Self-reflection, comparative reflection and analogical reflection in the framework of metacognitive modelling activities using the ModellingSpace technological environment

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ABSTRACT
The modern educational technological environments do not focus on the transmission of knowledge, but on the triggering of metacognitive functions. Reflection acts as a booster for metacognition. In this work, we present initially a review of the research on reflection in technological environments. Through the review and in combination with the benefits of analogical reasoning, we propose an alternative kind of reflection, the analogical reflection, instead of self-reflection and comparative reflection. Self-reflection is considered as someone’s reflection on his/her own actions. As comparative reflection, we consider the reflection on others’ actions. By the analogical reflection, we mean the reflection on analogies. Based on the analogical reflection, we outline our pilot research, which is a case study on three groups consisted of two students each. The students work collaboratively in the ModellingSpace technological environment. Our basic hypothesis is the following: In self-reflection, it is very possible that someone cannot recognise his/her own mistakes. In comparative reflection, this possibility is potentially reduced, because perhaps the others do not make the same mistakes. We estimate that this possibility is minimised when the analogical reflection is activated, because it is easier to recognise a strange behaviour in a familiar cognitive domain, where the normal behaviour is well known. Finally, we present briefly an instructional framework, in which students are asked to reason analogically and reflect on modelling activities, in order to exploit and improve their metacognitive skills.

KEYWORDS
Reflection, analogical reasoning, metacognition, modelling

INTRODUCTION
Analogical reasoning is a mental process by which learners adapt their knowledge from a familiar cognitive domain to an unfamiliar domain. Through the analogical reasoning, students exploit their own existed knowledge in the familiar domain in order to understand the studied domain. The two domains are similar in their structure and/or functionality, while students must be capable to analyse and compare them. The models that are created in the framework of analogical reasoning are called analogical models. The analogical system is called “source” while the system that is being studied is called “target”. One target may be related with sources from different domains (Meyer, 2002). For example, a computer network (target) could be represented by different analogs (sources), such as road network, rail network or post office. If a characteristic/function of the source shares similarities with the target, then the analogy is “positive”, while if the characteristic/function is opposite to the target then the analogy is “negative”. Negative analogies may generate misconceptions to students and, therefore, they must be clarified. If the characteristic/function of the source seems similar/opposite with one of the target, but is not actually similar/opposite, then the analogy is “neutral” (Harrison, 2002).
THE REFLECTION IN TECHNOLOGICAL LEARNING ENVIRONMENTS

Many researchers have studied the contribution of reflection in learning. Below, we present a review, focusing on the way that reflection arises in technological learning environments.

In educational artificial intelligence, the student model saves information about students’ actions. The past artificial intelligence systems used to hide the student model from the student. The modern ones, “Open Learner Modelling” (OLM), bring to light the student model. The student model can be visible to the system’s user for self-reflection, or to other users for comparative reflection.

W-ReTuDiS (Web-Reflective Tutorial Dialogue System, Tsaganou et al., 2004) is an OLM system that uses dialogues based on the student model and it is applicable for teaching history. The system asks questions to the students and then returns their answers, annotating the wrong ones or validating the right ones. The students may ask from the system for extra explanations. In such case, the system responds by setting up a dialog with the students, in order to pull the trigger of reflection. Another tutoring system is DIALOG (Tsovaltzi & Fiedler, 2003), which exploits the artificial intelligence algorithms to use natural language and reflection arises from Socratic dialogues.

Besides dialogues, concept maps support learning through reflection. Cimolino et al. (2003) proposed the Verified Concept Mapper (VCM) system as an innovative way of creating concept maps. The innovation is consisted in students’ verification about the concepts they deal with.

Van Joolingen et al. (2005) distinguished the reflection between “reflection-on-action” and “reflection-in-action”, considering that the reflection-on-action corresponds to the evaluation at the end of the activity, while the reflection-in-action is a kind of monitoring the activity’s progress. Manlove (2007) also used the distinction between reflection-on-action and reflection-in-action, as Schön (1991) had defined it. The reflection-on-action emerges from the requirement for summary and evaluation of the entire activity. On the other hand, by the reflection-in-action students monitor specific stages of the activity and reassign its progress.

White et al. (1999) used the SCI-WISE agent based software, in which each agent has its role, trying to accomplish specific targets. Such agents are the Planner, Collaborator, Assessor, Inventor and Analyser. Their inquiry activities followed the cycle: Question – Hypothesise – Investigate – Analyse – Model – Evaluate. At the beginning, a question about a phenomenon is given to the students, who make a hypothesis, for investigation. Then, they analyse the results and start modelling. Finally, the results’ evaluation accomplishes the cycle. At this last stage, students reflect on the entire activity, searching for their model’s limitations.

ANALOGICAL REFLECTION

At the reflection stage, educators ask the students to reflect on their own actions, in order to improve their metacognitive skills. As the students reflect, they reconsider their progress from the beginning and revise by appropriate scaffolding. If the students study an analogical model instead of the target domain, then the revision is more substantial, because they find out their errors through their own existent knowledge from the familiar source domain of the analogical model. The kinds of reflection, which appeared in the researches we reviewed above, are the self-reflection and the comparative reflection. We propose an alternative kind of reflection, the analogical reflection. Hence, we distinguish the reflection in three kinds (Figure 1), according to
where the students reflect on. First, in self-reflection, students reflect on their own actions (Schön, 1991). Second, in comparative reflection, students reflect on others’ actions (Elbers, 2003). Third, in analogical reflection, students reflect on analogies, collating their actions with the analogical model’s functions. During the collation, students are asked to correlate the source with the target.

![Figure 1. Kinds of reflection (a) self, (b) comparative, (c) analogical.](image)

Our basic hypothesis is the following: In self-reflection, it is very possible that someone cannot recognise his/her own mistakes. In comparative reflection, this possibility is potentially reduced, because perhaps the others do not make the same mistakes. We estimate that this possibility is minimised when the analogical reflection is activated, because it is easier to recognise a strange behaviour in a familiar domain, where the normal behaviour is well known.

By the analogical reflection, students exploit their correct perceptions in revising the incorrect ones. The idea for introducing and examine the analogical reflection came from the state of the art and, specifically, from the combination of the analogical reasoning with the comparative reflection:

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\text{Analogical Reasoning} \setminus \text{Comparative Reflection} \] \hspace{1cm} \text{Analogical Reflection}

**RESEARCH**

The scenario, which the students were dealing with, was the motion of a body moving towards the top of an inclined smooth plane. The body was shot by an initial impulse and then continued free. The aim of the scenario was the students to conclude to the Principle of Conservation of Mechanical Energy.

**Method**

According to the inquiry cycle of White et al (1999), we propose the following inquiry modelling activity, enriched with the intermediate stage analogical reflection. In White et al. (1999), the reflection took place at the Evaluation stage. In our research, we tried to pull the trigger of
reflection at the Analogical Reflection stage, while at the Evaluation stage students explore the limitations of their models, as they have revised at the previous stage.

**Question**: Which are the energy conversions, as a body moves towards the top of an inclined smooth plane?

**Hypothesis**: Decrease of speed $\Rightarrow$ Decrease of kinetic energy ($K$)

$\text{Increase of height } \Rightarrow \text{Increase of potential energy (U)}$

\{ $K \rightarrow U$ \}

**Investigation**: Study a simulation to discover the relations among the involved magnitudes.

**Analysis**: Study given graphs that describe the motion.

**Modelling**: Creation of a model in the educational, metacognition oriented, software ModellingSpace.

**Analogical Reflection**: Detection and description of the analogies between the created model and a given analogical model.

**Evaluation**: Detection of the created model’s limitations, through other conditions (e.g. rough instead of smooth plane). In such case, the model and the analogical model shall be reformed, in order to fit the new conditions. This is the new question, from which a new inquiry cycle opens.

Based on the above pattern we designed a pilot research, which is a case study on three groups consisted of two students each. The students worked collaboratively in the ModellingSpace. The target of our research was to study the contribution of analogical reflection in metacognition, compared with self-reflection and comparative reflection. Below, we outline the Modelling and the Analogical Reflection stages.

**Modelling stage**

The modelling activities took place in the ModellingSpace (Dimitracopoulou et al., 1999) technological environment. ModellingSpace has been designed and developed to support modelling based collaborative learning in a wide spectrum of domains (Science, Maths, Social science, Economic science). Some examples of Interaction Analysis tools, during and at the end of the activities, of the ModellingSpace are given below.

- History of messages.
- Indication of the active participant’s name (the one who acts on the common modelling workspace).
- Collaborative Activity Function (CAF) graph. It counts the number of messages per participant. The educator may choose any combination of participants and compare their activity.
- Hold-down key percentages per participant.
- Inserted entities and relations in the common workspace.
- Actions like insertions, deletions, messages.
- Complete history of messages.
- Playback video.

\{ During the activities \}

\{ At the end of the activities \}

![Figure 2. ModellingSpace’s interfaces. (a) Modelling and Communication workspace, (b) Metacognition workspace (Interaction Analysis tools).](image-url)
There are two workspaces (Figure 2). First, the Modelling and Communication workspace, where students design their models, supported with representation tools (simulation, graphs, tables), and communicate in a chat space (if students work collaboratively). The second one is the Metacognition workspace, where students utilise the Interaction Analysis tools.

**Analogical Reflection stage**
The reflection mode we chose was the reflection-on-action, hence, students were asked to reflect only at the end of the activities. Right after they had finished with the model design (Figure 2a) we provided them an analogical model (Figure 3), created in the ModellingSpace. That analog represents the water transfusion from one container to another. Its visualisation shows the water that goes out of the one container gets in the other one. Therefore, if a third container represents the total water in both containers, its water level should be constant.

![Figure 3. Analogical model in the ModellingSpace.](image)

The students of the first group (A) were not involved with analogical reasoning, because we wanted them to reflect on their own actions (self-reflection). The second group (B) had to reflect both on their actions and on the answers of group A (comparative reflection). To the third group (C), we provided the water transfusion analog, in order to reflect analogically. At first, we did not explained how the analog works and asked them to find out its functionality (the containers had no captions above). Then, we captioned the containers and explained the analog’s functionality. Namely, we explained how the analog “works” and which container corresponds with each type of energy (kinetic, potential and mechanical). By this way, group C reached the analogical reasoning through external scaffolding and then reflected analogically.

**Results**
At the end of the Modelling stage, we asked the students to reflect, answering a questionary form and then discussing with their teacher. The main target of the questionary was the argumentation of the created model by the students. In this pilot study, we tried to discover the difficulties in reflection combined with analogical reasoning, in order to design a respective tool. Therefore, we
did a qualitative analysis of the results. At the next research, which we are preparing, we will develop a quantitative measurement in order to test the tool (ART) we are designing.

The results showed that group A (self-reflection) had difficulties when documenting their model. The Interaction Analysis tools helped them to review what they had done, but they were unable to express why the model was working correctly. The only prove they mentioned was the energy-height graph, which was correct according to the theory (given at the beginning of the activities). For example, as they mentioned, “Our model is correct because its graph is as we expected according to the theoretical one. The kinetic energy is decreasing while the potential is increasing. The mechanical energy is constant”. On the other hand, group B was helped by the comments (right or wrong) of group A. At first they claimed, “We noticed that the as the body was moving upwards, the kinetic energy was decreasing while the potential was increasing”. Then, considering the answers of group A, group B went deeper in explanation, noticing “As the graph shows, the kinetic energy reduction is in every height equal to the potential energy increment. That’s why the mechanical energy remains constant”. Finally, group C appeared as the most accurate in their documentation. They explained exactly the mechanism of the energy conversion and mechanical energy conservation. In addition, they resembled their model with the water transfusion analog. As they described, “The water transfusion analog has similar functions with our model. The water is transfused from one container to another, like the kinetic energy is converted to potential”.

According to the results of group C, scaffolding is determinant for analogical reflection. Even group C documented correctly the energy conversion from kinetic to potential, however, they could not find out the analogy of the third container and, therefore, they did not conclude to the mechanical energy conservation. As they noticed, “the third container doesn’t do anything, it is stationary”. After we explained that the third container was representing the sum of the two other containers, the students responded, “So, this is like the mechanical energy! That’s why its level remains constant. Mechanical energy remains constant too”. Then, we captioned the three containers with the letters K, U and E, according to the kinetic, potential and mechanical energy.

To go deeper into reflection, we asked the students to guess what would happen, in point of energies, if friction were present (rough plane). Parts of the dialogues with each group were the following:

- Group A: “The body will stop earlier, hence the kinetic energy will end earlier.”
- Teacher: “Right. What about the potential and mechanical energy?”
- Group A: “At the highest point, the potential energy will be equal to the kinetic energy at the lowest point. The mechanical energy will be equal to the potential.”
- Teacher: “As you say, the only change is how fast the energy conversion will happen, right?”
- Group A: “... Yes...”

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- Group B: “Part of the kinetic energy will be converted to heat. Therefore, the mechanical energy will be less.”
- Teacher: “OK. Now, let’s have a look at the opinions of group A. What do you think? Are they right?”
- Group B: “Group A claimed: 1) The body will stop earlier. Yes, that’s true, we didn’t think about it. This also means that the energy conversion is faster now. 2) The mechanical energy is equal to the initial kinetic energy. This is wrong, because, part of the kinetic energy will be converted to heat.”
- Teacher: “So, the energy conversion will be faster and the mechanical energy will be decreasing.”
- Group B: “Yes, it will be decreasing until the body reach the highest point and stop.”

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- Group A: “The friction will cause mechanical energy reduction. Therefore, the body will stop at a lower point than before (smooth plane).”
- Teacher: “Right. Now, is the analog, which we gave you, still analogical to these new conditions? If no, how would you reform it to be analogical again?”
- Group C: “No, it’s not any more... The E container should be losing some water, as the water is transfused from the K container to the U container. Also, the same volume of water must run out of the K container, it won’t get into the U container.”
- Teacher: “Do you have any idea-trick how to do this?”
- Group C: “...”
- Teacher: “What about a hole somewhere high, but not highest, at the E container?”
- Group C: “... Yes!”
- Teacher: “I think we should make another hole at the K container. But where would you place it?”
- Group C: “... It should be at the lowest point; otherwise the K container won’t be empty completely!”

Group A could not find out the energy conversion, from mechanical to heat. They pointed only at the kinetic energy conversion rate, which was greater comparing to the smooth plane conditions. Group B, at first found out the mechanical energy reduction. After reflecting on the comments of group A, they also realised the kinetic energy conversion rate’s increment. Group C appeared again as the most accurate in their documentation, especially when scaffolding was present.

CONCLUSIONS

One of the basic subjects, which educational technology researchers study, is the components that enhance metacognitive skills. Analogical reasoning can enforce the reflection, as a booster of metacognition. In the analogical reasoning stage, students exploit their knowledge in a familiar domain (source), in order to understand an unfamiliar domain (target). The researches on reflection are based, mainly, on the dialogues between educator and students. The dialogues conclude questions about the progress of the students during an activity and about the validation of their results.

In most of researches, the technological environments are based on artificial intelligence using a student model, which is either opened (Tsaganou et al., 2004) or closed to the students. Reflection may arise from the students’ own ideas or from others’ (classmates, teachers, software) ideas (Manlove, 2007). Besides student model, other artificial intelligence tools boost the reflection, such as Socratic dialogues (Tsaganou et al., 2004; Tsovaltzis & Fiedler, 2003), software agents (White et al., 1999) and concept maps (Cimolino et al., 2003).

In our work, we presented briefly an instructional framework, in which students were asked to reason analogically and reflect on modelling activities, in order to exploit and improve their metacognitive skills. We introduced this kind of reflection and called it analogical reflection, discriminating it from self-reflection and comparative reflection. We assume that the students’ errors may be recognised easier by the analogical reflection than by the other two kinds of reflection. Our hypothesis is based on the state of the art and, specifically, on the composition of the benefits of the analogical reasoning and the comparative reflection.

According to the results of our pilot study, when students reason analogically, especially when proper scaffolding is present, they reach exceedingly the metacognition level through reflection (analogical reflection). Without scaffolding, students have difficulties in analogical reasoning. Thus, the major outcome is that there is a need for a scaffolding tool, assisting students to reason and reflect analogically.
In order to examine deeper our hypothesis and confirm our results, we are designing a software tool that supports analogical reflection. The tool is called ART (Analogical Reflection Tool, Figure 4) and is going to be a mapping tool, assisting students while reflecting analogically. Closing, we cite an Oscar Wilde’s quotation that accentuates the reflection’s value and, on the other hand, brings to light the handicap of self-reflection.

I like to hear myself talking. It is one of my greatest pleasures. I often have long conversations all by myself, and I am so clever that I sometimes do not understand a single word of what I am saying.

Oscar Wilde

Figure 4. ART’s splash screen.

REFERENCES


