FaSMEd-Case Study Report for Science Lesson

by Biology Education Department, University of Duisburg-Essen

I. Portfolio of evidence

1. Tasks and resources used

The following case study was conducted with developed materials of the FaSMEd toolkit. These developed materials are made for formative assessment in classroom use, where the students are given an open problem and get encouraged to solve this by designing their own experiment (and creating a graph based on their measured results). For this concept there were two possible applications developed for use in class: If the concept is used as a teacher diagnosis, the teacher acts as a consultant when problems arise. He diagnoses potential problems and stimulates the learning process during the experimental process. Suggestions for questions and prompts which the teacher can use to help with individual problems and issued were developed for each context. If the students work on their task autonomously, they are working with the self-diagnosis materials, where they will be offered a variety of context-sensitive aid cards (called “Good to know” (GTK) cards), which help with individual difficulties problems and provide further information. Therefor the students diagnose their own difficulties in individual or partner work independently with diagnostic cards and select an appropriate referred GTK aid card with content-bound support and solutions. Furthermore the students have access to definition cards which illustrate and explain used definitions on the diagnosis and GTK aid cards. If the students understand the problem, definition or mistake they can continue on the following diagnosis card.

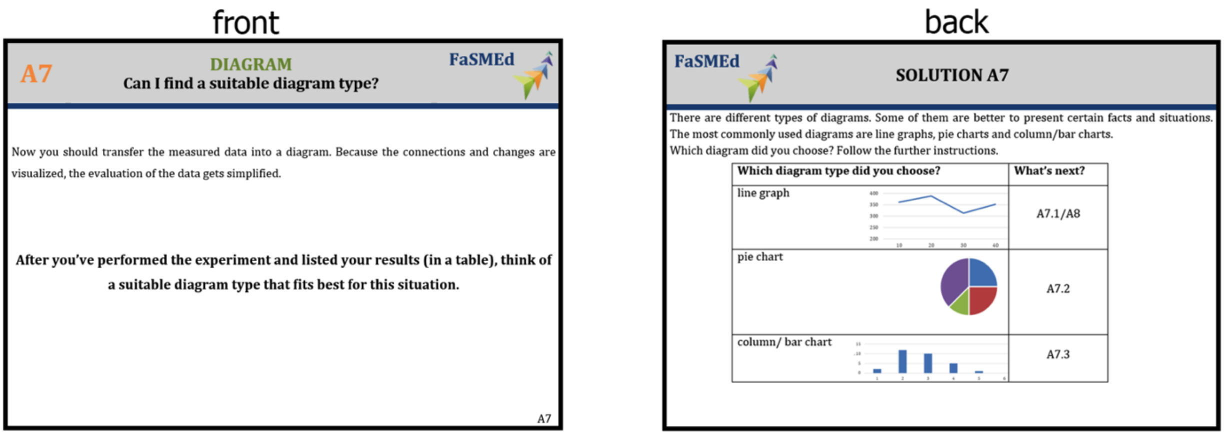

Figure : exemplary diagnostic card

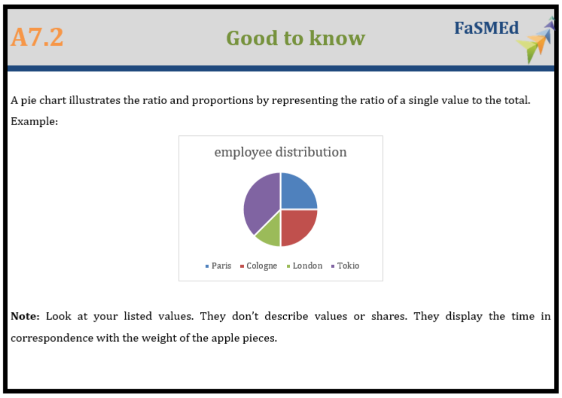

Figure : exemplary GTK card

This set of cards was developed for both paper based and digital use. When the teacher decides to use the paper based material the students have to look on the given card for a reference to the next card. In the digital version the students use a mobile or tablet computer (e.g. iPad) and select their problem or choice directly on the current card where they are directed to the next card.

Each material for a given context was developed with the following guideline: For each context we searched for a science experiment which can be performed by the students on their own and with given materials from the school or the students' home. For this experiment typical mistakes in planning and performing an experiment (and creating a graph) were derived based on literature and teachers' experience. Afterwards diagnostic cards were designed which guide through the experimental steps and the natural scientific way to acquire knowledge. These cards were linked to GTK cards which illustrate typical mistakes. Afterwards the developed materials were given several teachers for further optimization and testing.

The used context for this case study was the evaporation protection in which the students plan, perform, and record an experiment to find out “Who has the juiciest apple?”. Therefore they examine in a student-related context the morphological and physiological adaptions against evaporation of fruits in general and apples in particular. The students plan independently a suitable experiment including the creation of a proper scientific hypothesis and the evaluation of the results by creating a diagram. Afterwards they can conclude that the apple skin and the low surface-to-volume ratio ensure less water evaporation.

The developed materials aim for the following educational goals, based on the German curriculum in North Rhine-Westphalia for the subject biology:

The students can …

(Experiment)

- plan, structure and communicate their work alone or in a team

- develop questions that can be answered through biological knowledge and studies

- perform and protocol simple quantitative experiments and studies develop hypotheses, plan appropriate studies and experiments for validation, perform them in compliance with safety and environmental aspects and evaluate them with reference to the hypotheses

(Graph)

- document and present the progress and result of their work appropriately to the situation and audience by using graphs

- illustrate data adequately with mathematical design possibilities

(Evaluation)

- interpret and explain data as well as trends and draw appropriate conclusions

Figure : Educational goals

These educational goals are composed for the (german) forms 7 to 9 for the students in the age from 11 to 15. Because of this classification and the advice of the contributing teachers the case study was performed in form 7 with 12 to 13 year old students. The materials were developed to be used regardless of any previous or following lessons so the implementation focus was one lesson. On the following pages the developed worksheet and the mind map overview of the self-diagnostic material are constituted.

(Resources: developed material for „Who has the juiciest apple?“: worksheet, teacher manual, deck of cards)

Who has the juiciest apple?

The students of the seventh class are doing a school excursion in the mountains. Bahri and Sandra got wrapped apples as supplies from their mothers. Bahri doesn't like the bitter skin so his apple is already peeled. Sandras' mother however has cut him his peeled apple into bite-sized pieces.

During the day the temperature rises to 35°C in the shade. Who is going to have the juiciest apple in the afternoon?

Task:

Formulate a hypothesis for the stated problem. Afterwards plan an experiment that verifies your hypothesis. Also name what you have to observe and note during the experiment.

The following **materials** are available:

2 apples, knifes, cutting boards, stop-watches, 1 scale, 2 petri dishes, 1 hair dryer (or a drying cabinet)

Write down your results in a trial protocol (including setup, procedure, monitoring and interpretation) and display them in an appropriate diagram of your choice. You may note especially the significance of the size of the apple surface.

Accomplish your goal:
Additional help and instructions can be found on the „Good to know" cards:

First pay attention to the headlines on the front of the cards displaying the individual task steps. The back of the cards show appropriate help and instructions that explain and illustrate associated knowledge. Use the cards only if you are stuck or unsure about how to continue.

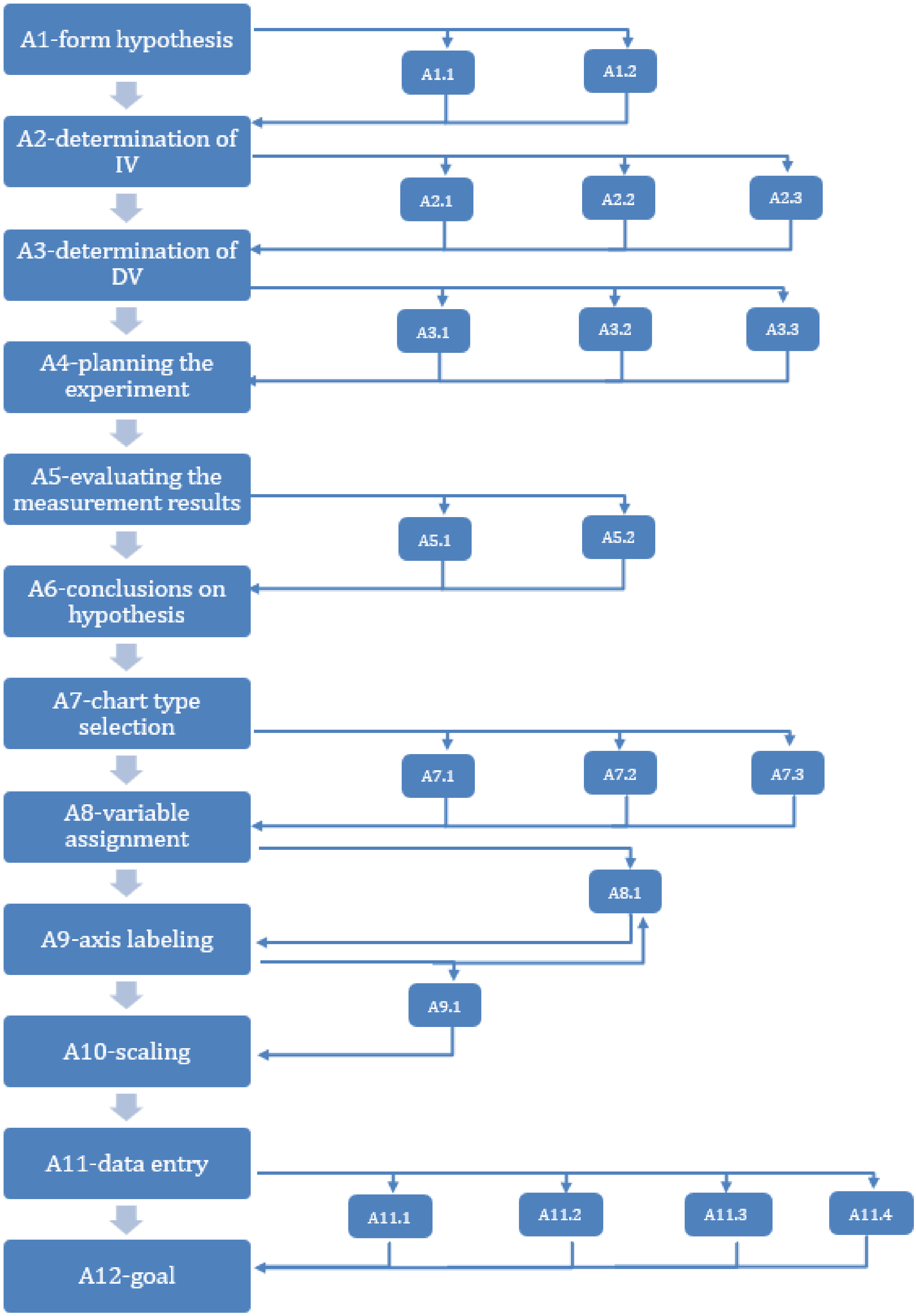

Figure : mind map of the self-diagnostic material

2. Work with teachers

The work with the teachers consisted of one general preliminary meeting for all contributing teachers and individual specific meetings for the case study in particular. All sessions were organized by the project members of the university. Eligible schools and teachers were asked via E-Mail. All interested teachers were invited to participate at the general preliminary meeting at the university which was hold in December 2014 and took about two hours. Ten teachers were present at this meeting. The meeting was hold to present FaSMEd, get first feedback for the developed material drafts and make arrangements for the case study with interested teachers. After the greeting the university project leaders gave information about FaSMEd in general, its purpose and the toolkit by using a digital presentation in front of the teacher group. Afterwards first drafts of the developed materials were shown and the possible use of several technologies were explicated. Also the general conditions for the participation in the case study were mentioned. After a short coffee break the teachers got the chance to test the developed materials in groups for usage in class. For this purpose the teachers were asked to put themselves in the position of a "difficult student" and make first drafts of a possible lesson planning for this material. Every teacher was given a questionnaire to write down critical comments considering content and feasibility in class. The group work was complimented by an exchange in plenary. The questionnaires and written teacher comments were collected and used for the further development of the materials.

For the case study realization the university members contacted the participants if they were interested to take part in the case study. The outcome of this was a case study arrangement with two teachers at one school. These two teachers work collectively in two separate grades in the same form (7), develop materials and plan the lesson contents together.

After this agreement with the teachers, further meetings followed. All meetings were held at the school of the contributing teacher by request. After contact via phone and e-mail the teachers and the university project members met at school to discuss formative assessment and arrange the schedule as well as material and tool usage. A short digital presentation and a layout plan was used for this purpose. Furthermore the observation protocol was explained for use during classroom testing. Both teachers decided to use the same resources in the same form. Due to the nature of the developed materials there was no need that the teachers had to plan anything for the case study lesson. This fact was considered very positively by the teachers in the conclusion interview. The teacher were also asked to choose between the paper based and the digital version. Both decided to use the digital version to gain more attention and motivation by the students and to manage the diagnostic and GTK cards more clearly and easily. The teachers asked the project members of the university to take over the introduction in the testing lesson to introduce the digital tool use. When the material was tested in each classroom the teacher worked autonomously with the observation protocol for one lesson. The communication between teacher and university partner was limited to organization during this lesson. Two weeks later each teacher was interviewed for one hour by using the interview guide. In this context we will report on the teachers and her lesson.

3. Framework reference

Regarding the three dimensional FaSMEd framework this material takes an account of several elements of three dimensions which distinguish technologically enhanced formative assessment. This framework is divided into the dimensions *assessors*, *strategies* and *functionality of technology* and displayed hereafter. Elements found in this case study concept have been inked in grey.

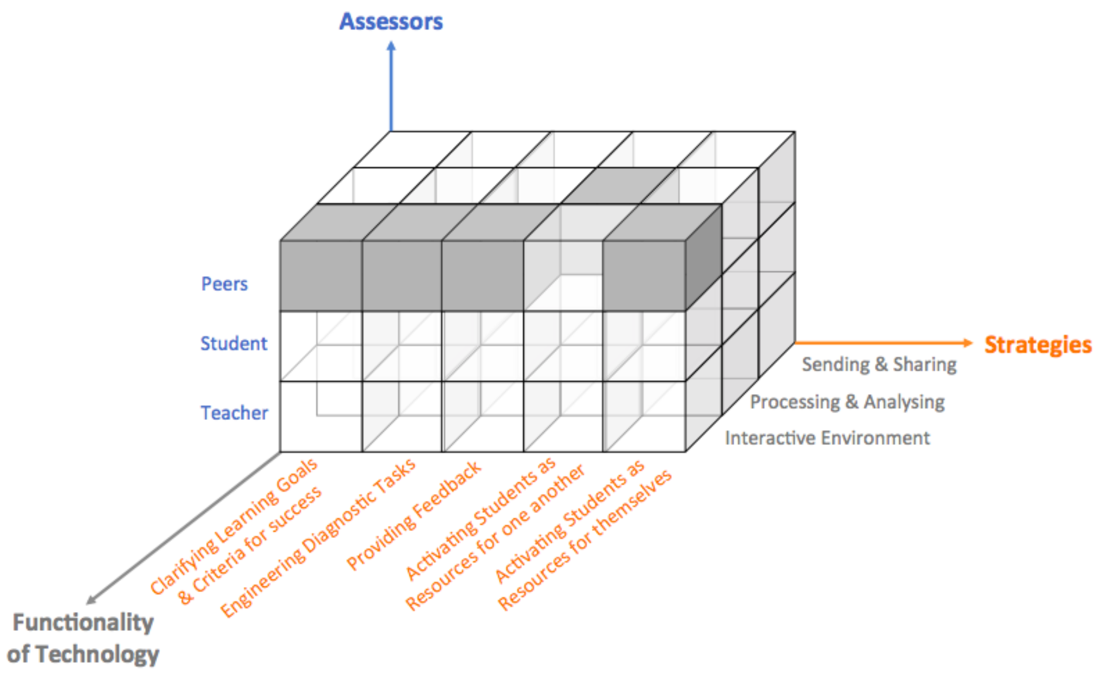

Figure : three dimensional framework with identified elements for this case study

Because the participating teacher decided that the students should work autonomously in groups with the self-diagnosis materials and digital tools this case study focuses on the category *peers* within the dimension of assessors. The developed materials were adapted for the used digital technology to enable an interactive use. The material as an *interactive environment* fulfills four formative strategies: On the one hand the material is used for *clarifying learning goals and criteria* for success because the students try to achieve the specific learning goal for the particular experimental step in group work, which is shown on the first page of each diagnostic card. Afterwards they check together if their approaches match with the learning goal criteria displayed on the respective second diagnostic card. Also the developed self-*diagnostic tool should elicit evidence of student understanding*: If the groups' approach matches with the learning goal, the students get linked to the next diagnostic card. If they have problems or don't know how to continue they can access several GTK-cards for each experimental step. Afterwards they get redirected to the previous diagnostic card. With the information and hints from these GTK-cards they can extend their own knowledge and try to fulfill the task respectively the specific learning goal (otherwise they can choose another GTK-card). The GTK-cards *provide feedback that moves learners forward* as the students get feedback via the diagnostic tool in terms of explanations, examples, hints and definitions. These details are customized for the individual problem and don't contain any solutions. The use of the digital diagnostic tool is voluntary; students can always work on the task without any help. Even if the students can use the tool for every experimental step the texts encourages them to answer the questions on their own. Therefore this concept is also *activating students as resources for themselve*s.

On the other hand the concept initiates also *processing and analyzing* to *activate students as resources for each other*: During group work the students can ask group members besides the digital tool. Especially the experiment implementation is designed and posed to be executed in cooperation. According to this the digital tool is in fact giving hints and explanations but nevertheless the group interaction promotes productivity.

4. Classroom teaching

According to the interview guide the teacher was asked questions in the teacher interview by one university project member. This interview was realized after testing in class. The conversation was recorded using a voice recorder.

The interviewed teacher is female and has been teaching for 1.5 years at this school. So far she has only been teaching at this school. She has completed the university education with the state examination (master degree equivalent qualification) following a 1.5 year school internship. At the school she is contributing in a working group called *fostering diversity* which is all about the consideration of heterogeneity at school and implementation of suitable methods. Also she operates as chairwoman in the expert conference for the subjects English and Biology. In her past teaching practice she has been using technology like computers, smart boards, and a small number of portable tablet computers (iPads). She said that there are not enough devices for each individual so the pupils have to form larger groups in class regularly. In the interview she emphasized the advantages that the students get easily motivated and the contents can be displayed in a more compact way. Especially when the pupils work with the technology on their own there are differences in the use of technology based on the knowledge of this technology: Pupils who are not so familiar with the use of the technology need more time to get used to the working method. In context of formative assessment the teacher talked about the working group *fostering diversity* where she already tested the implementation in various lessons. In subject English she already used formative aligned materials in class. According to this she emphasized that she would like to use formative materials in biology too if there would be any developed material. In general she said that this type of assessment is getting more and more important and that there is a need for an adjusted concept.

"Without diagnosing anything, you can't just really help the students. It should be something that you do by the way the whole time. But therefor it is important to have an adjusted concept." [Teacher quote]

On the other hand her concerns are the preparations needed for this and the time consuming implementation in class, which is not yet intended in the teachers' timeline so far.

Considering important features of teaching and the personal opinion about effective teaching strategies the interviewed teacher explained that she doesn't prefer one teaching style but a mixture of different teachings styles and methods which depend on the class, the content and the lesson goal. Open lessons where students can work independently and problem orientated lessons where students elaborate a certain problem were considered very effective. All in all she attaches importance to high students' activity and the possibility that each student gets what they need. Therefor methods and contents should be adjusted to different levels and student arrangements (such as working alone, with a partner or in groups) should vary. From the pupils perspective the teacher suggests that the lesson should be exciting and contain at least one experiment. The students want to perform the experiment on their own- try something new. In this context she underlines that students have to be slowed down in some lessons because they would neglect things like the experiment protocol otherwise. In science the students want to know how to gain new insights along a practical way in particular. She said when she is teaching science that problem orientated and differentiated lessons are especially useful. To deal with heterogeneity in the class she wants to consider the pupils' individual needs by using support system in class (such as helping your neighbor), using differentiated material and aid cards to match low and high achievers level. She emphasized that mistakes have to be corrected in the long term when students make mistakes. In the short the mistakes are left in a discussion and only corrected at the end to avoid students' demotivation. Mostly the classmates correct the mistakes directly afterwards.

5. Lessons

School and Class in general

The case study was conducted in a *Gesamtschule* in Krefeld, Germany in subject Science in cooperation with the University Duisburg-Essen. Based on the teachers' choice the material "Who has the juiciest apple?" was used in the digital version with tablet computers (iPads). This school is situated in a suburban area in the Ruhr area of North Rhine-Westphalia in Germany. The school type *Gesamtschule* is a secondary state school (and comprehensive school equivalent) which offers the students the possibility to absolve any possible graduation without any previous selection. Within this school type the students can attend to different classes based on their ability in the specific subject. About 450 students attend and 40 teachers work at the school. The school itself was founded 2013 as a result of an amalgamation of two schools which both accommodate the school rooms now. Therefor school life takes place at two locations; following forms are extended each year. At the moment the age of the attending pupils ranges from 10 to 14. Besides mixed gender and ethnicity the comprehensive school affiliates students with special needs and disabilities. To enable students working with digital technologies the school provides an internet connection, classrooms with smart boards, computer rooms, and ten tablet computers (iPads). In context of formative assessment the school has founded a working group called *fostering diversity* where all forms of assessment which consider the heterogeneity are being discussed. Furthermore the school cooperates with research projects and scientific institutions like a local environmental center and a local technology and science center for schools.

The class which took part in the case study was established for the compulsory optional subject science in grade seven. The 17 attending students were between 12 and 14 years old (12 male and 5 female) while 30 percent of them had a migration background. Because of the voluntariness of the class the students are very interested in science and characterized by their commitment and good cooperation (based on the teacher observation protocol and teacher interview). In addition these students are only being taught within this constellation in this class.

Lesson

The testing lesson took place on November 31, 2015, from 9:50 to 11:30. This time period was due to the double lesson structure of the timetable at this school. The classroom observation was conducted with an observation protocol which both teacher and university project member used to document the lesson. The protocol itself was discussed with all project members and teachers to ensure joint understanding of the observed aspect. Based on the needed information for evaluating and writing the case study the protocol was divided into six segments: At first the observer should register *general information* and *conditions* for the observed lesson. During the lesson the observers were asked to comment on the *handling with the material* and the *interaction* of all involved (students, teachers). After the lesson the segments *reflection of the lesson* and *further comments* should be filled out.

17 students attended the lesson which was about planning, performing and recording an experiment ("Who has the juiciest apple?") about evaporation protection. The lesson structure was predetermined by the chosen material, the teacher didn't has to plan anything further. In general the lesson was divided into two segments: At first the university project members introduced themselves and the project FaSMEd with its intention, participants, and the significance of the current lesson. Afterwards the lesson procedure was outlined by highlighting that the students have to read the text and tasks at first, plan and perform an experiment afterwards and represent their logged data in a diagram at the end. It was also emphasized that they will have the possibility to work completely on their own or use the given digital tablet computers (iPads), which guides them through the experimental steps. Therefor the use of the digital tablet computer was presented in plenary. The path guidance and the procedure when using the digital materials were presented visually. Also diagnostic, GTK and the definition cards were introduced and explained how to get there. The students were told that they can work on the task until 11.20. At the end it was also emphasized that all questions can be answered within the group and with the given materials and tools. The students were asked to avoid questioning the teacher and the project member for this purpose. With exception of technical questions and problems that could asked. Before starting with the task the students were asked to form groups of two or three people so that

the whole class was divided into six groups. The experiment material was already placed ready before the lesson on each group table. After this introduction the working phase started, which took the major time of the lesson. In this phase the pupils worked autonomously in groups in their individual learning pace with the given materials and tools as described earlier. Ten minutes prior the end of the lesson the pupils were asked to clean up their tables, put away the materials, and answer the questionnaires.

Hereafter the observed work with the materials and the interactions between students and teacher are explained: The general working methods of the pupils was characterized by high activity: The individual groups worked most of the time concentrated on the given task in which every pupil was integrated. Only a few off topic talks and activities were observed (the hair dryer was used for example to irritate other group members) [observation]. It appeared that these talks and activities never stopped or hindered the group work. Except one admonition at the end of the lesson the teacher never intervened these activities [observation]. The overall work behavior within the group was motivated: The students specified, that they reassigned the tasks within the experiment (for example time measuring, peeling apples, observation, taking notes …) [pupil interview]. The volume level in class was decent; the teacher commented that the level was just like in any other lesson with experiments. Only in the experimental phase of execution the hair dryers caused a higher volume level. The students handled the digital tablet computers with care, one pupil got a small cutting damage when he peeled the apple [observation].

The groups behave differently using the given tools: After the introduction and the reading of the worksheet in plenary some groups started by using the digital tool directly. Among these only a few followed the instructions step by step, read the diagnostic cards carefully and discussed possible answers with the group (unidirectional sequence of cards). Most groups didn’t read every text on the diagnostic cards, continued directly to the GTK refers and used the possible answers and GTK cards to design their experiment. This working method was characterized by a multidirectional choice of cards, whereby they often went back and forth. Other groups started immediately with the experiment execution without using the digital tool after they reassigned roles in their group. All of these groups had to restart and repeat the experiment after they compared their experimental approaches with other groups and/or used the digital tool after some time. While these groups where always the fastest at first, their need for repeating the experiment caused them running out of time at the end of the lesson. It could be observed that all these groups used the tablet computer more frequently after they discovered their discrepancies which was not primarily intended. All in all the diagnostic cards weren't read completely in most of the observed groups but used to get to the GTK cards [observation]. This observation is underlined by the pupils' answers in the questionnaire: 33 percent stated, that they used the diagnostic cards but 80 percent said that they used the GTK cards [questionnaire]. The students pointed out, that they used the definition cards often, and had the impression that they were especially helpful for the experimental design [pupil interview]. The teacher used the material in this lesson only to aid the students when problems arose, so they could work independently with the material. Within the group the students' interaction was mostly concentrated on agreements and discussions about the experimental design and execution. No conflicts could be observed, but instead the students pointed to the digital aid when a group member had a question or made something "wrong". Between students and teacher was only little interaction: The teacher walked around and only talked with the group when questions were posed. Thereby the teachers' feedback was restricted to referring to the digital tool and material; no solutions were given. At the beginning there were some questions regarding terms and GTK usage. In that case the teacher referred only to the definition cards and illustrated the link in the digital material as well. When this note was given the groups continued working alone [observation]. The teacher pointed out that the students generally don't hesitate to ask questions. After they got used to the new type of work in this lesson the questions were limited within the group [teacher interview]. According to the questionnaire 35 percent said that they needed assistance from the teacher [questionnaire]. Regarding the time it can be said that except one group all groups finished the experimental execution as well as the diagram construction. This other group completed the execution after they had to start over with the experimental design (this group started straight with the experiment execution and did not use the digital tool).

In the following reflection all (100 percent [questionnaire]) students expressed that they had fun in this lesson and especially liked working with the digital tool and within groups [pupil interview]. The teacher hold that the students were concentrated and motivated for the whole lesson [teacher interview].

6. Pupil perceptions

Pupils' perceptions about science and its learning in general, formative assessment and technologies in particular and the specific case study lesson were determined by evaluating the q-sorting, the group interview and two pupil questionnaires. The q-sorting and the group interview were performed at the same day of the case study in the following lesson. Therefor the participating students were released from their usual classes. Three male and one female pupils were chosen randomly from each student group at the end of the case study lesson. The q-sorting took approximately 15 minutes and started with a short introduction of the q-sorting procedure. Therefor the students were asked to sort the statements to four categories representing degrees of agreement from *disagree completely* to *agree fully*. These categories were displayed on a small piece of paper on a big table. Smiley faces on each papers visualized the category (see picture). For the q-sorting the statements were given to the pupils, read aloud by one of them and then discussed in group. The order of the given statements was randomized by the university project members before. When the students came to an agreement about the assignment of the statement to a degree of agreement, the statements where places under the chosen degree. All in all 23 statements were discussed and assigned to an agreed category within the given time.

Agree Completely	Rather Agree	Rather Disagree	Disagree completely
Science is something everybody can learn.	When we use technology during the mathematics/science lesson, I quickly understand if and why I am wrong.	Using technology in science is exciting.	I do not like using technology in science.
With the technology I can find out myself whether I can do the tasks in science.	I feel that I can do/understand science.	I like exams because I can see how I am doing.	Science hepls us to see/understand our surroundings.
Science is important.	Exams are boring.	Using technology in science is frustrating.	If I do not understand something, I work with it until I get it right.
Science makes sense in the real world.	The use of technologies during the mathematics/science lesson enable me to better understand the objectives of the activities.	I do not like science	I am nervous in science lessons.
	When we work together, it makes sense to use the technology.	Our teacher uses the technology to find out where we are in our learning/with our exercises	Science is difficult
	Science means exploring and experimenting.	Science is used in everyday live.	One is born with scientific understanding.
			For me, the technology does not work, or help.

Figure : Translated and digitized evaluation of q-sorting

After the q-sorting a 20 minute group interview followed where the pupils were asked several questions according to the given case study guidelines. All questions were asked by the university project members and answered by any pupil in plenary.

Two additional questionnaires were designed to determine the opinion of every participating pupil in class. On one questionnaire the pupils were asked to make notes of their opinion about respectively the lesson as a whole, the used technology and the content of the experiment. The second sheet was conceptualized as a yes/no questionnaire. Eleven questions were asked with the selectable answers *yes* and *no*. The questions concerned aspects like the material comprehensibleness and the technology use. These two questionnaires were handed in class after the lesson was finished.

The results of the range of collection methods were used to justify pupils' perceptions and opinions. The corresponding resources for each argument are quoted in brackets.

Q-Sorting was used to determine pupils' perceptions regarding science and its learning. The participating students think of science as an easy but very important subject which nearly everybody can learn if they are interested. Science is characterized by a concrete relation to life. Contradictions regarding assignment and oral discussions were found when they talked about the possibility to perceive the environment with science: While they assigned "Science helps us to see/understand our surroundings" to strong rejection they often emphasized the use of science as a functional, life-relating subject. Through the evaluation the presumption can be established that the verb "see" was interpreted as a visual process and not the perception.

"*Actually it's not really helping. You can see things better, for example with trees, so you know what tree this is. But you can perceive the nature without too, you really don't need science for that.*" [Pupil quote]

Regarding the subject science the pupils expressed that they like this subject and understand nearly everything. In the lessons they are not nervous at all and ask the teacher for help if they need any. They sorted the statement "I like exams because I can see how I am doing" to *rather disagree* but emphasized in their discussion the need of exams and the advantage that you can see how well you proceed in the subject after you get the exams back [q-sorting, pupil interview].

The students also like using digital tools (87 percent [questionnaire]) but expressed that they are aware that it's not a solution for everything and a good teacher lecture can be as good, too. Also they declined that digital tools are exciting and expressed that they are used to these type of tools in everyday life in the present time (83 percent don't have any problems by using digital tools [questionnaire]). When the questioned pupils work with digital tools in science they always know how to use them. The pupils stated that their teacher only uses digital tools rarely. [Q-sorting, pupil interview]

In context of learning science with technology the students emphasized that the overall experiment was difficult but the clear contents on the digital tool helped them a lot with the experiment design and execution [pupil interview]. In general they expressed the advantage that you don't have to ask the teacher the whole time when working with such kind of digital material [pupil interview]. In contrast to common digital materials the contents were adjusted to the specific experiment whereupon the students could concentrate on the content and not on the search for appropriate answers [pupil interview]. 93 percent would prefer this material towards usual lessons [questionnaire].

Regarding this particular FaSMEd lesson the advantages were the new experience with digital tools, the self-diagnostic work,and the group work. The pupils said that they already knew helping cards and digital tools but do not have experienced the combination, which was new and helping in context of independent work [questionnaire, student interview]. 92 percent wouldn’t have liked to work on the tasks alone [questionnaire]! These advantages were named by five to seven students respectively. The following disadvantages were named by one person a time: One pupil said that he didn’t like that he had to cut the apple and got cut, one each has disliked the division of labor within the group and the independence work [questionnaire].

II. Discussion

In the following observation protocols, pupil interviews and questionnaires were used to discuss material development and case study implementation. All in all the developed materials and tools were accepted very well by both students and teachers. The pupils said that they enjoyed working with the digital material as a new experience [questionnaire, pupil interview]. They emphasized the independence of work and the possibility to get individual answers based on the individual experiment [pupil interview]. 87 percent said that the content was easy to understand whereby 53 percent evaluated the tasks as difficult [questionnaire]. Teachers told in the interview, that the material handling was simple and clear. Regarding the teachers opinion some texts were too long or contained complex phrases which needed more explanations by various diagnostic cards [teacher interview]. Some difficulties were expressed regarding the graph construction (especially time intervals and comparison between the different experimental approaches).

For further material development these arguments and observed problems can be used to improve the material: Textual passages will be reduced, images and figures will be added to enhance understanding and complex phrases will be simplified where possible. Because of observations in class motoric skills (apple peeling) and the use of the weight should be guided and clarified. This could be implemented by using additional GTK-cards, videos or introductory explanations. To simplify the possibility to go back or read cards again, the digital navigation will be simplified by adding links to the overview guide. The case study lesson revealed that the participating students weren't practiced in writing protocols for experiments, whereupon they needed more time for writing. Therefor a pre-structured experimental protocol worksheet can be designed for handing in class.

The case study execution took place without any unexpected problems. Nevertheless the observations and experiences from the participating persons lead to improvement suggestions: Working with the used digital tools could be practiced before material testing in class to ensure safe handling and avoid time consuming explanations in front of the class or within the groups. Besides the pre-structured experimental protocol the material could be extended with suggested evaluations and discussion for use in the following lesson as the developed concept needs about 90 minutes and leaves no room for plenary evaluation and discussion.

III. Conclusion

With this concept the students work independently with the digital material; the teachers assist the student groups when questions arise. The digital tool processes the individual formative assessment data and links to respective cards with aids, tips or examples based on the chosen answer. The students get feedback about their learning pathways any time via the tablet computer. After the group work the teachers discuss the created experimental protocol and graph to ensure a consent reflection within class. This raises issues for the teachers regarding feedback about the pupils' learning pathways: Because the pupils use the digital tools independently to detect misunderstandings the teacher can't reproduce individual pupil understanding. They only have the possibility to get snapshots about individual success or problems as they go through the class and observes the pupils instead. They also have to trust the students in working with this kind of method because the digital materials give them the possibility to go back, forth and skip the aid cards to the next experimental step without ever developing or thinking about own ideas. Therefor this self-diagnostic-concept gives them the opportunity to make a critical study of their own thoughts.

This case study was performed to evaluate self-diagnostic formative assessment material. All in all both students and teacher emphasized that the digital tool supplemented the material by adding interactivity which in turn enabled self-diagnostic assessment. Interactivity, formative assessment as well as self-diagnostics work well together: On the one hand students got the possibility to name individual conceptions in a small environment. In this context they got the space to make mistakes and develop ideas without supervising. The students also felt personally addressed because the content adapted to the individual learning pathway, which in turn motivated them in the exercise. This was also conductive for the formative assessment because the students could identify individual conceptions instead of general global conceptions.

IV. Appendix

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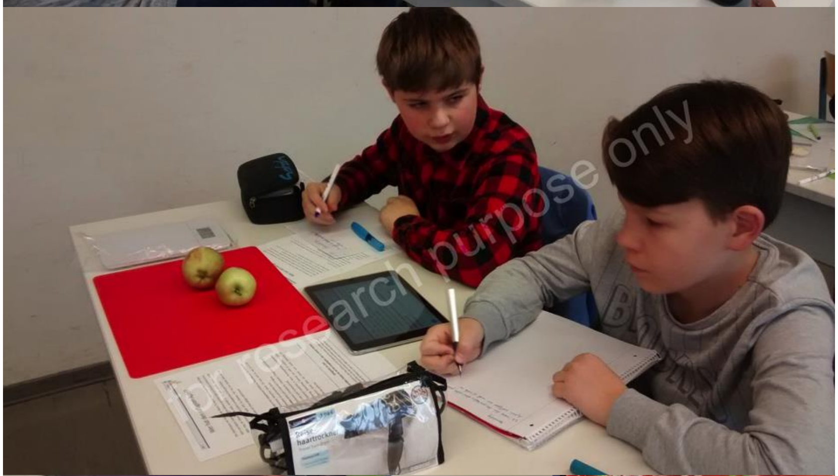
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