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Assess Inquiry in Science, Technology and Mathematics Education

ASSISTME

Assessment method description for 'modeling in science' competence

Interactions on-the-fly on students' artifacts

Olia Tsivitanidou, Peter Labudde

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Lead participant	University of Applied Sciences and Arts Northwestern Switzerland FHNW School of Teacher Education Center for Science and Technology Education
Contact person	olia.tsivitanidou@fhnw.ch
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1. Summary

This description will provide ideas and inspiration on how to formatively assess the 'modeling competence' using the interactions on-the-fly method. There will be a description of what students and what the teacher are expected to do (their task) and how students' learning working process could be formatively assessed.

The "Interactions on-the-fly" assessment method certainly could be used in many fields of competence. Here the focus lies on the modeling competence in a paradigmatic example in Science.

Subject	• Modeling competence generally integrateable in all science subjects, in mathematics and technology education. • Paradigmatic example in Physics unit: particle nature of matter/ Boyle's law on a very basic level, 1 lesson of approximately 60 minutes.
School level	• Modeling competence integrateable in lower and secondary education level • Paradigmatic example in lower secondary school level
Assessed competences in the paradigmatic example	In modeling "Model construction (Stratford, Krajcik, & Soloway, 1998); model use (NRC, 2012); comparison between models (Penner, Giles, Lehrer, & Schauble, 1997); model revision (Schwarz & White, 2005) and model validation have been identified as the practices in which students can be usefully engaged during modelling" (taken from ASSIST-ME report D4.7)
Data collection about student learning	• Students' artifacts/ drawings: modeling air particles
Feedback method	• Interactions on-the-fly
Combination with summative assessment	• Description, guidelines and paradigmatic example for formative assessment, assessment criteria also usable for summative assessment.

Table 1. Main characteristics of assessment method "Interactions on-the-fly on students' models".

2. Modeling competence

Modeling is the process of constructing and using scientific models (Hestenes, 1987) and it is considered an integral part of science (NRC, 2012). Efforts to design modelling-based learning (MBL) instruction have relied on a theoretical framework about the modelling competence, which analyses its constituent components into two broad categories, namely *modelling practices and meta-knowledge* (figure 1). Underlying this framework is the idea that student modelling competence can emerge as a result of active participation in specific modelling practices and can be reinforced by meta-knowledge about models and modelling (2009). Model construction (Stratford, Krajcik, & Soloway, 1998); model use (NRC, 2012); comparison between models (Penner, Giles, Lehrer, & Schauble, 1997); model revision (Schwarz & White, 2005) and model validation have been identified as the practices in which students can be usefully engaged during modelling. Meta-knowledge, on the other hand, is analysed into the metacognitive knowledge about the modelling process; this refers to student ability to explicitly describe and reflect on the actual process of modelling, but also on the knowledge about the nature and the purpose of models (Schwarz & White, 2005). In other words, this framework posits what scientists do during modelling and at the same time what we want students to do, so as to be modelling competent.

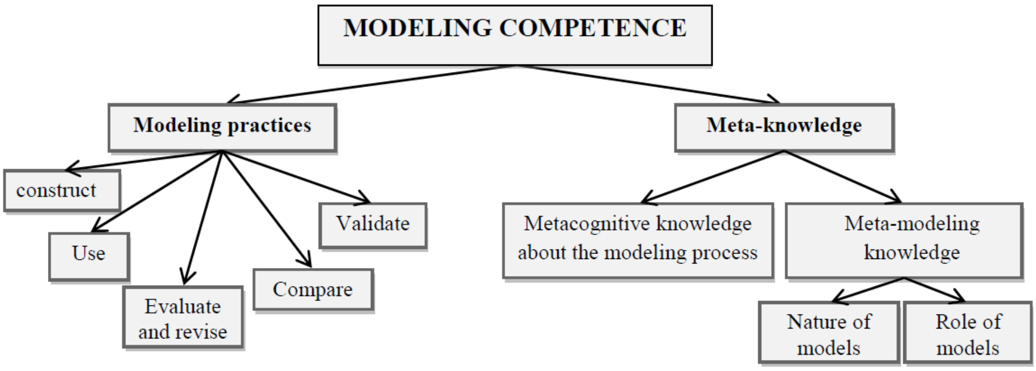

Figure 1: Modelling Competence Framework (Papaevripidou, Nicolaou, & Constantinou, 2014).

(Taken from ASSIST-ME report D4.7, p. 43)

3. Description of the assessment method with guidelines how to use it

The feedback method "interactions on-the-fly" describes informal formative feedback. This chapter will provide a description of the principle along with short summaries of different varieties.

Principle of interactions on-the-fly
"On-the-fly formative assessment arises when a "teachable moment" unexpectedly occurs, for example, when a teacher circulating and listening to the conversation among students in small groups overhears a students say that, as a consequence of her or his experiment, 'density is a property of the plastic block and I doesn't matter what the mass or volume is because the density stays the same for that kind of plastic.' The teacher recognizes the student's grasp of density and challenges the student with other materials to see if she or he and her or his group-mates can generalize the density idea." (Shavelson et al., 2008, p.300).

Complementary to 'on-the-fly formative assessment' is 'planned-for-interaction formative assessment'. Planned-for-interaction formative assessment includes marking (see chapter 6.2); peer- and self-assessment (see chapter 6.3); open classroom discussion and structured classroom dialogue (see chapter 6.4).

Varieties (non-exhaustive list)

Assessment conversation (Duschl, 2003; Duschl & Gitomer, 1997; Ruiz-Primo & Furtak, 2006)

Ruiz-Primo and Furtak (2004), Ruiz-Primo and Furtak (2006a), and Ruiz-Primo and Furtak (2006b), describe typical assessment conversations as a four-step cycle, where the teacher elicits a question, the student responds, the teacher recognizes the student's response, and then uses the information collected to student learning (see figure 3). 'Eliciting' means evoking, educing, bringing out, or developing. To describe a teacher’s actions as eliciting during informal formative assessment is thus an accurate description, as teachers are calling for a reaction, clarification, elaboration, or explanation from students. Typical examples of such eliciting questions include "Why do you think so?" or "What does that mean?" (Ruiz-Primo & Furtak, 2006b). During informal formative assessment, teachers must react on the fly by recognizing whether a student’s response is a scientifically accepted idea and then use the information from the response in a way that the general flow of the classroom narrative is not interrupted (e.g., calling students in the class to start a discussion, shaping students’ ideas).

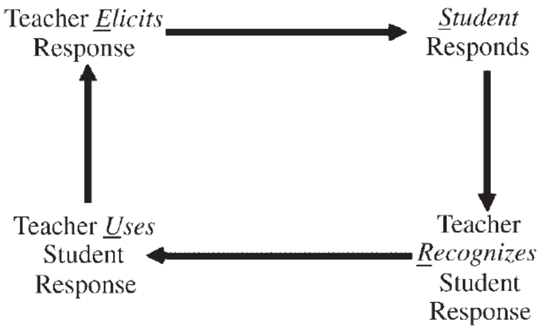

Figure 2: The ESRU model of informal formative assessment (taken from Ruiz-Primo & Furtak, 2006).

(Taken from ASSIST-ME report D4.7, p. 18-20)

4. Paradigmatic example: Physics, lower Secondary level

In this chapter, the use of a method for formatively assessing students' modeling competence will be illustrated by an example. The assessment method used in this paradigmatic example is interactions on-the-fly. The example is for a Physics unit in particle nature of matter (Boyle's law on a very basic level) at lower secondary education level and it is inspired by examples for classroom assessment in the book *Developing Assessments for the Next Generation Science Standards* (National Research Council. Developing Assessments for the Next Generation Science Standards. Washington, DC: The National Academies Press, 2014, p. 94-99).

The main learning objectives of this activity are the following: (1) the development of conceptual understanding of air particles, (2) the development of the modeling competence in order to explain the behavior of air and (3) the progress of oral argumentation during the whole class discussion while students try to support their reasoning. However, in this example the emphasis is placed on developing the modeling competence.

In this example, the students already have prior knowledge on the following aspects: (1) operationally defining matter as anything that takes up space and has mass, (2) considerate that gases are matter, (3) are aware of the possibility that air can be added to a container, even though it already seems full, and correspondingly air can be subtracted from a container without changing its size. The main objective of this activity is to inquire on how much supplementary matter can be forced into a space that already seems to be full and what exactly happens when the air spreads out to occupy more space.

The task begins with experimentation in groups of students. For this experiment a syringe is given to each group. Students are asked to gradually pull the plunger in and out of the syringe, placing their finger in the front part of the syringe (see figure 3) so as to explore the air pressure. It is expected that the students will notice the pressure against their fingers when pushing in the plunger and the resistance while they pull it out. Then they are probed to develop a model to explain what happens to the air so that the same amount of it can occupy the inner space of the syringe, regardless of the available volume of space. In particular, they are asked to construct drawings modeling this phenomenon, with the syringe in the three positions demonstrated in figure 3.

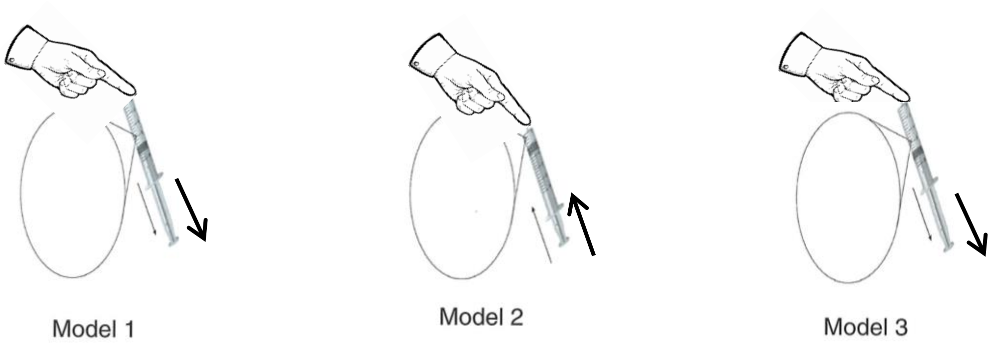
Model 1 Model 2 Model 3

Figure 3: Modeling the air inside the syringe (students should draw inside the circle how the air is modelled) in three situations of pulling in and out the plunger (Krajcik et al, 2013; as cited in National Research Council, 2014).

As soon as the students have accomplished their task, a whole class discussion follows. The objective of this discussion is to reach on a consensus on how to model the air behavior for explaining the experiment's observations but also to provide the opportunity to the teacher to formatively assess students' conceptual understanding and modeling skills, as well as their argumentation skills. In particular, the teacher asks the students to present their models and explain their reasoning.

Results of previous research using this teaching example with 6th grade students (Krajcik et al., 2008; Schwartz et al., 2008; as cited in National Research Council, 2014), revealed that the students while presenting their models, agreed that "air particles" should be present in their models (usually illustrated as dark dots) and that the particles are moving (illustrated by arrows attached to the dots). The results indicated an inconsistence in students' models in regard to what is between the particles. The scientifically accepted idea would be that there is an "*empty space between the moving particles, which allows them to move, either to become more densely packed or to spread apart*" (National Research Council, 2014, p. 96). Nevertheless, this possible inconsistence during a classroom discussion could be the starting point for the teacher for promoting students' thinking by asking them to elaborate their response (why, how?) and promote debating and discussing among students' ideas. The teacher could also draw by him/herself students' ideas eliciting their reactions and puzzling them with possible inconsistences in their responses. In general, the teacher could further elicit questions regarding the representational power of the students' models (presence of objects e.g. air particles, what is between the moving particles; variable quantities e.g. the plunge's position; processes e.g. plunger's motion in regard to the syringe, interactions e.g. movement of particles within the syringe), their interpretive power (the story/mechanism behind it) and its predictive power (what would have happened in an another relative problem e.g. Imagine a balloon full of air. You squeeze the balloon without any air escaping. Can you model the air behaviour inside the balloon before and after the squeeze?). The teacher could use all this information (students' arguments during the whole class discussion, written drawings of student's models) to formatively assess students' modeling competences and also make further instructional decisions. Finally, following the whole class discussion, the students could return in their groups and try to refine their models. The revised models could also be utilised by the teacher for assessment purposes.

5. Assessment criteria

The following table displays typical teacher's strategies for the different dimensions of the ESRU cycle (compare to the first chapter).

Eliciting	Recognizing	Using
Epistemic frameworks		
Teacher asks students to:	Teacher:	Teacher:
• Compare/contrast observations, data, or procedures	• Clarifies/Elaborates based on students' responses	• Promotes students' thinking by asking them to elaborate their responses (why, how)
• Use and apply known procedures	• Takes votes to acknowledge different students' ideas	• Compares/contrasts students' responses to acknowledges and discuss alternative explanations conceptions
• Make predictions/provide hypotheses	• Repeats/paraphrases students words	• Promotes debating and discussion among students' ideas/conceptions
• Interpret information, data, patterns	• Revoices students' words (incorporates students' contributions into the class conversation, summarizes what student said, acknowledge student contribution)	• Helps students to achieve consensus
• Provide evidence and examples	• Captures/displays students' responses/explanations	• Helps relate evidence to explanations
• Relate evidence and explanations		• Provides descriptive or helpful feedback
• Formulate scientific explanations		• Promotes making sense
• Evaluate quality of evidence		• Promotes exploration of students' own ideas
• Suggest hypothetical procedures or experimental plans		• Refers explicitly to the nature of science
• Compare/contrast others' ideas		• Makes connections to previous learning
• Check students' comprehension		
Conceptual structures		
Teacher asks students to:		
• Provide potential or actual definitions		
• Apply, relate, compare, contrast concepts		
• Compare/contrasts others' definitions or ideas		
• Check their comprehension		

Table 2: Typical teacher's strategies for the different dimensions of the ESRU cycle (Ruiz-Primo & Furtak, 2006).

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