PROCESS EVALUATION FOR INTEGRATED STEM

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Teaching integrated STEM in secondary schools requires a new teaching approach. STEM@school is a research project founded to develop such a new teaching approach, based on the following principles: Integration, problem-centred and cooperative learning, with explicit attention to research and design, and taking into account discipline specific educational research results. This approach requires an aligned assessment strategy. Since pupils work cooperatively on problems and the teacher becomes a coach, process skills have a more prominent place in the STEM-course. As assessment experts suggested, a list of necessary criteria for assessment is made and based on this list, three different assessment instruments are developed. These instruments are tested by teachers in secondary school and at university level. While applying, teachers made adaptations to the instrument in order to feel familiar and confident with the instrument. Questionnaires, discussions with teachers and filled in assessment instruments are used to gather the adaptations with motivation and the experience. This data will be discussed. Also the differences between the adaptations in the two settings will be illustrated. By providing this information, we answer the following two research questions: Are the developed assessment instruments valid, reliable and easy to use in classrooms? Does the setting influences the use of the assessment instruments?

Keywords: Integrated learning, assessment of competence, secondary school

INTEGRATED STEM

Although Flemish secondary school pupils acquire high scores on international science and mathematics tests (Vakgroep Onderwijskunde, 2015), they don't see the relevance and the application of these courses (Sjoberg & Schreiner, 2010). STEM@school is a four year research project unrolled in Flemish secondary schools targeting these problems by the development and implementation of an integrated STEM approach (Science, Technology, Engineering, Mathematics). Therefore learning materials were developed that focus on integration of the different STEM-components, are problem-centred, stimulate cooperative learning, pay explicit attention to inquiry and design based learning and take into account results from discipline specific educational research. These newly developed learning materials are implemented in a new STEM course in which pupils are challenged by a research or design problem. This problem can only be solved by implementing and integrating knowledge from the different STEM courses as well by following a research or design cycle (Wallin, Adawi, & Gold, 2017), although they should realize the path to the solution is not fixed (Banks & Barlex, 2014). By applying this approach, pupils are introduced to the relevance of the different course topics and the pillars of STEM (Riordáin, Johnston, & Walshe, 2016). To assess pupils' work in such a new setting, requires to rethink assessment. The development of an assessment instrument particularly suited for our teaching approach is the subject of this paper.

THE INSTRUMENTS FOR PROCESS EVALUATION

A first version of an assessment instrument was developed based on the available literature and setting of the STEM@school project (Goovaerts, De Cock, & Dehaene, 2016). This instrument has been a starting point for further development and specification. To validate the instrument, four experts with expertise in (process) evaluation were interviewed by the semi-structured interview technique of Emans (2002). Their most common feedback included lining up the desired competences of the pupils, making different instruments and less assessment by the teacher but more by the pupils. All experts indicated they experienced that teachers need some freedom in their assessment. In fact the assessment strategy should fit the teachers' approach and feel familiar to them.

Based on this feedback, the instrument was refined with the following criteria as a result:

- The desired competences listed are divided into four categories, as presented in Table 1, each with their own purpose.

Table 1: Desired competences of the pupils

Planning	The proposed planning is feasible in the time frame provided.
	The proposed intermediate steps have a logical order.
	The provided intermediate steps are relevant.
Teamwork	The discussions are conducted in a socially correct way.
	The discussions are conducted in a constructive way.
	The group works independently.
	The group asks for help when necessary.
	The group gets to work with comments of teachers and fellow students.
Adjustment of the planning	Pupils can tell in which phase of the planning they are right now.
	Pupils are able to indicate what needs to be adjusted in the planning.
	Pupils are able to indicate why the planning needs to be adapted.
	Pupils are able to indicate when they have decided to adjust the planning.
	Pupils already reflect enough during the process about possible improvements in the planning.
	Pupils can propose relevant and feasible improvements.
Results	Pupils can point the finger to what went good during the whole process.
	Pupils can point the finger to what went wrong during the whole process.
	Pupils can propose relevant and feasible improvements.
	Pupils are able to look critically at themselves.
	Pupils are able to look critically at others.
	Pupils are able to indicate how the different STEM-components were integrated.

- Based on these desired competences, three different assessment instruments are constructed, all based on the same criteria. Grading with the first instrument (Figure 3) forces the teacher to indicate for each group or pupil whether they possess the competence or not. The second variant (Figure 1) asks the teacher to situate the group or pupil on a continuum for every competence. The last instrument is a rubric (Figure 2), in which different competences are grouped and described at four different levels.

Criteria	Achieved
Draft planning	
The proposed planning is feasible in the time frame provided.	1
The proposed intermediate steps have a logical order.	0
The provided intermediate steps are relevant.	0

Figure 3: Checking criteria

Draft planning	Inadequate	Sufficient	Good	Excelent
Realistic planning	The order of the proposed planning is not right.	The proposed planning is feasible in the provided timeframe, but the	Most of the planning is realistic, still for some steps the timeframe needs to	The proposed planning is feasible in time frame and order.
Completeness	The planning contains none or irrelavant intermediate steps.	Some intermediate steps in the planning are relavant, others aren't.	The planning contains most of the necessary steps in order to reach the goal.	The planning contains all necessary steps in order to reach the goal.

Figure 2: Rubric

Draft planning		
The proposed planning is definitely not feasible in the time frame provided. 0	The proposed intermediate steps have absolutely no logical order. 0	None of the provided intermediate steps are relevant. 0
The proposed planning is completely feasible in the time frame provided. 100	The proposed intermediate steps have a perfect logical order. 100	All provided intermediate steps are relevant. 100

1: Continuum

- The desired freedom is handed to the teachers through a lot of choices. First of all, they can choose themselves which assessment instrument they will use. Secondly, they can decide on their own whether they will grade the pupils individually or in group, or let the pupils grade their own group. Finally, the teachers can make improvements to the instrument.

THE APPLICATION OF THE ASSESSMENT INSTRUMENTS

The proposed assessment instruments are implemented in two different settings. Within STEM@school the instruments are used to assess pupils following the newly designed curriculum in secondary school. Secondly, in the University of Leuven the assessment is implemented as evaluation method in an engineering course called Problem Solving and Design. These two cases are described more detailed below.

Within the STEM@school curriculum

Thirty schools, participating in the STEM@school project, test the new curriculum and teaching approach. In each school, a teacher team consisting of approximately two teachers per grade, implements the new curriculum. Since STEM@school addresses the 3rd and 4th year of secondary education, and some teachers teach in both years, approximately 100 teachers are involved in the project. This enhances a tremendous amount of teachers testing the assessment instruments. In this setting, the pupils are assessed with this instrument during the STEM course, which is taught three hours a week. Strikingly, teachers want to perform the assessment themselves and do not want to leave the assessment process to the pupils, although this contains more workload for the teacher. Some classes are given in co-teaching, therefore pupils are assessed by two different graders. Moreover, these graders are in a constant dialogue about the pupils and the assessment instrument. In addition, the teachers involved in STEM@school received several trainings about the teaching method and assessment instrument. As previous research proves (Aschbacher & Alonzo, 2006), this dialogue and training is crucial in grading equally. Since this setting provides data about two teachers assessing the same pupils, it is also valuable in order to calculate the reliability of the assessment instruments.

In an engineering course at a university level

In the engineering education at university level, the course named “problem solving and design” implements similar principles as STEM@school. Therefore, the developed assessment instruments are appropriate for usage in this situation, although the assessment system is quite different. In this case, 93 students follow the course, divided in teams of 10 to 11 students. Each team has three coaches consisting of a professor and two teaching assistants. These three coaches differ for every team. This setting makes it more difficult to grade equally over the different teams. After many iterations and adaptations based on the feedback of the coaches, the final assessment instrument was a well written rubric, although the team started with the system of checking for each competence whether the group possessed it or not.

DISCUSSION AND CONCLUSION

First communication with teachers proves that the proposed assessment instrument is usable for evaluating integrated STEM courses in different settings. Depending on the setting and the teachers, adaptations are crucial in order to facilitate teachers to use the assessment instrument. This implies that one ideal assessment instrument is an Utopia. However, providing a strong base with a rich set of criteria to assess, different options and support, creates an opportunity to adapt the assessment strategy of the teachers into a more suitable assessment strategy. In the presentation detailed results on filled in questionnaires, discussions adaptations will be discussed.

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