-Groen et al., 2010). Reflection as a whole and its specific activities need guidance. As an outcome of this theoretical study, a new model for improving students' reflection skills was developed based on several previous studies (White & Frederiksen, 2005; Bain et al., 1999; De Vries, 2004; Aleven & Koedinger, 2002; Smits et al., 2009; Sööt & Leijen, 2012). A main principle of this model is that different reflection activities require somewhat different support because of the unique challenges related to these activities. Moreover, it is possible to propose that the principles of adaptive guidance (Veermanders, 2002) need to be applied in order to support the learning process of individual students. In brief, the theoretical relevance of the study consists in comparing conceptions, activities, and guidance practices of reflection from various fields of studies. The practical relevance of the study is concerned with the implications of the developed model in the context of inquiry-based and technology-enhanced science education for improving students' reflection skills.

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