Next-Lab

Next Generation Stakeholders and Next Level Ecosystem for Collaborative Science Education with Online Labs

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Deliverable 3.1

Specifications, mock-ups and/or prototypes of 21st century apps, self- and peer assessment apps, ePortfolio, and modelling app

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Executive Summary

WP3 in Next-Lab is the work package in which, next to the apps that already existed in Go-Lab, new (or re-designed) apps are developed to empower learners. More specifically, apps will be developed for supporting a selected set of 21st century skills, self- and peer assessment, keeping an ePortfolio, and learning by modelling. The current deliverable collects and presents the initial specifications, mock-ups, and early prototypes concerning the 21st century apps, the self- and peer assessment apps, the ePortfolio, and the modelling app. The goal is to cover all aspects of WP3 apart from Task 3.5 "Labs and apps" for which a separate deliverable (D3.2) will be available by the end of 2017.

As shown in this deliverable, the development of the different apps follows different paces. Initially this deliverable would focus on specifications and mock-ups showing early prototypes. For the apps for 21st century apps we have chosen to focus on apps for collaboration, cooperation, and discussion and apps for reflection/critical thinking. These apps are in an early stage of development or idea forming. The apps for peer-assessment, the ePortfolio, and the modelling tool are in a more advanced stage of development than originally planned but also these apps, as is to be expected at this stage of the project, are still in need of further user testing and additional refinements.

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1. Introduction

WP3 in Next-Lab is the work package that is labelled "Empowering Learners". In WP3 we work on apps that support students in the learning process. This concerns, compared to what was existing in Go-Lab, new learning processes such as additional 21st century skills (the inquiry process itself already contained a number of 21st century skills), self- and peer assessment, keeping track of learning results in an ePortfolio, and learning by modelling. These learning tasks are supported by apps (new apps or existing aps that are adapted) or in some cases by additional features of ILSs or teacher support. A final task in WP3 concerns the identification, adaptation, or development of labs that are specifically suited for primary education and the adaptation (where necessary) of existing apps for younger children. This younger age being a new target group for Go-Lab in the Next-Lab project.

This deliverable is the first in a series of seven deliverables that will present the requirements for, specifications of, and the release of a series of apps for supporting students in their learning process. This current deliverable collects and presents the initial specifications, mock-ups, and early prototypes of the 21st century apps, the self- and peer assessment app, the ePortfolio, and the modelling app. It covers all aspects of WP3 apart from Task 3.5 "Labs and apps" for which a separate deliverable (D3.2) will be available by the end of 2017.

As this deliverable shows the development of the different apps follow different paces. Initially this deliverable would focus on specifications and mock-ups showing early prototypes only when possible. This is certainly true for the 21st century apps presented. These apps in many cases still need to be developed. Prototypes that are being presented of 21st century apps were sometimes designed in related projects and need to be adapted, extended and made stable in Next-Lab which requires a series of additional testing and developments. Other apps, the peer-assessment app, ePortfolio, and modelling tool are already in a more advanced stage than planned, but still needing further user testing and additional developments. Two apps, SpeakUp and GoModel, are already available at Golabz. Part of the testing is done in participatory design sessions as carried out in Task 4.4 (see Next-Lab deliverable D4.1 for the already performed participatory design sessions with some of the development presented in the current deliverable).

2. 21st Century Apps

The 21st century apps in Next-Lab are planned to support and foster students' 21st century skills. These skills are seen as pivotal for a well-equipped workforce and should therefore be an important aspect of the students' curriculum, preparing them for being part of the future labour market (Commision of the European Communities, 2008). The support for acquiring 21st century skills within the Golabz ecosystem will be realised through a combination of adaptations of existing Go-Lab apps and newly created apps.

There is much discussion on what constitutes 21st century skills, in other words what skills do people need, apart from being a domain expert, to be successful citizens and workers in the coming age. In the first section that follows we will very briefly summarize this discussion and select the skills that, in first instance, will be in the focus of the Next-Lab developments. Then, for each of the selected skills, a section is devoted on how support for the acquisition of these skills can be realized through Go-Lab apps.

2.1 What Are 21st Century Skills?

The term "21st century skills" was introduced to indicate that in the modern society new skills are needed to adequately function as a citizen and that jobs are being offered that require different skills than the jobs in the 20th century (and before). 21st century jobs need more than just domain knowledge and skills (although this is still at the heart of each profession) but in addition employees should be able to collaborate, be creative, be critical and reflective, etc. These skills have often been denoted as 21st century skills (e.g., Binkley et al., 2012; Dede, 2010). Of course, these skills have always been important, but the need for these skills has increased as they are expected to play an important role in future jobs. Combining these 21st century skills with domain specific knowledge and skills should lead to what is called T-shaped professionals who in Wikipedia are defined as:

> "The concept of **T-shaped skills** or **T-shaped persons** is a metaphor used in job recruitment to describe the abilities of persons in the workforce. The vertical bar on the *T* represents the depth of related skills and expertise in a single field, whereas the horizontal bar is the ability to collaborate across disciplines with experts in other areas and to apply knowledge in areas of expertise other than one's own."

In a recent synthesis, Thijs, Fisser, and van der Hoeven (2014) (see also, Vermeulen & Vrieling, 2017) summarized 21st century skills into: creativity, critical thinking, problem solving, communication, collaboration, cooperation, discussion, digital literacy, social and cultural skills, and metacognition and self-regulation[1]. Some of these skills are more related to citizenship, such as cultural skills, and others are general and implicitly included in Go-Lab as an approach (e.g., digital skills that are practiced by learning with an ILS per se) or that inherently interwoven with parts of the inquiry cycle that is followed in an ILS (e.g., problem solving that occurs in, for example, experiment design). In Next-Lab we will, in first instance, therefore, focus on the following 21st century skills:

- Collaboration, cooperation, and discussion
- Reflection (critical thinking)

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[1]   Admittedly, in the literature, there are very often also other skills being mentioned as 21st century skills and there are many classifications, but we believe this list of skills gives a comprehensive view on the existing frameworks for 21st century skills.

- Metacognition and self-regulation
- Creativity

In Next-Lab we will extend the Go-Lab ecosystem in such a way that the exercising of the four skills mentioned above is enabled and that students can learn about these skills and practice them. The extension of the Go-Lab ecosystem may concern the building of a new app, or the reconstruction or adaptation of an existing app. Even, sometimes, a combination of apps or teacher activities may be necessary to practice and acquire a specific 21st century skill.

21st century skills is a concept in development and many individuals and organization have their own view on what skills are needed for being professionally or personally successful in the 21st century. The 21st century skills we focus on and for which we will develop or extend apps are additional to 21st century skills that are inherently present in Go-Lab. For example, in the 2012 report on Science Education Standards (National Research Council, 2012) skills alike asking questions, developing and using models, analysing and interpreting data are mentioned as key skills in a science and engineering curriculum and these skills are related to 21st century skills. Since these skills are already part of Go-Lab and that we have already developed apps for supporting these activities we will not further detail those in the current deliverable, but instead focus on 21st century skills that may not be inherently part of an inquiry cycle.

There is a debate if 21st century skills should be learned "stand-alone" or in the context of a domain. In the Next-Lab project we follow the latter approach and we design learning experiences for students in which we combine learning of 21st century skills always with specific domain (science) related skills and knowledge.

Due to the complexity of the skills, the 21st century apps in Next-Lab will follow a longer development path than the other apps that are presented in this deliverable. In the following sections, we will work out how we plan the support for the development of 21st century skills in the Go-Lab ecosystem. In doing so, we have outlined more specific plans for the first two sets of 21st century skills, collaboration, cooperation, and discussion and reflection (critical thinking). Metacognition and creativity will follow later in the project.

2.2   Collaboration and Cooperation

Students who work together to reach a certain goal are collaborating or cooperating. Collaboration and cooperation share that in both approaches students need to exchange information and have to tune their own outcomes of subtasks with those of fellow students. They differ in respect to the division of labor. In collaborative learning students, all perform the same task together and each student should reach the outcome of the task individually. In cooperative learning, different tasks are divided among group members and all individual outcomes should be brought together to reach one overarching goal. This means that in collaborative learning, basically, each student performs the same task, in cooperative learning there is a set of tasks that are divided over the students (Roschelle & Teasley, 1995).

Review studies and meta-analyses on collaborative and cooperative learning consistently show the virtues of these approaches, both for cognitive (Hattie & Donoghue, 2016; Lou, Abrami, & d'Apollonia, 2001; Lou et al., 1996) and social outcomes (Slavin, 2015). The mechanisms through which collaborative and cooperative learning work mainly concern the fact that students need to explain subject matter to their peers and also receive explanations from their peers. Collaboration and cooperation are seen as important skills by themselves

as well because these skills are needed in professional life too, and, as it is argued, this is even of more importance in the 21st century as it was before. In collaborative and cooperative learning students learn how to take the stance of other students, weight the differences between these stances and their own standpoint, need to explain these differences and find bridges. For professional life, these are very important skills.

An important aspect of successful collaboration or cooperation, however, is also the grouping of the students (homogenously or heterogeneously). Putting students together, who are too different in cognitive ability, may not work well, and in any case specific arrangements should be made (van Dijk, Eysink, & de Jong, 2016).

In order to be able to engage in collaborative and cooperative learning, and even more importantly, to learn how to perform the skills that are involved in this approach, in the Next-Lab context, the following conditions should be met:

- Students should be able to communicate (through for example a chat facility)
- Students should be able to share interfaces and work on shared objects (labs, apps)
- Student should infer themselves or be taught rules on how to effectively collaborate and cooperate
- Student should be aware of their collaboration or cooperation skills and think on how to improve them.

In addition, teachers should be able to compose groups, such that an optimal composition of students' knowledge, attitudes and personalities is within a collaborating or cooperating group of students. The next sections describe an example of how this can be realized in Next-Lab.

2.2.1 Collaboration and Cooperation, the Tw1st Example

The example we present here comes from the Tw1st project[2]. In this project, apps for 21st century skills are designed specifically for students who follow vocational tracks. These students become electricians, car mechanics, and the like. These professions require students to work with very practical challenges and solve problems with a direct impact on every-day life. In the Tw1st project students work with the Go-Lab electricity lab (see http://www.golabz.eu/lab/electrical-circuit-lab) and a newly developed lab on electricity transport (to be posted on Golabz soon). In the electricity transport lab students get different roles, e.g., looking at costs or efficiency of the network, etc.) and then they have to design together the best electricity network. In Tw1st students therefore work cooperatively (they have different tasks/ perspectives and need to combine their experiences to reach the best solution).

2.2.2 Communication and object sharing

In Tw1st students can share apps and the lab synchronously. Figure 1 displays the electricity transport lab that is shared between students within one group, together with the current version of the chat. In Tw1st it was decided to have separated chats (one per lab and one for each app) instead of one overall chat that encompasses all labs and apps.

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2 The Tw1st Education project is sponsored by NWO and Tech Your Future as project 409-15-209 and is a collaborative project between the University of Twente, Saxion University of Applied Sciences and four schools for Vocational training. The UT researchers are Elise Eshuis, Judith ter Vrugte, Anjo Anjewierden, and Ton de Jong.

Figure 1. Chat facility with the (shared) electricity transport lab

2.2.3 Teaching Collaboration and Cooperation Rules

Collaboration and cooperation are skills (like all other skills) that need to be learned. In the Tw1st project a set of good collaboration/cooperation rules (the RIDE rules - see Figure 2) from Saab, Van Joolingen, and Van Hout-Wolters (2007) has been used to train students. These rules were explained to students in separate presentations and presented to them by dedicated apps (see the next subsections).

RIDE Rule	Sub-rules
(R) Respect	Everyone will have a chance to contribute
	Everyone's ideas will be thoroughly considered
(I) Intelligent collaboration	Sharing all relevant information and suggestions
	Clarify the information given
	Explain the answers given
	Give criticism
(D) Deciding together	Explicit and joint agreement will precede decisions and actions
	Accepting that the group (rather than an individual member) is responsible for decisions and actions
(E) Encouraging	Ask for explanations
	Ask till you understand
	Give positive feedback

Figure 2. RIDE rules for collaboration (from Saab et al., 2007)

2.2.4 Awareness, Assessment, and Lessons Learned

In order to facilitate that students learn from their experience in Tw1st, a number of apps was created that supported students in making judgements of their own collaboration activities in relation to the RIDE rules and also of their opinion of how the peers in their group had acted according to these rules. This was done after the collaboration took place at which point the app was available in the ILS (students had to work through a compulsory

sequence of phases in this ILS (see Figure 1, Navigation). With this app, as displayed in Figure 3, students can chart their own collaboration behaviour and that of their group mates based on the four criteria of the RIDE rules. The app subsequently shows the students' average scores they themselves and their peers have received together with the score they have given themselves per RIDE rule. In this way, they can get insight into the collaboration process (Figure 4). This renders a sense of *awareness* of their own collaboration behaviour.
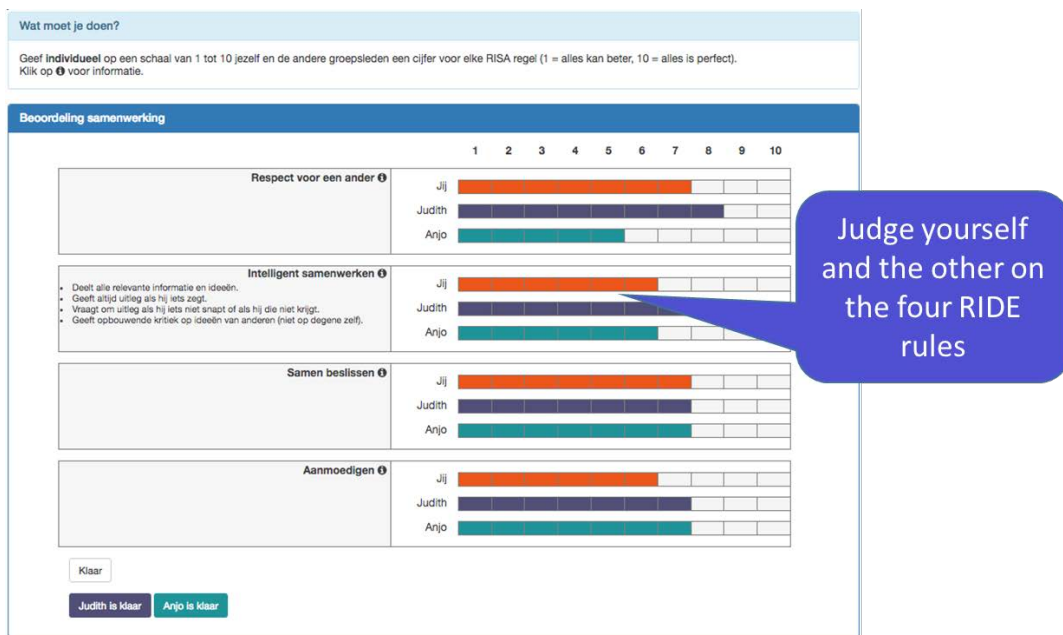

Figure 3. App to chart own and other's collaboration behaviour[3]
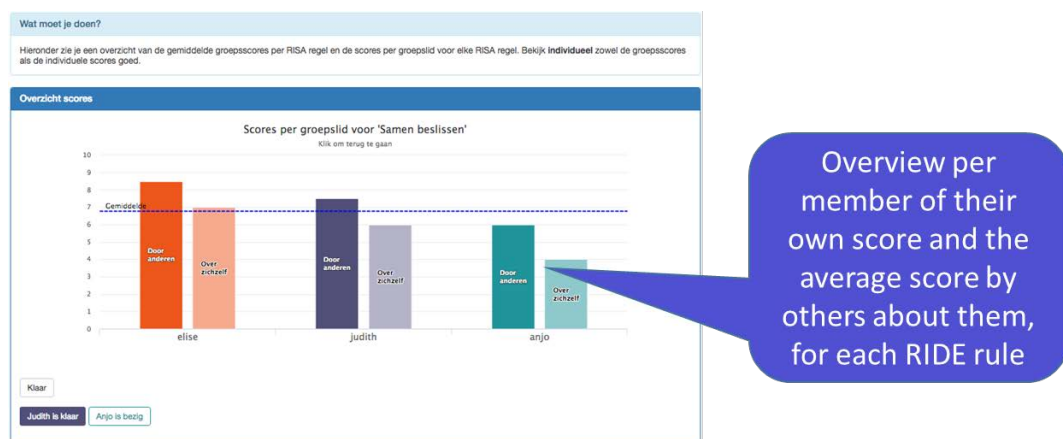

Figure 4. Overview of judgement of own and other's view on the collaboration process

As a next part of the app, students can write down how they think they have acted in accordance with each of the RIDE rules (*assessment*) and they can decide on what went fine and what they need to improve in the future (*lessons learned*) (Figure 5). This helps students to reflect upon their own collaboration and make plans for the future. In Tw1st, the teacher didn't play a role in this process but the app could also be used as a teacher dashboard and as a basis for teachers to start the discussion with their students.

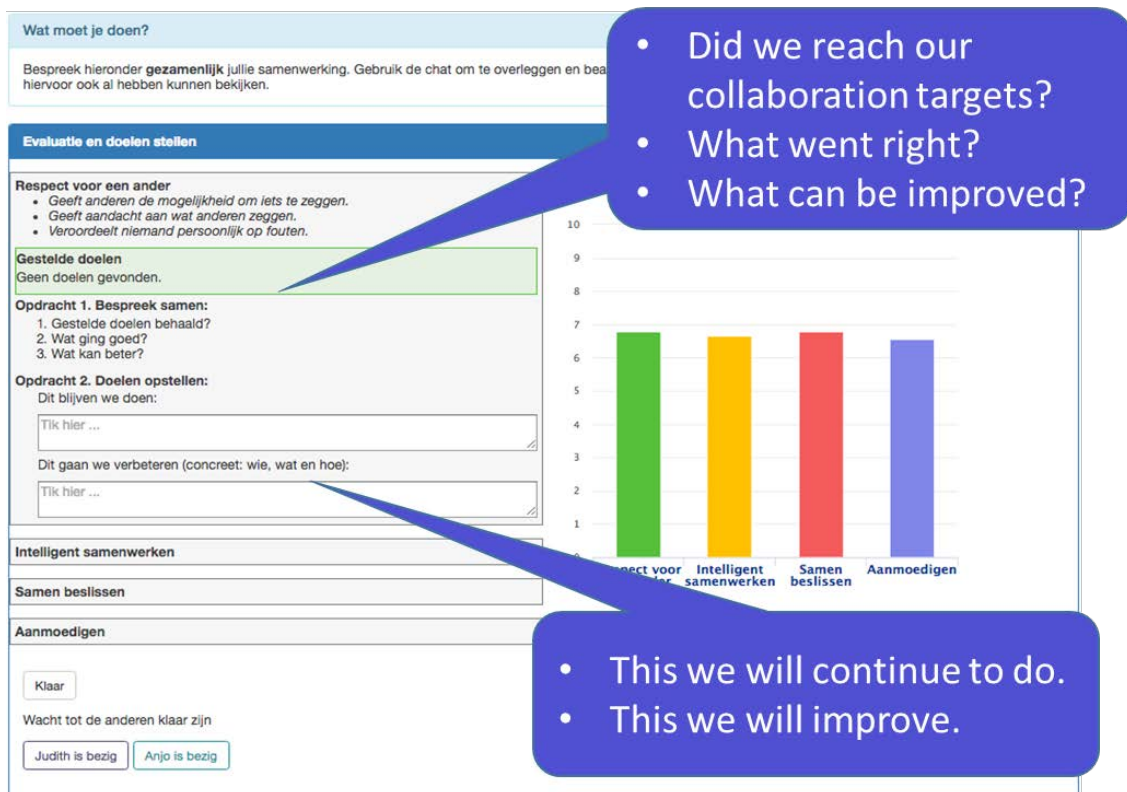[3] Interfaces are still in Dutch, call-outs present the main content of the apps.

Figure 5. Students' assessment of and future plans for collaboration

2.2.5   Group Composition Tool

In order to realise collaboration, a system to compose and recognize groups of students is also necessary. Normally, it will not be the case that complete classes work together but smaller groups (normally of 3-5 students) will collaborate so there needs to be a group composition mechanism within an ILS. The teacher needs a tool to compose groups (using background characteristics of students) so that students within one group share an ILS (with labs and apps included). Figure 6 gives an impression of the current version of the group composition tool. With the app, the teacher can drag names of students to groups (in this case divided over different conditions) after which these students when starting up the ILS will be together in the same ILS, sharing a chat, the labs and the apps.
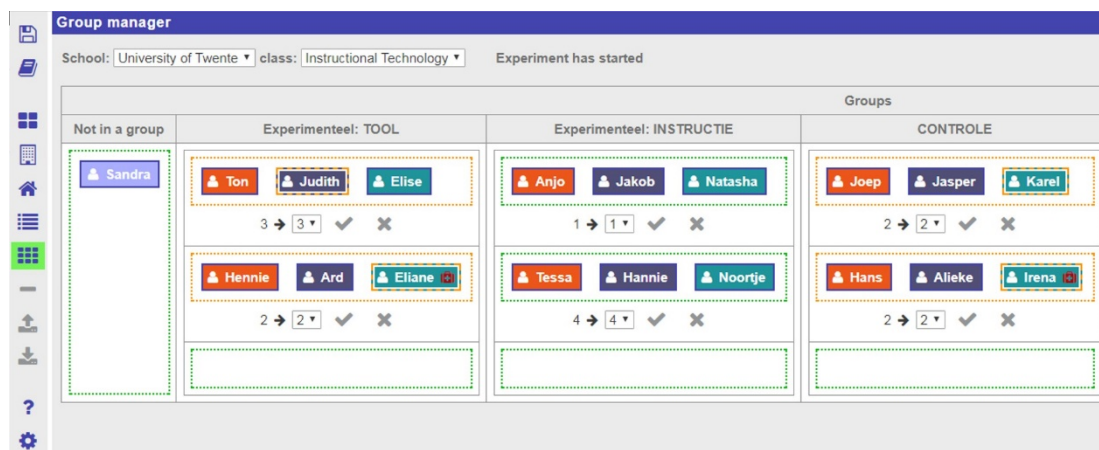

Figure 6. Group composition tool from Tw1st

2.2.6 Outlook

The apps (and the lab), the chat facility, and the student allocation system in Tw1st were built in the Go-Lab ecosystem but are not available for teachers and students in Golabz yet. Despite the fact that they have been used in an extensive study with close to 200 participating students, from a technical and conceptual point of view these facilities need to be further tested and made stable, which is a task set out for Next-Lab.

In the example above the chat facility was presented per app and lab, so each of them had its own individual chat. It might be more effective and efficient to create one overall chat for the ILS, which still needs to be decided. From a technical point of view, we have used TogetherJS, but TogetherJS is not supported anymore and we intend to replace it by SharedJS.

The first version of the group composition tool (app) has functioned in an initial study for vocational students but this app still needs further piloting and testing in participatory design activities to make it user friendly for teachers.

The overall structure of the approach with the different components as sketched above, may stay in place. However, for each of the specific components alternative approaches may be developed. For the *learning goals*, other approaches next to the RIDE rules will be explored, alternatively we will design a configuration option so that teachers can configure an app with their own chosen collaboration rules. For *awareness*, students have currently charted the collaboration behaviour themselves, as alternatives, characteristics of the collaboration may be inferred automatically on the basis of interaction data or a chat analysis. Also, different ways of visualising the collaboration process may be explored. For *assessment* and *lessons learned*, also different (more open) approaches can be taken.

2.3 Discussion

Discussion is group exchange information and concerns an exchange of arguments. In collaboration or cooperation students also exchange arguments but the main difference with discussion is that in collaboration and cooperation students have a specific goal to reach (a problem to solve, a design to finish, an experiment to perform etc.). Such a goal is not necessarily present in discussion. Discussion elicits students to present good underpinnings for their ideas and to adapt their ideas on the basis of arguments of others. In the Go-Lab project a specific scenario was developed to stimulate discussion between students. In this "structured controversy" scenario a problem is presented to students that has a number of different angles from which it can be approached so that different arguments can be given (de Jong, 2015). Debate over controversies is often seen as a way to deepen students' knowledge on a certain topic (see e.g., Mansoor & María, 2002)

In Next-Lab we have included an app (SpeakUp) that facilitates discussion between students and also adds opportunities for teachers to follow the discussion and participate in it. The next section presents the app, the section that follows gives an example on how the app can be used in a dedicated configuration of apps and ILSs.

2.3.1 SpeakUp

SpeakUp aims at enriching face-to-face (f2f) interaction in classrooms by encouraging students to voice opinions and to position themselves regarding other students' opinions. The idea of the app is to add a digital interaction channel on top of the face-to-face interaction channel that occurs in classrooms. Through the digital channel students can ask questions like in the face-to-face (f2f) channel, but the digital channel allows to do it

anonymously and allows other students to show that they also have the same question by voting them up (or down). Students can also directly answer each other's questions and thus the app promotes peer instruction. Furthermore, the app allows teachers to get the opinions of students on certain topics much more effectively than through f2f interaction (which only allows to get a few opinions). Moreover, it allows teachers to perform quick polls during the ILS to assess knowledge. This can be done by creating polls on the fly that will appear in the ILS. Finally, the app can be accessed through mobile phones, which allows teachers to see questions without the need to stay at their desks.

2.3.1.1 Requirements and Specifications

SpeakUp is a mobile application supporting interactions between teachers and students. At its essence, SpeakUp can be seen as a shared message board that can be added to an ILS. The requirements of SpeakUp were collected in Participatory Design sessions through two consecutive projects with the Education Support Center of the University of Lausanne in a project funded by the Pedagogical Innovation Fund from that university. The requirements can be summarized as follows:

R1: Proactive messaging

SpeakUp allows any student in the ILS to post messages, question or comment at any time during the course without being prompted by teachers. A posted message can be seen by all students inside the ILS.

R2: Peer interaction

SpeakUp allows students to react to other students' messages/questions by posting a reply (peer instruction) or an opinion (critical thinking). SpeakUp also allows students to simply vote up or down messages to show agreement or disagreement with other students' messages.

R3: Optional identity

SpeakUp allows teachers to create chatrooms, where students' messages are identified by their ILS nicknames, or anonymous chatrooms, where students are not identified.

R4: Polls

SpeakUp provides support for multiple-choice questions and polls to allow teachers to quickly perform polls to assess knowledge or to get input from students on particular topics.

R5: Mobile access

SpeakUp is also available as a standalone mobile application to allow teachers to access the chatroom without the need to be stationed at their desks.

R6: Feedback for awareness and reflection

SpeakUp allows teachers to give feedback on student answers through comments or by indicating the correct answers in a multiple-choice question. We are working on an activity visualization to provide teachers and students with more detailed information.

2.3.1.2 Prototype

The SpeakUp app is currently functional and can be accessed on the Golabz Portal (http://www.golabz.eu/apps/speakup). The page on the portal contains two tutorial videos on how to use the app in classrooms.

Figure 7 shows the configuration screen. Teachers can either join an existing chatroom that they have created elsewhere (e.g., in another ILS, on their mobile app, etc.) by providing

the number of the room. Alternatively, they can create a chatroom with a name and indicate if it is anonymous or if students are identified by their nicknames.
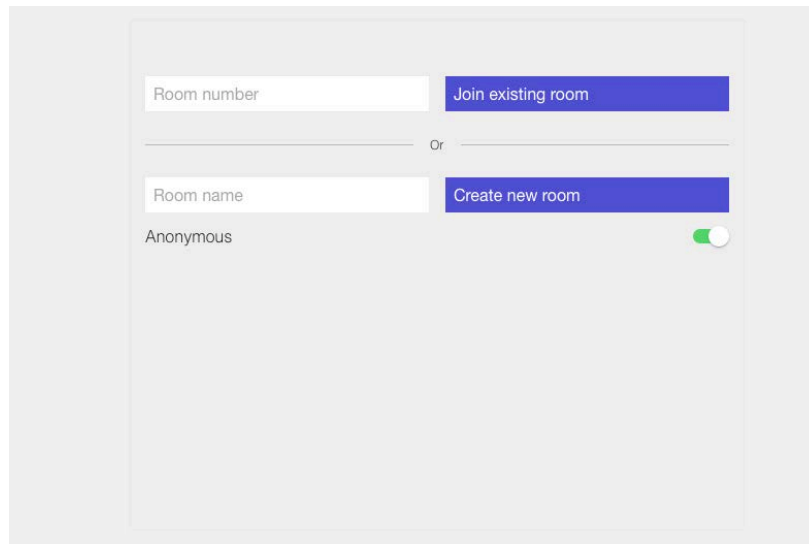

Figure 7. SpeakUp setup interface

Figure 8 shows the room with messages where students can post their messages by using the input box and vote on messages by pressing the thumb up and thumb down buttons. The screen on the left shows the teacher view and the screen on the right the student view. The teacher view has three main additional admin features compared to the student view. 1) the teacher can delete any message in the chatroom, which will then disappear from all screens. 2) the teacher view contains a "+" button on the bottom bar which they can use to create multiple choice questions (as shown in Figure 9). 3) the teacher view allows to share the admin rights with other users. To do so the teacher can press the chevron next to the room name and press on Admin Key. This will generate an admin key that anyone can use to access the room as an administrator.
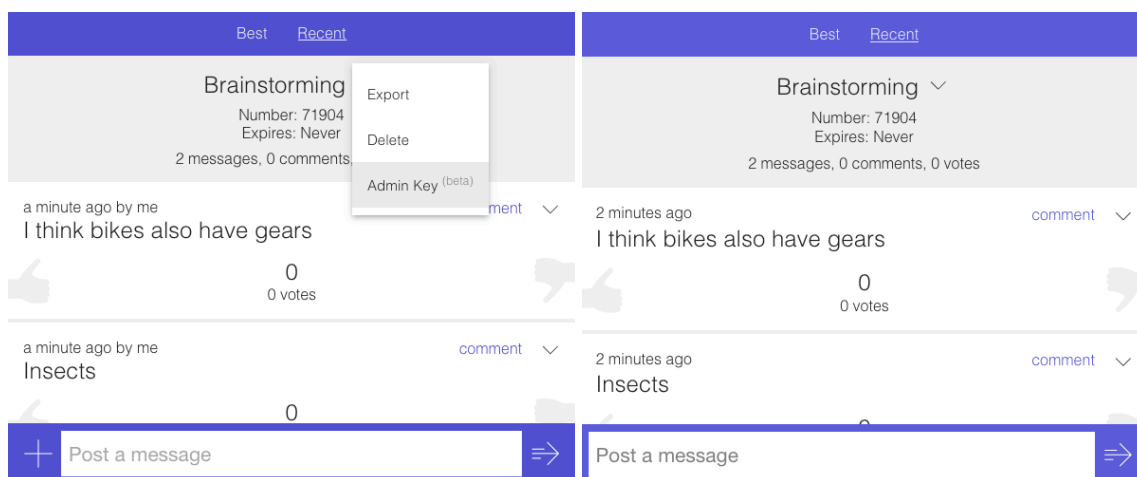

Figure 8. SpeakUp messaging interface (left student, right teacher)

Figure 9 shows the creation of a multiple-choice question on the mobile interface of the app (the same process applies in the online version). The screen on the left shows the interface triggered when the teacher presses the "+" button. Then the screen in the middle shows the

teacher view which tallies the multiple-choice answers in real time. The screen on the right shows the student interface. Note that teachers can decide upon creation of the multiple-choice question how many choices are possible (between 2-9), whether to allow multiple selection or single selection, and whether to show the results to students as soon as they have voted, or to allow teachers to decide (using the eye icon) when to display the results.
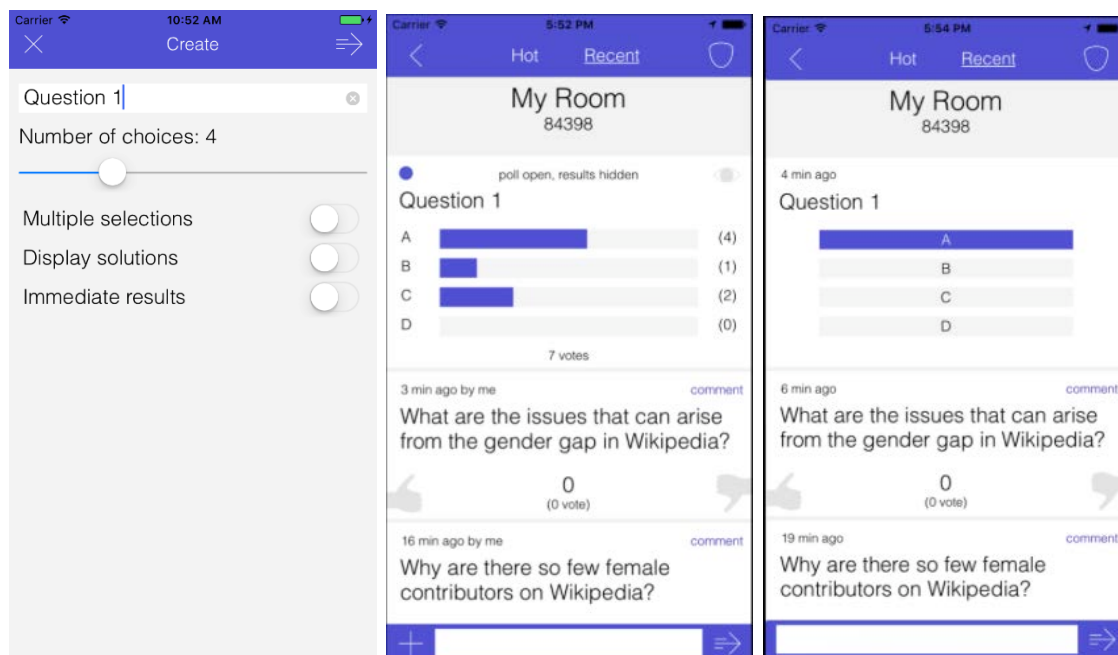

Figure 9. SpeakUp setup interface

2.3.2 An example of Using SpeakUp to Facilitate Discussion

2.3.2.1 Introduction

The ability to clearly communicate and express oneself is a key component of 21st century learning, and central to acquiring a number of 21st century skills, among them collaborative problem-solving skills. Two major international programs - the Programme for International Student Assessment (PISA) and the Assessment and Teaching of 21st Century Skills (ATC21S) - have developed conceptual frameworks of collaborative problem solving, along with interactive computer-based tasks to elicit collaborative behaviours from students. These initiatives offer insights as to how Next-Lab can support the development of young people's collaboration skills.

Both PISA and ATC21S define specific collaboration skills. In the PISA framework (OECD, 2017) collaborative problem-solving skills incorporate three competencies: 1) establishing and maintaining shared understanding, 2) taking appropriate action to solve the problem, and 3) establishing and maintaining team organization. The first competence (establishing and maintaining shared understanding) involves discovering perspectives and abilities of team members, identifying mutual knowledge and building common understanding about a problem. The second competence (taking appropriate action to solve the problem) involves identifying problem-solving steps or actions to be taken and monitoring the results of actions in relation to the group and problem goals. The final competence (establishing and maintaining team organization) relates to understanding different roles needed to solve the problem, adapting to changes, handling disagreements and monitoring the team organization. Within the ATC21S framework (Griffin & Care, 2015) there are three

dimensions of social skills individuals need to be successful in collaborative problem solving: 1) participation, 2) perspective taking, and 3) social regulation. Participation refers to activity in an environment, interacting with and responding to others, and perseverance to complete a task. Perspective taking refers to the degree to which students can relate and adapt to the different perspectives of others. Social regulation relates to the degree to which students can recognize and negotiate sharing of different tasks between each other. Consideration of the specific collaboration skills identified in the PISA and ATC21S frameworks guided the development of interactive computer-based tasks used to assess collaborative problem solving in those two international initiatives.

The computer-based tasks developed by PISA and ATC21S can be helpful in guiding the development of new collaborative learning experiences in Go-Lab. The PISA and ATC21S collaborative tasks share a number of common features such as:

- a computer screen divided into two major regions: 1) a work area to interact with stimulus material, and 2) a chat interaction area for communication;

- evaluation of collaboration skills based largely on examining learning process data rather than just learning outcome data;

- interdependence to ensure that no individual student could successfully complete a task alone.

It is also important to mention that a significant difference between the PISA and ATC21S tasks was that the PISA approach required students to interact with computer-simulated participants whereas the ATC21S approach employed human-to-human interaction. Nevertheless, the list of common features between the two approaches gives us some insight as to how to best support the development of students' discussion and collaborative problem-solving skills. Furthermore, the principle of interdependence can be found in the Johnson and Johnson model of cooperative learning (Johnson & Johnson, 1999), where *positive interdependence* is listed as an essential element of cooperative learning and defined as the perception that team members are obliged to rely on one another in order to succeed. An example below illustrates one way the concept of discussion, task interdependence and collaboration can be realised in an ILS that incorporates the SpeakUp chat facility.

2.3.2.2   The 'How Does a Seesaw Work' Inquiry Learning Space

The Seesaw Lab (http://www.golabz.eu/lab/seesaw-lab) is a virtual laboratory that integrates with the SpeakUP app to provide a collaborative learning experience in Go-Lab. An innovative aspect of this lab is that there are actually two versions of it. In one version a student can only interact with the left side of a seesaw. In the other version a student can only interact with the right side of a seesaw. Furthermore, a student sees only objects that are placed on his or her side of the seesaw. If an object is placed on the other side, the seesaw may move out of balance, but the reason for this is not immediately apparent to the student who sees only his or her side. Figure 10 shows the two versions of the Seesaw Lab. The lab and the ILS have been subjected to participatory design (see Next-Lab deliverable D4.1, Sections 7.2 and 7.3).

Although students can interact with only one side of the seesaw, they can pass objects back and forth between each other by dragging an object onto the box labeled 'Drag-and-drop and object here to share it.' This enables a pair of students to explore balancing the seesaw with objects of differing masses. However, in order to coordinate this collaboration, students need to communicate using the SpeakUP app.

The SpeakUP app can be used for peer-to-peer communication if an ILS creator who creates a new chat room – which automatically creates a unique room number - shares the room number of the chat room with only two students. For multiple pairs of students in a class, the ILS creator needs to create multiple chat rooms and distribute multiple room numbers to the students. Following the design of the SpeakUP app, the Seesaw Lab also requires a student to enter a room number before starting the seesaw simulation, which to simplify things is suggested to be the same number as the SpeakUP room number.
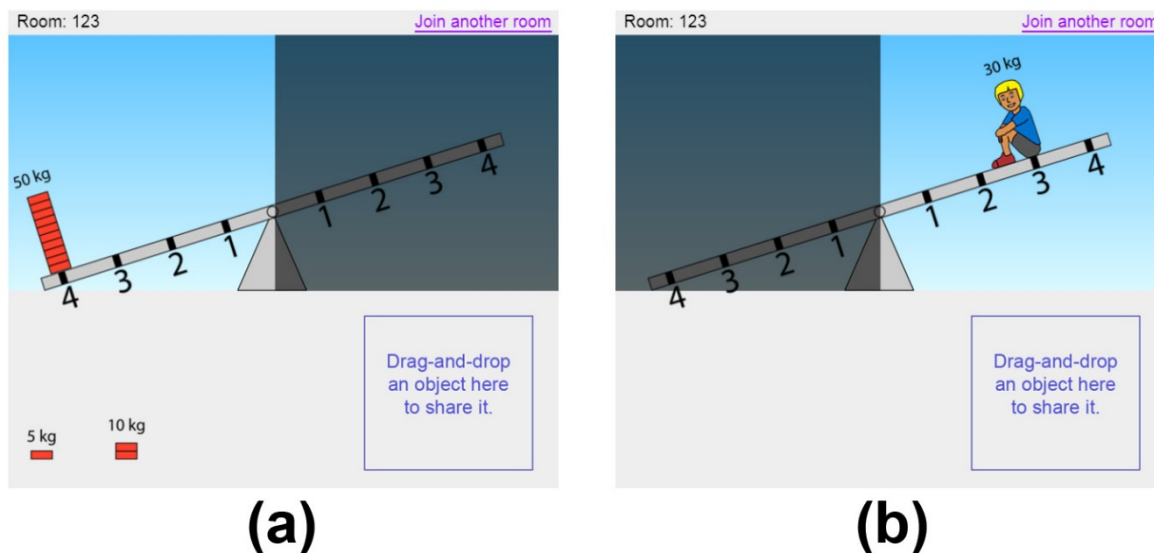

Figure 10. The two versions of the Seesaw Lab: a) only interaction with the left side of the seesaw is allowed, and b) only interaction with the right side of the seesaw is allowed

Since the Seesaw Lab presents two different functionalities to students, it ensures interdependence in the design of a collaborative problem-solving task. The Go-Lab ILS *How does a seesaw work?* (version A and version B) demonstrates how the SpeakUP app and the Seesaw Lab can be used together in the Orientation phase of an ILS to engage students in the topic of balancing a seesaw. Later in the Investigation phase students can perform a systematic study of how object masses and object distance from the seesaw pivot point are related.

As demonstrated in the *How does a seesaw work?* ILS, students can reflect on their collaborative experience and answer questions such as what would they do differently next time in a similar collaborative problem-solving situation, or reflect on how well their peer contributed to solving the task. These written reflections can be read and compared to a transcript of the SpeakUP chat dialogue, which is automatically saved by the SpeakUP app and available to the ILS creator, to evaluate how well students collaborated.

2.3.2.3 Conclusion

The SpeakUP app, together with other functionalities in an ILS, has the potential to foster students' discussion and collaborative problem-solving skills during inquiry learning. When used for communication between two students (or two groups of students), it allows each side to discover the perspectives of the other, set common goals together, coordinate actions, deal with ambiguity in a situation, handle disagreements, organize teamwork effectively, provide encouragement and positive feedback, monitor progress, and build knowledge together. Teachers can later read the chat dialogues, which are automatically

saved by the SpeakUP app, and evaluate how well their students are learning effective communication and collaboration strategies. Through practice solving collaborative inquiry tasks, students can simultaneously acquire both inquiry and collaboration skills. Next-Lab will continue to refine the SpeakUP app and take into consideration recent studies of collaborative problem solving from PISA and ATC21S which suggest that tasks deliberately designed to require interdependency among participants (i.e., one student cannot accomplish the goal alone) are well-suited to elicit a range of collaborative behaviours from students. An example ILS integrating the use of a collaborative Seesaw Lab was demonstrated as one way how interdependence can be achieved in the Go-Lab learning environment. The consideration of interdependence will help guide future development of new inquiry learning experiences in Next-Lab ILSs that employ the SpeakUP app for facilitating discussion and collaborative problem solving.

2.3.3 Outlook

We performed further evaluation of the app (see Next-Lab deliverable D4.1, Section 7.1.2) and are currently working on improving the usability and enable more advanced visual feedback to provide teachers and students with more detailed information for awareness and reflection purposes.

2.4 Reflection (Critical Thinking)

In the 21st century skills literature, critical thinking is mentioned as one of the key 21st century skills. Critical thinking involves activities in which decisions or processes of oneself or someone else are evaluated for internal consistency or against some criterion. In this respect, King and Kitchener (1994) use the tern reflective judgment and Halpern (1998, p. 451) writes: "When people think critically, they are evaluating the outcomes of their thought processes--how good a decision is or how well a problem is solved". The Partnership for 21st Century Skills at their website present the following aspects of critical thinking:

- Effectively analyze and evaluate evidence, arguments, claims and beliefs
- Analyze and evaluate major alternative points of view
- Synthesize and make connections between information and arguments
- Interpret information and draw conclusions based on the best analysis
- Reflect critically on learning experiences and processes

In all these definitions, reflection is a key component for critical thinking and we, therefore, for now will focus on reflection as a 21st century skill in Next-Lab. Reflection is a process "in which people recapture their experience, think about it, mull it over and evaluate it" (Boud, Keogh, & Walker, 2013, p. 19). Reflection is often seen as a process that is very important to draw lessons from what has been done and to improve performance (Land & Zembal-Saul, 2003; Lin, Hmelo, & Kinzer, 1999). Based on the seminal work by Schön (1987) often a distinction is made between reflection in action (in which a reflective component is used to improve the ongoing action (e.g., learning) and reflection on action in which reflection is seen as the basis for an improvement of a similar performance later.

Reflection can take place over a process (e.g., how to create a concept map) or a product (e.g., the concept map itself). In reflection, often a comparison is made to a "norm", this norm can be an expert's process or product, a peer's process or product or general (theoretical) rules that determine the quality of the process or product. There has been much and still is ongoing debate whether 21st century skills (and thus reflection) can be learned

in an abstract, domain independent, way, but in Next-Lab we will take the stance that learning these skills in the context of a domain is the most effective.

In this section, we focus on reflection and we design apps that are specific for reflection but the process of reflection (and thus critical thinking) is also part of other student activities. For example, reflection and learning how to be (constructively) critical is also an aspect of the "self- and peer assessment" app (Section 2.4 of this deliverable; in reflection we focus on self-assessment) and is also an aspect of "discussion" (Section 2.3).

In the following subsections, we will present some examples of reflection on artefacts created with other Go-Lab apps (e.g., a concept map, experimental design, and hypothesis) or on processes that have taken place in a Go-Lab ILS (the own learning process). First, however, we will identify which components are present in a reflection activity.

2.4.1 Components of Reflection

To promote a process of reflection the following components can distinguished:

Awareness. As a start, students should get insight into their own products or processes, which forms the basis for reflection. In fact, this is what the reflection is about. For apps such as the concept map, the app itself suffices since the concept map constructed is a direct representation of the students' insight in the domain. So, when students must reflect on a concept map, the necessary basic information on their own concept map is already there. For processes, basic data often need to be processed to give the students a clear view on their process. For example, when we ask students to reflect on their usage of different apps in an ILS, they first need an overview of which aps (in which sequence) they have been using. The construction of these overviews is very much related to the Next-Lab work on learning analytics.

Criterion. To be able to reflect on a process or product students often need a reference point (or norm). This reference point can be of three kinds:

a) An expert norm (e.g., an expert concept map or an expert estimation of time to be spent in inquiry phases).
b) A group norm, students can compare what they have done with an "average" of what has been done in their group. This can be for example the usage of apps by other students' in an ILS or a concept map that is aggregated from the concept amps of other students in the ILS (see later).
c) General rules about well-structured concept maps, proper experimental set-ups etc. In the case of concept maps these can for example refer to the optimal number of concepts or relations, using parsimony in the CM etc.

Guiding questions. In order to have students reflect (evaluate their own product or processes) giving specific questions or prompts will structure this process and may point students to specific aspects of the reflection. These questions may refer to or implicitly include the criterion against which the evaluation may take place.

In the next few sections we present examples of ongoing work on new apps or extended existing apps that are suited for the 21st century skill of reflection.

2.4.2 Reflection on a Product – the Concept Map

In the case of a concept map, for *awareness* no measures need to be taken. The concept map is there and students can take that as the basis for their reflection. As a *criterion* an expert concept map can be presented but students can also compare their own concept map to what their peers have done. For this situation we have created the *aggregated*

concept map. The aggregated concept map presents a map that displays an aggregation of all concept maps from students in the same ILS and indicates how often a specific concept occurred in the individual maps and how often concepts have been related in the underlying individual maps. The student can toggle between his/her own concept map and the aggregated concept map.

Figure 11 gives an example of a student concept map and Figure 12 displays an aggregated concept map that appears after the student has clicked the button on the left part of the screen. By means of this button students can toggle between their own concept map and the aggregated one to make comparisons. Following results from participatory design a fully new and better integrated version of the aggregated concept map (see Figure 12) is being developed (see Next-Lab deliverable D4.1, Section 7.1.6)
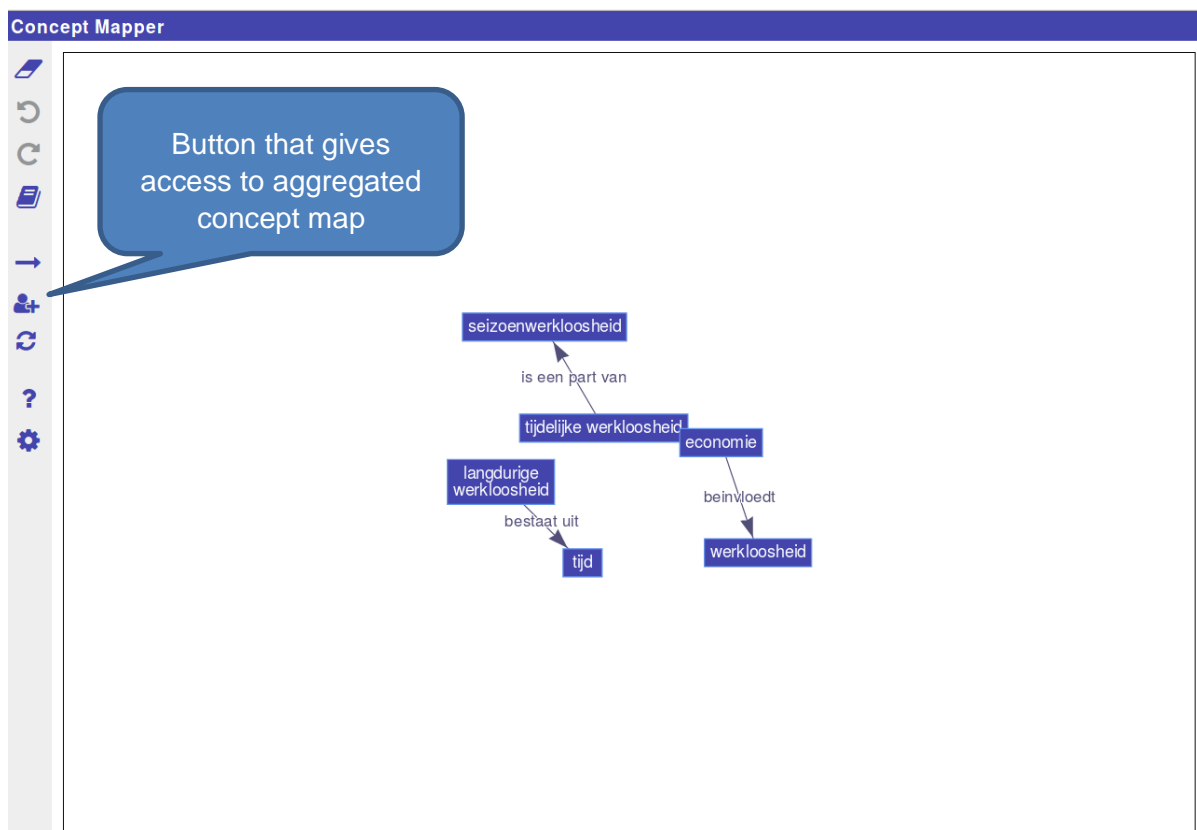
Figure 11. Student concept map with access to aggregated concept map
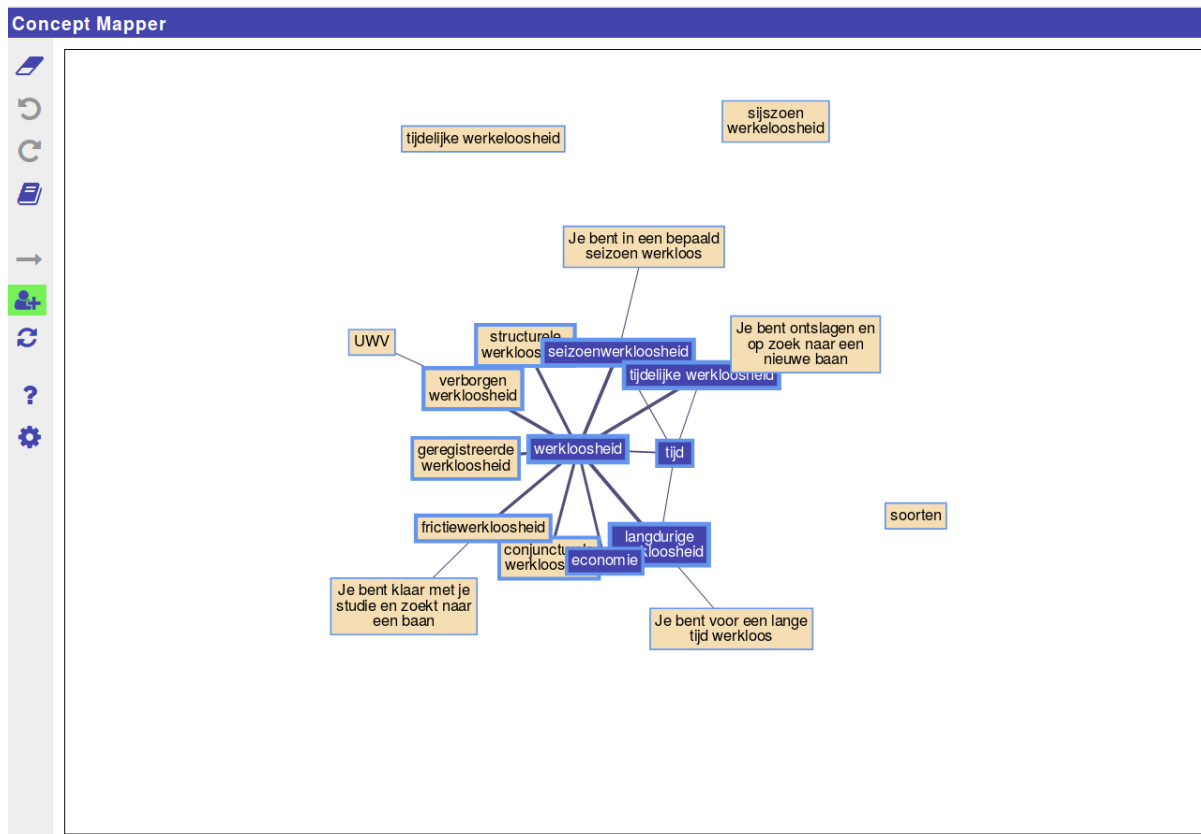
Figure 12. An example of an aggregated concept map

Through the configuration of the concept map app, the teachers can indicate whether students have access to the aggregated concept map or not.

What currently is not available yet are the *guiding questions* that would support students in the reflection process and hint them to important aspects for the comparison of concept maps.

2.4.3 Reflection on a Product – Experiment Design

The Go-Lab experiment design tool helps students in setting up experiments by offering them independent, dependent, and control variables and ways to give values to these variables and organize them in sets of experimental trials. The outcome of the experiment design tool, the set of designed experimental trials, could be subject to reflection. Students could compare their own set-up with the design of an expert, those of fellow-students, or with general rules about experiment design (e.g. the VOTAT rule to vary only one variable at the time) but they can also directly be *guided by questions* that implicitly include suggestions about the general rules. Figure 13, presents a structured set of questions concerning the experiment design (taken from van Riesen, Gijlers, Anjewierden, & de Jong, submitted). The questions point students to crucial decisions they have made in designing their experiment and also include suggestions for adaptation and asks student for improvements based on their reflections
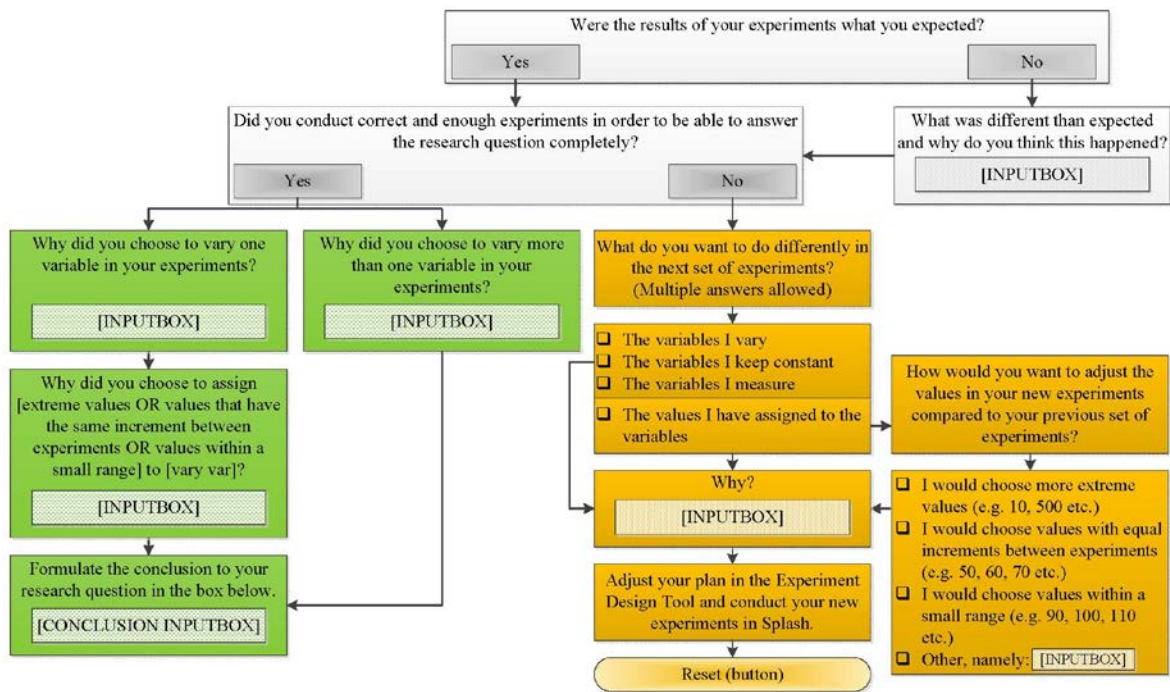
Figure 13. Assessment and lesson learned questions for the experiment design app (from van Riesen et al., submitted)

2.4.4 Reflection on a Product – a Hypothesis

The Go-Lab hypothesis scratchpad supports students in creating hypotheses by providing them with a set of domain terms, conditionals, and relational terms. In this way, the scratchpad supports students in creating testable and informative hypotheses. When reflecting on hypotheses the awareness is readily available, students have created their hypotheses and can directly inspect them. As a *criterion*, they could be given general rules about proper hypotheses or they could be presented expert (teacher) hypotheses that they can compare with their own hypotheses. They could also be given a set of *guiding questions* to reflect on their hypotheses. These could be questions that alert them to common mistakes being made in hypotheses. Another approach is to present them with a more dedicated and dynamic criterion in the form of an, automated, expert review of their hypothesis. For this we are developing a parser that makes an automated evaluation of a hypothesis and presents students suggestions of what is still missing. In presenting feedback to the student (in fact the criterion related information) the parser will combine general rules about hypotheses with domain relevant knowledge. The latter needs to be configured by a domain expert (teacher).

Figure 14 presents a first impression of the work of the (prototype) parser. In the figure, a student has created three hypotheses on electrical circuits and by clicking on the call-out button right to the hypothesis feedback on this hypothesis is presented. The advantage of this approach is that students do not just receive general rules but that they do receive them dedicated to their own product (hypothesis). This feedback can serve as a criterion that students can use to reflect on their hypothesis and use the outcome of this reflection to adapt the hypothesis.
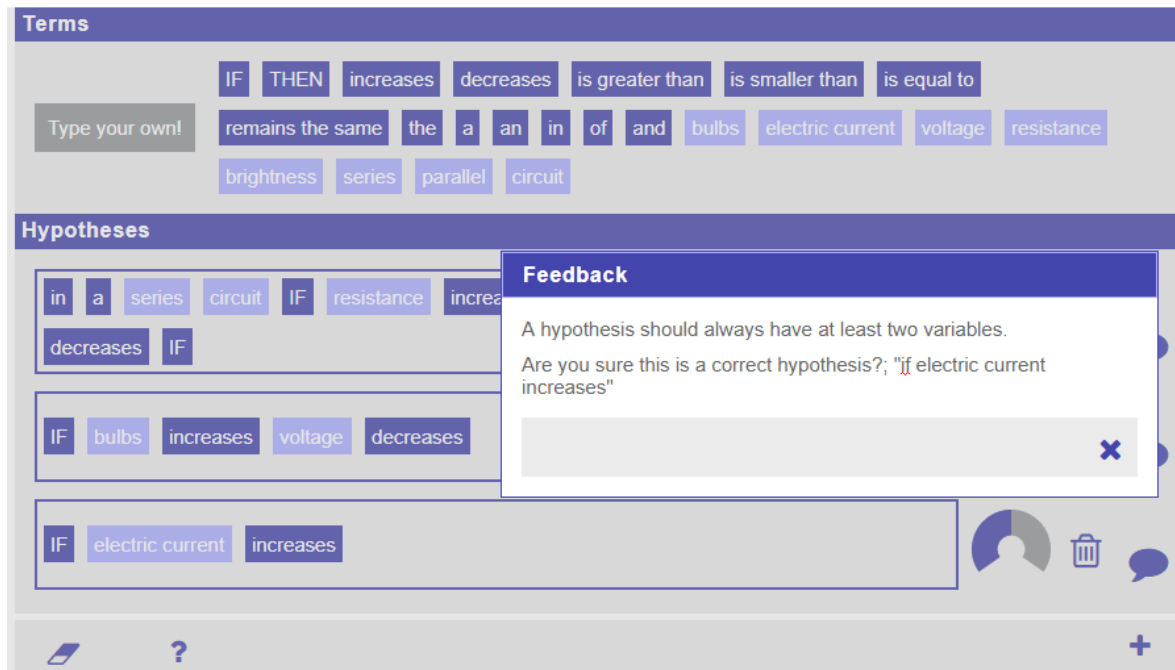
Figure 14. Feedback on the hypothesis scratchpad urging students to reflect on their hypotheses

2.4.5 Reflection on a Process – Time Spent in Phases

In the examples above *awareness* was straightforwardly introduced because students had to reflect on a product that they created themselves and this product (concept map, experiment design, hypothesis) is directly visible. In other cases, awareness first needs to be created which is illustrated in the next example. One aspect of the learning process is how much time students spend in a certain phase of the inquiry process. Students may, for example, take too much time for the initial phases and then experience time pressure when doing their investigations or, alternatively, they may jump too easily and unprepared to an investigation phase. To gives students *awareness* in their own time spending in phases this first needs to be measured and visualised. Figure 15 presents an app that calculates students' percentage time spent in a phase of an ILS and displays it visually to the student (black coloured bars). The *criterion* in the form of an expert (teacher) suggested distribution of time over the phases is represented by the blue bars. Under the app *guiding questions* can be presented. The criterion and the questions are both configurable by the teacher. This app was rated as useful in the participatory design (see Next-Lab deliverable D4.1, Section 7.1.11).

Overall, students can be made aware that they not necessarily have to adapt to the criterion but that the outcome of their (critical) reflection may also be that their time distribution (or taken the other examples, concept map, experiment design, or hypothesis) was the best approach.
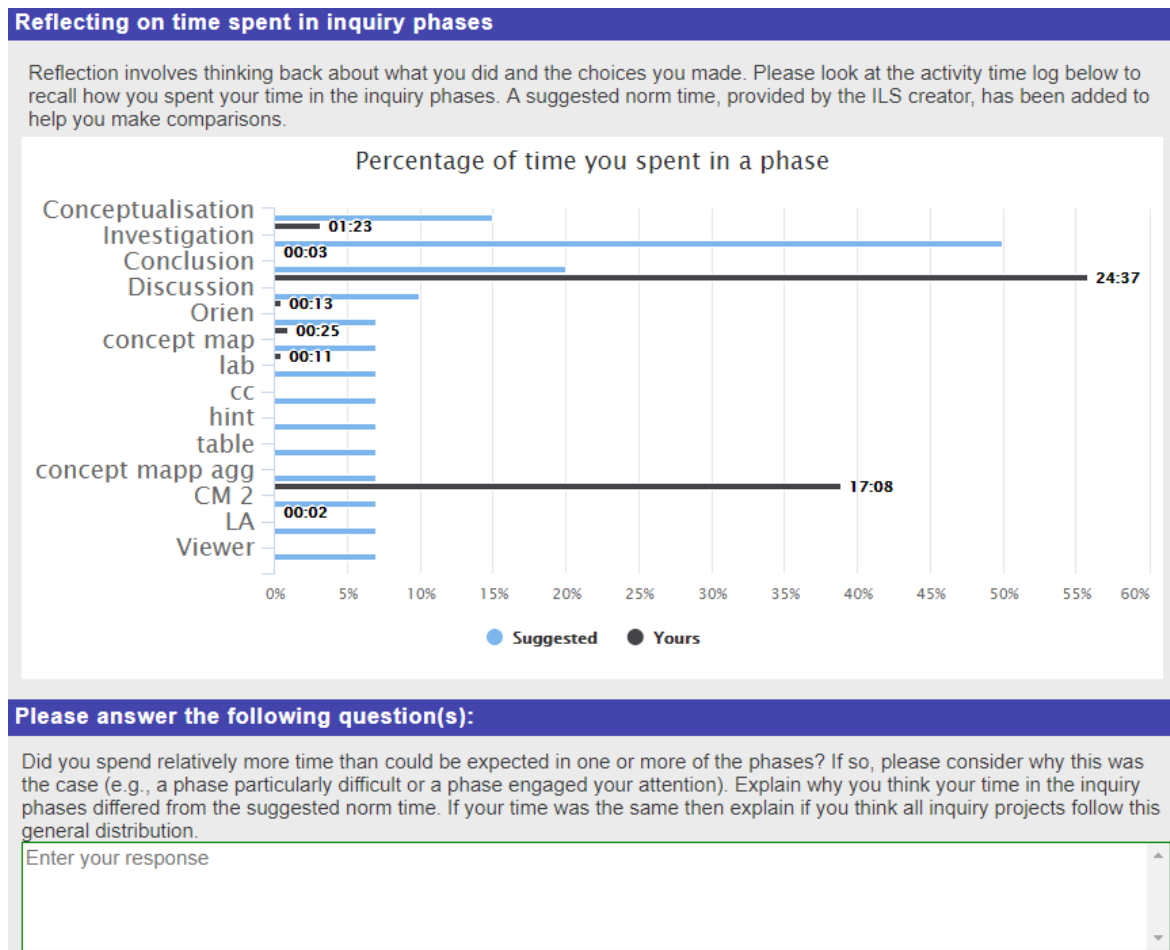
Figure 15. Students' reflection on time spent in inquiry phases

2.4.6 Outlook

Reflection is always regarded as an important, yet underspecified, aspect of the learning process. In inquiry learning, as realized the Go-Lab ecosystem reflection, can refer to many different products and processes, which means that there cannot be one general reflection app but, for each product or process a dedicated solution should be created. Still we can draw some general conclusions with consequences for design activities in Next-Lab:

- In case an app doesn't show students a clear view on their product or process this view should be created (often in relation to learning analytics apps),
- A reference point (norm) in the form of an expert model, a (generated) group norm, or general rules (configurable by the teacher), can be very helpful for students to arrange their reflection process
- Students should be guided in their reflection by dedicated questions/suggestions. These should be provided per app and be configurable by the teacher.

In the remaining of the Next-Lab project we will further explore which inquiry products and processes are suited for reflection and build or extend apps that help students to reflect on them, creating views for awareness, expert models, peer models and /or rules and (configurable) guiding questions when applicable.

2.5   Outlook on 21st Century Skills Apps

At this stage, many of the 21st century apps are at the earlier stages of development. This is the case since there will be a multitude of 21st century apps (there is no one general app) and they do require quite some design activity. In some cases, we can use prototypes from other projects (as displayed in this deliverable) in other cases the app (or extension of the app) needs to be designed anew. In this task we will take care that there is consistency in how 21st century apps (or 21st century extensions of existing apps) will be designed, for example in the way guiding questions for reflection are presented together with an app.

The focus in the upcoming work will be on creating, extending, finishing, tuning, and stabilizing the apps on collaboration, cooperation, discussion, and reflection. If possible, extra work will be done on metacognition and planning and creativity. The first will require apps that help students create overall plans, possibly over a complete ILS the latter may focus on training students' cognitive flexibility, considering multiple route in an ILS or multiple outcomes of investigations.

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3. Self- and Peer Assessment App

The Self- and Peer Assessment App ("Assessment App"), currently being tested in a first version, aims at supporting the learner and teacher in self- and peer assessment activities. For the teacher, it provides features to plan, organize, and configure such activities, while learners will be provided with an assessment interface, guidance, and assessment rubrics. The following sub-sections will describe the Assessment App in more details.

3.1 Requirements and Specification

3.1.1 Rationale

Peer assessment involves the evaluation of student work by their peers. The core rationale behind peer assessment is that students who have undergone a learning activity sequence may offer valuable feedback to their peers, which can then be used for assessment purposes. A reciprocal peer assessment arrangement foresees that students will undertake two roles (e.g., Tsivitanidou, Zacharia, & Hovardas, 2010). They will provide peer feedback (role of peer assessor) and they will also ask peer feedback and use it to improve their work (role of peer assessee). A central assumption in this reciprocal setting is that students who have experience in using tools and applications and who have constructed a series of learning products (e.g., concept maps, hypotheses, tables) can provide constructive critique and guidance to their peers. As soon as they themselves will receive peer feedback, they can screen it to optimize their work.

3.1.2 Learning and Instruction Objectives

Peer assessment is considered to be a type of collaborative learning, which promotes reflection and metacognitive skills[4], and improves the quality of learning. In that regard, peer assessment offers a valuable complement to teacher assessment and it can be used for purposes of enacting formative assessment. Peer assessment in a school environment will desirably deliver the positive outcomes it has been delivering within the scientific community and academia. Namely, peer assessment, when implemented thoroughly and optimally, may ensure the quality and validity of a scientific work before it is disseminated. In that direction, it may deliver insightful peer feedback for revisions, which is an important means for improving the scientific work (e.g., Sung, Chang, Chiou & Hou, 2005, Tseng & Tsai, 2007 Hovardas, Tsivitanidou, & Zacharia, 2014; Tsivitanidou, Zacharia, & Hovardas, 2011a, b). As in the scientific community, peer assessment needs to be a blinded process in school environments, as well. In that way, the peer assessor and the assessee will not be influenced by their attitudes towards each other. Among the long-term benefits of peer assessment, one can list: fostering constructive support among students; enhancing student responsibility and self-regulation during inquiry-based learning; fostering self-confidence and motivation for learning; developing a trusting relationship among peers (Hovardas, Tsivitanidou & Zacharia, 2014).

3.1.3 Integration of Peer Assessment in an Inquiry Learning Space (ILS)

Objects to be assessed are learning products, namely, artefacts produced by students themselves along the learning activity sequence (e.g., concept maps, hypotheses, tables). Learning products to be assessed must be familiar to students, which is guaranteed when all students have undergone the same learning activity sequence before undertaking the role of the peer assessor. Since different learning products are constructed by using

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[4]   Peer- and self-assessment are therefore also closely related to 21st century skills.

different applications, the peer assessment procedure is based on assessment criteria that are specifically formulated to address each different application and learning product. The Assessment App displays different assessment criteria for different learning products, which are presented for peer assessors to guide the production of peer feedback and for peer assessees after peer feedback has been offered, so that they can re-work and improve their learning products. The Assessment App should be integrated in a separate phase of the inquiry cycle, especially foreseen for the peer assessment procedure. This Peer Assessment Phase may be conceptualized as a version of the Communication Sub-Phase of the Discussion Phase[5]. The Peer Assessment Phase should be completed exactly before students proceed to the Conclusion phase. The main reason for that is to give the opportunity to students to improve their work before they have concluded the inquiry cycle.

3.1.4 Workflow for the Peer Assessment Procedure

Students enter an ILS, where a Peer Assessment Phase has been foreseen before the Conclusion Phase (Figure 16). Students use applications to construct learning products and undertake tasks in the learning activity sequence. When students would like to receive peer feedback, they need to activate the option offered in all applications for which the peer assessment procedure is to be implemented (i.e., Concept Mapper, Hypothesis Scratchpad, Question Scratchpad, Table Tool, Data Viewer). Students may also withdraw their feedback request and resent it after they had modified their learning product. When a peer feedback request is submitted, students can no more re-work their learning products, until the Peer Assessment Phase is reached. In that phase, students undertake two roles in a reciprocal peer assessment arrangement. The role of the peer assessor involves the provision of quantitative peer feedback (i.e., scoring learning products according to assessment criteria) and qualitative peer feedback (i.e., comments and suggestions for peers to improve their learning products). The role of the peer assessee involves the screening of peer feedback as well as re-working of his/her learning products after a critical review of peer feedback. An artefact can be reviewed by more than one peer. This allows students to get more than one perspective on their work. This will also allow for the calculation of the reliability of peer feedback, namely, the degree of overlap in the quantitative part of peer feedback provided by two different peer assessors for the same learning product.

3.1.5 Training

A major prerequisite before implementing any peer assessment procedure is student training. This needs to involve (1) a familiarization with tasks associated with the two roles of students in reciprocal peer assessment arrangements, namely, the role of the peer assessor (providing quantitative and qualitative peer feedback) and the role of the peer assessee (asking for peer feedback and using peer feedback to improve one's learning products); (2) a familiarization with peer assessment criteria; (3) a familiarisation with both quantitative (i.e., scores across assessment criteria) as well as qualitative peer feedback (i.e., comments explaining the rationale of the peer assessor for his/her scores across assessment criteria); and (4) good practice on how to use peer feedback to improve one's learning products. During training, students will have the opportunity to identify and reflect on good practice in peer assessment.

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[5]   When the Assessment App is used for self-assessment purposes, then the self-assessment procedure can be seen as a version of the Reflection Sub-Phase of the Discussion Phase.
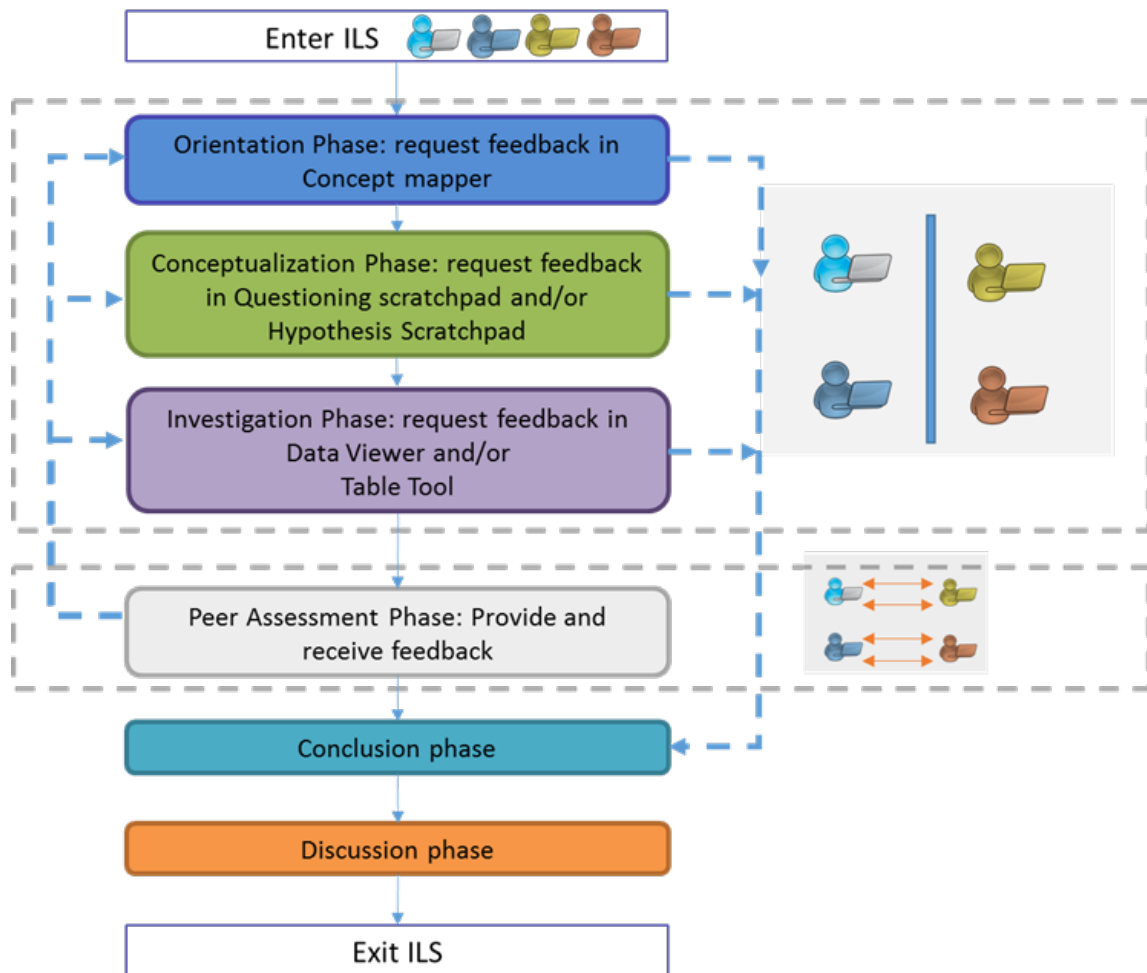
Figure 16. Workflow for the peer assessment procedure

3.1.6 Learner User Story

Demetra is working in the Conceptualization phase of an ILS and while formulating her hypotheses in the Hypothesis Scratchpad, she did not feel confident with regard to the variables she had incorporated. Demetra activated the feedback request option in the Hypothesis Scratchpad. While entering the Peer Assessment Phase in the ILS and accessing the Assessment App, Demetra realized that she was also asked to give feedback to one of her classmates. Demetra responded to all questions by clicking on the smileys offered. She also provided a couple of comments to explain her reasoning for her scoring. After Demetra went through her responses to be sure that she left no item unanswered, she submitted her feedback. Then, she moved back to the Conceptualization Phase and she accessed the Hypothesis Scratchpad to see if she had received any peer feedback to the request she had submitted. Indeed, peer feedback was there for her to review. Demetra followed all responses included in the peer feedback. Some qualitative comments that accompanied scores given by smileys were particularly informative for her, since they elaborated on peer response and offered guidance for improving her hypotheses. After reviewing peer feedback carefully, Demetra changed the independent variable in her second hypothesis.

3.1.7 Teacher User Story

Artemis has planned a peer assessment procedure for her students. She has authored an ILS and integrated a Peer Assessment Phase. There, she embedded the Assessment App. Artemis configured the application so that peer assessors would provide their scoring across peer assessment criteria with 3 different smileys and she has also provided to peer assessors the option of accompanying their scores with comments. Artemis marked all items in the application as required for peer feedback, which meant that peer assessors would needed to respond the entire list of assessment criteria. Artemis left peer feedback requests at the discretion of each student, which meant that students would ask for feedback whenever they were not confident with the content or quality of their learning products. Artemis assigned peer feedback requests to her students. To do so, she followed a random matching procedure and paired peer assessees to peer assessors by using a random number generator. Before the assignments, Artemis cross-checked if all her students had followed the same learning activity sequence, as it was reflected in the ILS. This was necessary because her students needed to be familiar with using applications and delivering learning products before acting as peer assessors. Two students who did not request feedback for any of their learning products were not assigned any feedback request, as well. Artemis went through the peer feedback provided by peer assessors to peer assessees. She was attracted by several comments of her students that indicated a thorough mastering of scientific knowledge and inquiry skills. She has also identified a number of assessment criteria, where the responses of peer assessors seemed to be quite heterogeneous. She noted that these criteria needed to be re-formulated or left out in a future peer assessment procedure.

3.2 Prototype

This section describes the current state of this prototype, along with screenshots, functionalities, and their relation to the requirements from the previous section.

The feedback can be requested in several tools (concept mapper, data viewer, hypotheses/questions scratchpad and the table tool). In the configuration of each of these tools, the feedback request option can be activated. The following screenshot (Figure 17) shows the asking for feedback in the concept mapper (pop-up message appears after pressing the bubble with the question mark).
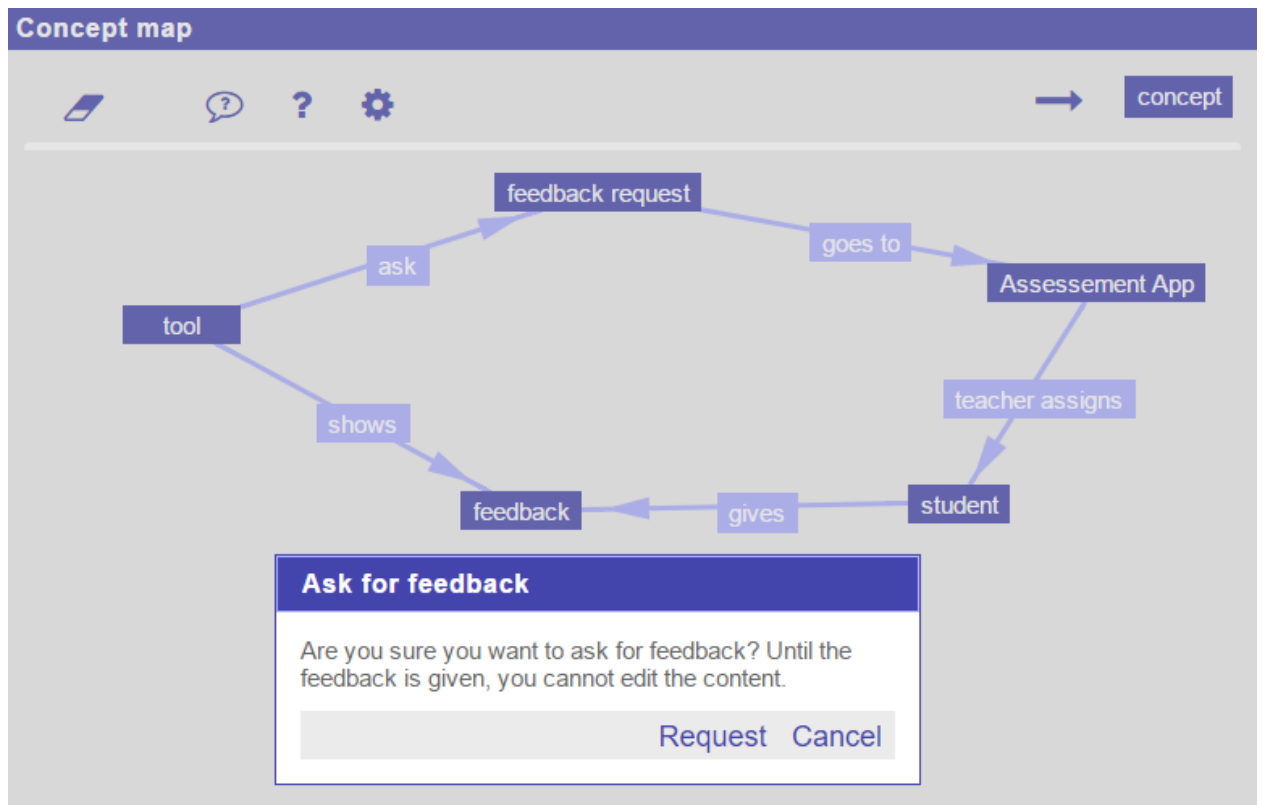
.

Figure 17. Asking for feedback in the concept mapper (Student View)

After the student requests for feedback, the teacher can assign the feedback request to a student. The next screenshot (Figure 18) shows the teachers view of the Assessment App with the unassigned requests and an assigned request. The teacher can assign a request by dragging the requesting student to one of the green dotted "Assigned to" areas. Feedback requests can only be assigned to students who have requested feedback.

Figure 18. Assigning of a feedback request (Teacher View)

The student can give feedback by answering some questions in the Assessment App. This is shown in the next screenshot (Figure 19).
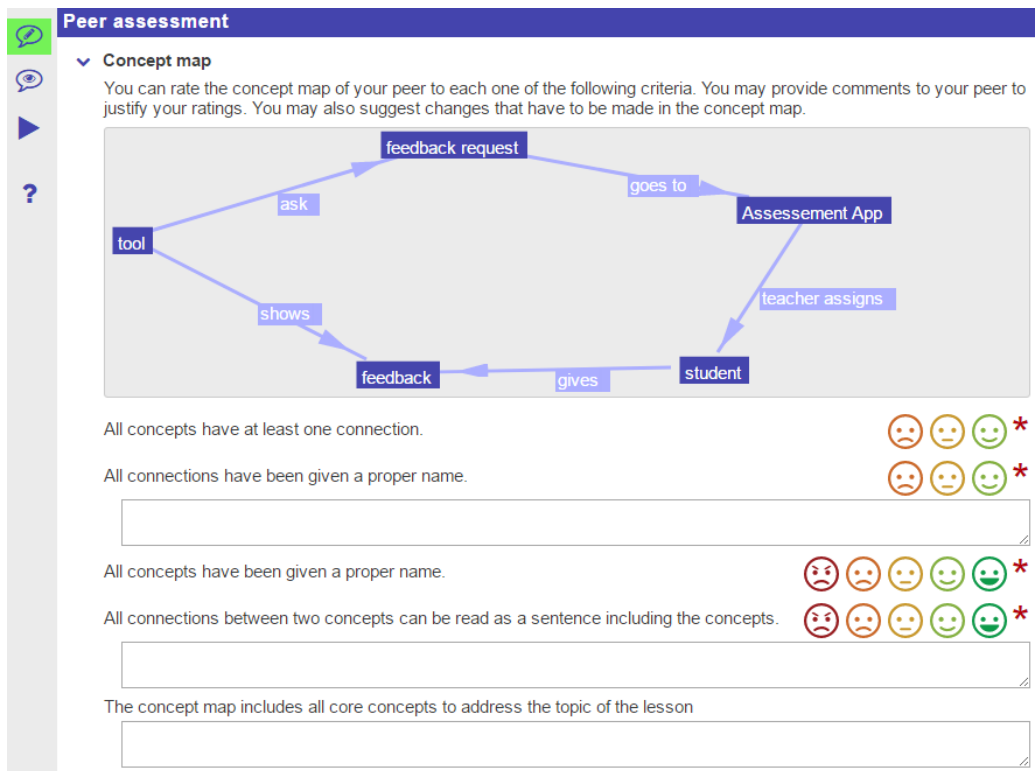
Figure 19. Enter feedback screen (Student View)

After the student has answered all feedback questions, the feedback can be send by clicking on the blue triangle in the button bar. The feedback can then be seen in the requesting tool (by clicking on the ⌾ icon the toolbar. This is shown in the next screenshot (Figure 20)
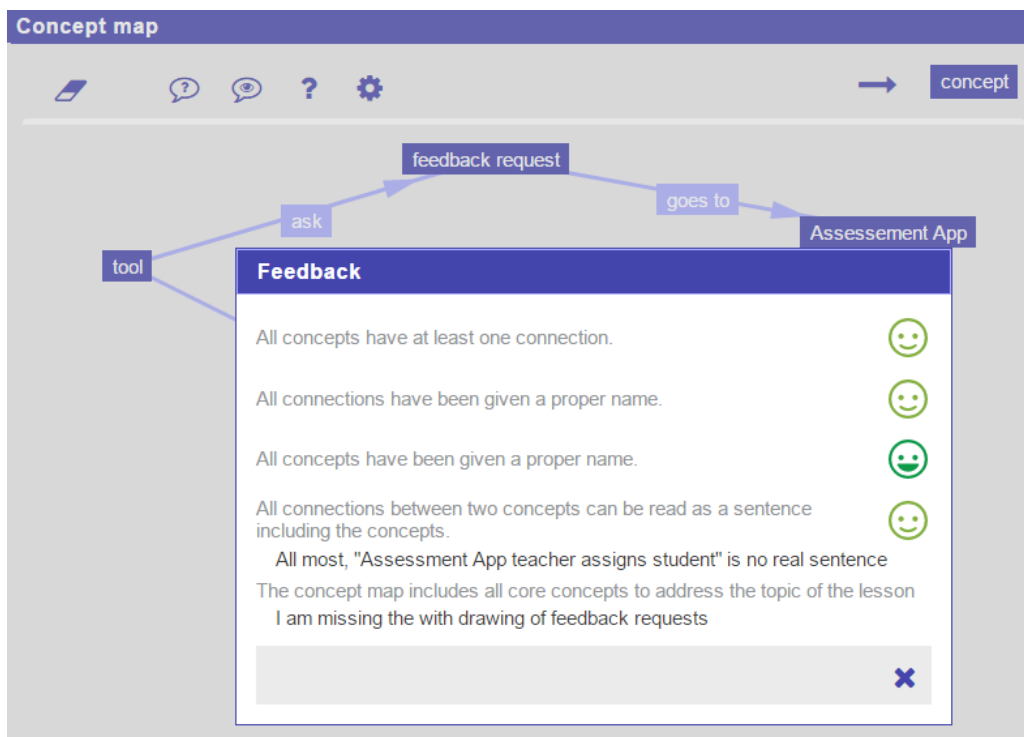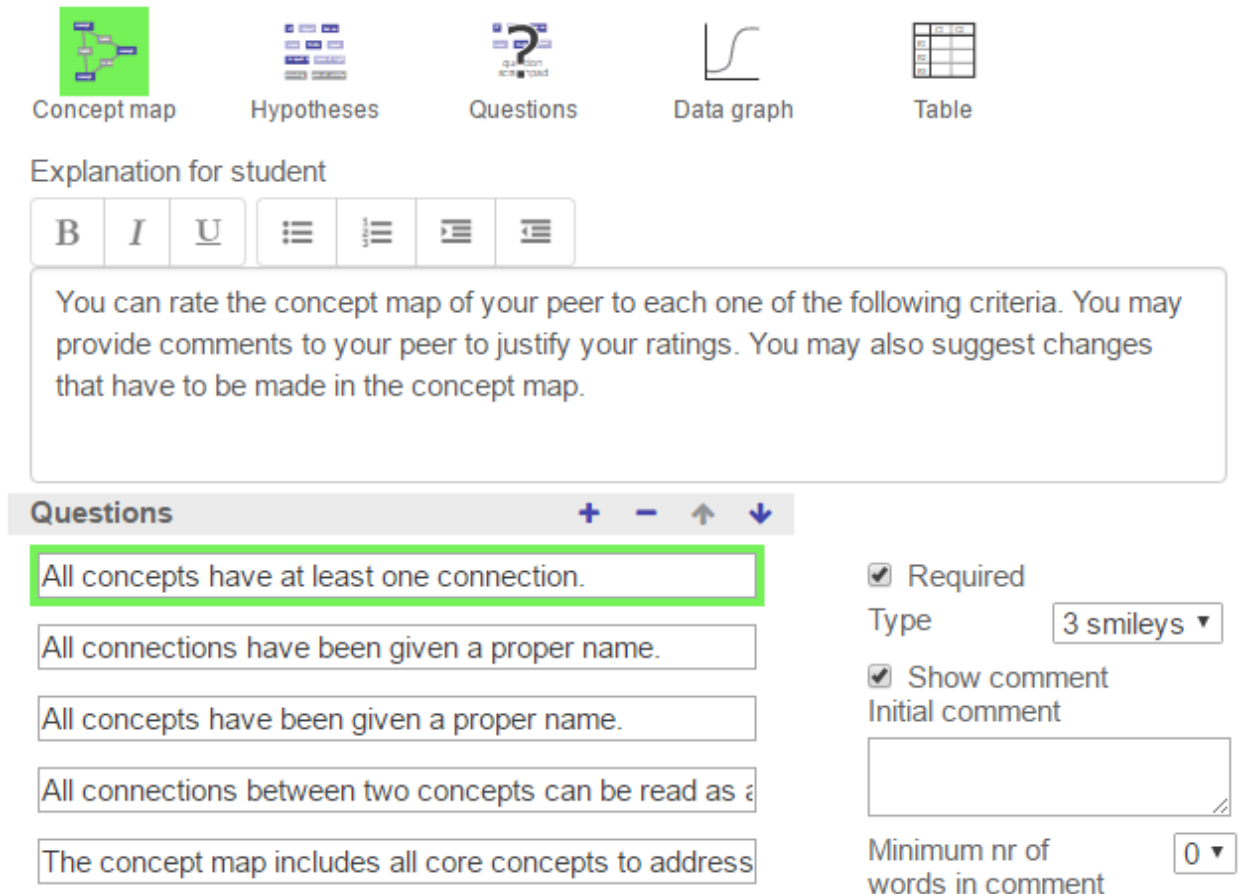

Figure 20. The display of the feedback inside the concept mapper

The student can see the requested feedback (including the received feedback, if available) also in the Assessment App. All the feedback answer (from the student) stay visible in the Assessment App.

The teacher can configure the feedback questions for each type of resource. For each question, the teacher can select the type of the answer (3, 5 or no smileys and an optional comment field). Each question can be marked as required, meaning that the student has to answer it before the feedback can be send. The next screenshot (Figure 21) shows the configuration options. In the enter feedback screenshot all the currently available answer types are shown.

Figure 21. Feedback question configuration options

The teacher can follow all feedback requests and answers by opening the requests in the assigning screen. The content of the request resource, feedback questions and answer and the current content of the resource are then shown in a dialog box (Figure 22).
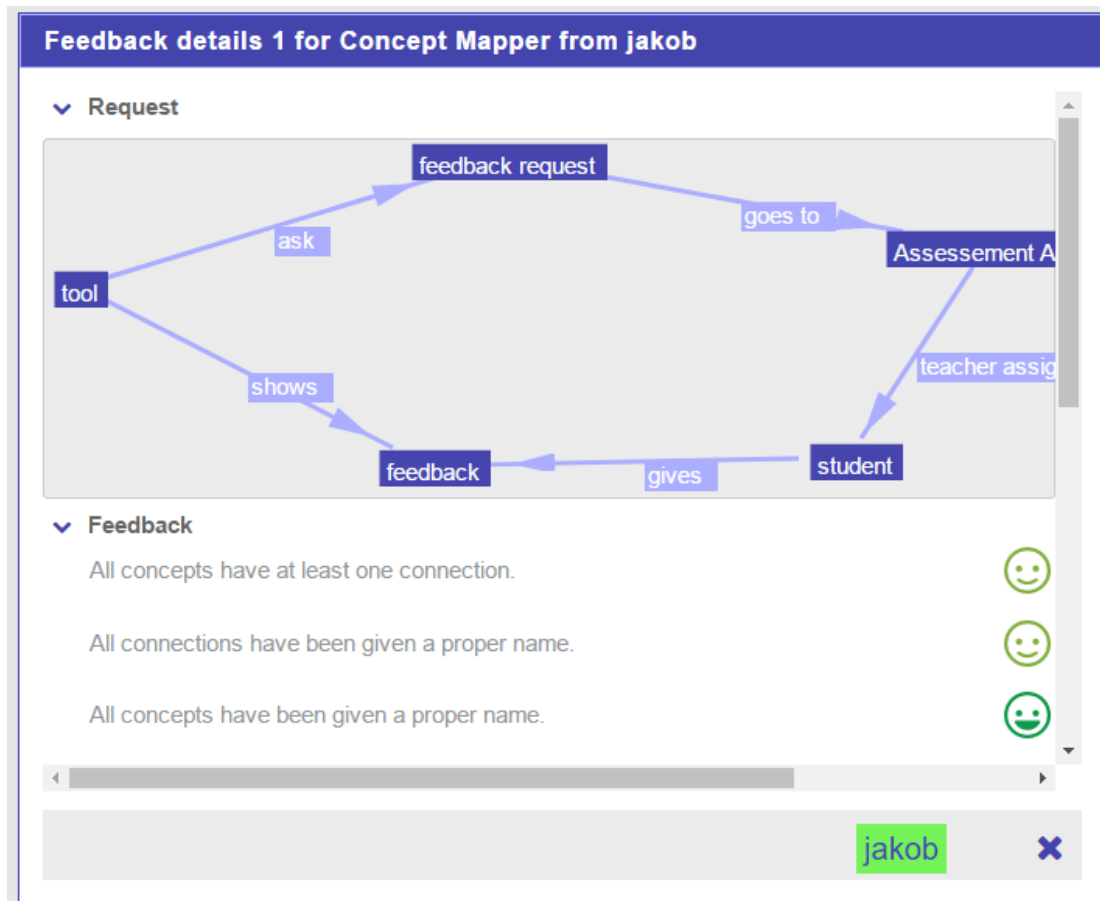
Figure 22. Overview of a feedback request

3.3 Outlook

We have first focused on a synchronous peer assessment procedure, where the roles of peer assessor and peer assessee are undertaken within the same time frame, in a whole-class setting. An asynchronous peer assessment arrangement would need to allow for addressing peer feedback requests upon availability of peer assessors, and it would necessitate a more advanced capability of matching among student ILS users. The latter is due to the fact that familiarity with the learning activity sequence in the ILS would be still needed when enacting asynchronous peer assessment.

Although the peer assessor has to work with a pre-defined set of assessment criteria in the current version of the Assessment App, another option would be that the peer assessor would be able to edit these criteria. Such a configuration would provide the opportunity to employ different peer assessment formats, e.g., a format where all assessment criteria would be pre-defined (structured), a format where peer assessors would be able to edit assessment criteria or add their own assessment criteria (semi-structured), or a format, where all assessment criteria would have to be defined by peer assessors (unstructured).

Initial participatory design activities targeting the Assessment App have provided valuable insight from teachers (see Next-Lab Deliverable D4.1, section 7.4.2). Progress in developing the Assessment App further may also include an option for the teacher to have an overview of learning products revised by peer assessees after they have received and reviewed peer feedback. Additional participatory design activities will be needed for collecting views from students.

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4. ePortfolio App

The concept of ePortfolio has been introduced in 1999 as an electronic learning record [1] and further developed to overcome the time limitation of learning management systems [2, 3] not offering persistent storage to students. Nowadays, almost two decades later, educational platforms have evolved towards personal learning environments and social media platforms [4] enabling the creation, the exploitation and the archiving of activities traces, learning outcome and learning analytics together with the resources provided by the teacher(s) [5] thanks to built-in export and sharing features. Such features enable students at any time to store their learning outcome and activity traces as archive files, pdf documents, eBooks, or sharable online spaces that can be considered as rich open educational resources [6].

4.1 Requirements and Specifications

4.1.1 Requirement elicitation

For the elicitation of requirements for ePortfolio features, we followed two complementary approaches, taking into account that the development resources available in the Next-Lab project only permit to offer ePorfolio features in the *Graasp* platform (no new platform should be developed or integrated) and through limited modifications. First, we carried out a comparative study between *Graasp* and *Mahara* — a popular tool for ePortfolio management. The purpose of this study was to understand how the current capabilities of *Graasp* compare with *Mahara* and to identify directions for improvement within *Graasp*. Additionally, we organized a participatory design session with 24 teachers in July 2017 during the Next-Lab Summer School. These teachers were proficient users of *Graasp* and the Golabz repository. By involving them in the design process, our goal was to learn how useful they considered ePortfolio services and archiving features in *Graasp*. Furthermore, we aimed to gather feedback on what data should be included in these ePortfolios and archives, as well as their preferred export formats.

4.1.2 Comparative Study

The typically set of ePorfolio features are the following:

- digital collection of artefacts and reflections;
- representation of an individual's learning and achievements;
- set of items to be shared with others.

The two platforms, *Mahara* and *Graasp*, integrate this required set of features. Nevertheless, there are implementation differences regarding the collection of artefacts. *Mahara* includes various ways to collect learning artefacts and especially common multimedia documents. On the other hand, and in addition to collecting multimedia documents, *Graasp* enables the aggregation of external web apps and embedded web pages. The *SmartEvidence* feature of *Mahara* is a competency-visualizing tool in which the competencies acquired by students through their learning activities are associated with evidences. There is currently no such a feature in *Graasp*. On the *Graasp* side, the main advantage is the flexibility to personalize the platform through apps or embedded pages that can be easily integrated. These integrations enable the display of learning outcomes acquired in other platforms.

4.1.3 Participatory Design

We organized a participatory design session with 24 expert teachers in July 2017. In this session, teachers reflected on how they envisioned the archiving of ILSs and ePortfolio features be integrated into *Graasp*.

Archiving for teachers. Out of 24 teachers, 21 (87.5%) considered that keeping an archive was relevant for their own practice, 1 (4.16%) was not sure, and 2 (8.33%) did not answer. By decreasing number of votes, the main reasons motivating teachers to keep an archive of their ILSs were (1) assessment purposes (as evidence of the student's work and their progress), (2) compiling and having access to the material generated by the teachers, (3) re-usability (including reviewing and redesigning), (4) sharing with other peers, (5) self-reflection, and (6) research.

Regarding the content that such archive should include, teachers considered that it should contain evidence not only about the content (24, 100%) but also about the activity (23, 95.83%). Table 1 shows the teachers' preferences in terms of archiving solutions. It should be noted that several solutions could be chosen by the teachers at the same time. While the main options were to keep the archives in *Graasp* (20, 83.33%), in their own computer (15, 62.5%) or as a PDF (14, 58.33%). Regarding the certification, most of the teachers (23, 95.83%) were interested in getting a certification from the platform showing that the ILSs were produced by them.

Table 1.Teacher interest in the different archiving and ePortfolio strategies

Archiving / ePortfolio Strategies	For Teachers	For Students
Printed Copy (Paper-Based)	4 (16.66%)	5 (20.83%)
PDF File	15 (62.50%)	15 (62.50%)
ePub / eBook File	7 (29.16%)	10 (41.67%)
In Graasp	20 (83.33%)	14 (58.33%)
In User's Computer	15 (62.50%)	4 (16.66%)
In Another Server (e.g., In User's School Network)	5 (20.83%)	7 (29.16%)
Google Drive	1 (4.16%)	1 (4.16%)

Student ePortfolio. Out of 24 teachers, 21 (87.5%) stated that it would be useful for students to add their ILSs to their ePortfolios, and 3 (12.5%) were not sure, and 1 (4.16%) considered it unnecessary. In order to better address the student needs, we asked the teachers what kind of information should be included in an ePortfolio. On this regard, 21 teachers (87.5%) agreed on the need for combining evidence about the learning outcomes as well as the learning process. Besides, other data sources were considered as relevant in an ePorfolio, for example the student self-assessment or the feedback provided by peers or teachers.

Indeed, 22 teachers (91.67%) were willing to certify the authenticity of the work done by the students (the other 2 were not sure).

In terms of how ILSs could be exported, the preferences diverge from the ones chosen for teacher archiving. As it is shown in Table 1, the most voted options were PDF files (15 teachers, 62.5%), in *Graasp* (14 teachers, 58.33%), and ePub/eBook (10 teachers, 41.67%). Interestingly, as for teacher archiving, despite the PDF format appearing among the main options, it is not aligned by default with the possibility of including raw evidence about the learning process. Nevertheless, this data could be aggregated and analyzed by ad-hoc analytics apps, which can also provide some guidelines for interpretation and reflection.

4.1.4 Current and Upcoming Features in *Graasp*

To enable reflection and lifelong competence management in a digital society where the lifespan of cloud or legacy platforms is unpredictable, the most important feature to enable ePortfolio features is to ensure easy export and archiving in standard formats. This section describes the current and envisioned design and seamless integration of such features in *Graasp* towards its extension for exploitation also as an ePortfolio. For teachers, being able to export and archive the outcomes and traces of activities with their students is a way to reflect on and improve their teaching practices and professional achievements. For students, being able to export and archive the outcomes and traces of their activities is a way to support self-assessment of their learning practices and enable competence management. We focus hereafter on the archiving of ILSs, as placeholders of the content offered by the teachers combined with the learning outcomes and the activities traces of the students.

As illustrated in Figure 23, an ILS running in *Graasp* can already be printed. This represents the first step towards an ePortfolio implementation. Thanks to this current feature, the full content of the inquiry learning spaces can be saved as a png image or a pdf file (using the small chevron icon located next to the name of the standalone user on the top of the ILS in Graasp).

We are currently implementing a second step which will indicate to students that they can create an ePortfolio as shown in Figure 24. Pressing this "Create ePortfolio" button will generate a personal copy of the space in Graasp, providing proper credentials are provided by the students, i.e. by first signing up and then logging in. The copy of the space should include content such as documents and images, but also activity traces and analytics. This copy of the space can be exported and kept for later use by the student, even in the case the teacher decides to delete the original space created to support a given class activity.

Finally, as it is currently the case for teachers, it will be possible for students to archive an ILS from the Graasp authoring platform by downloading the space to the desktop as a zip archive (as shown in Figure 25). There, spaces become folders and all content and descriptions are saved as files. Eventually, this folder can be reuploaded to Graasp where it recreates a space. The *vault* subspace contains the learning outcome of all students (for the teacher) and only personal production and traces in the personal archived copy which can be made by the student. The personal collection of inquiry learning spaces stored in *Graasp* can be considered as an ePortfolio, as it is persistent and can be freely shared by its owner(s) for temporary or permanent consultation or exploitation.
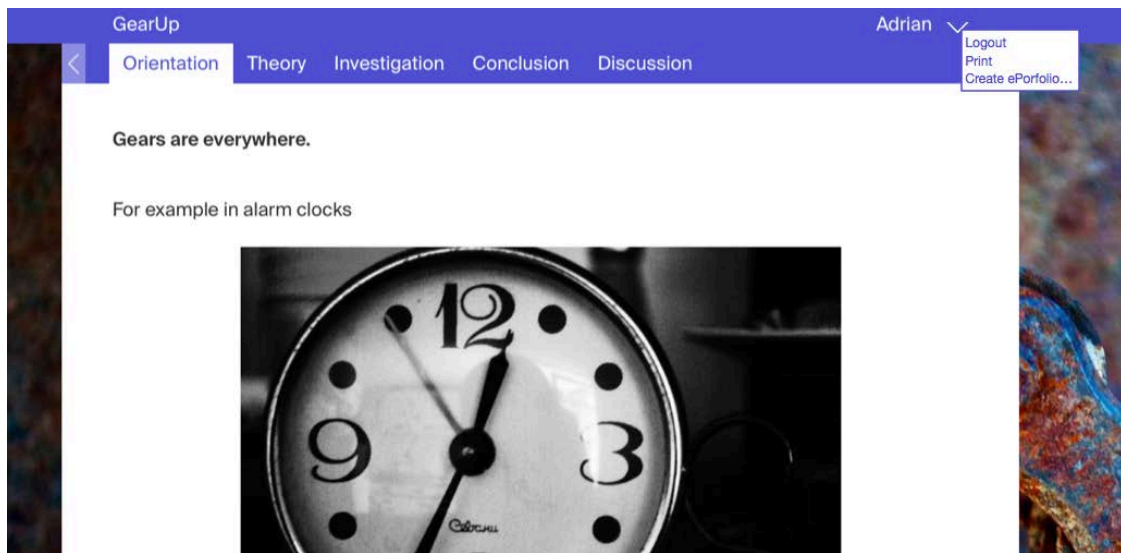
4.2   Mock-ups

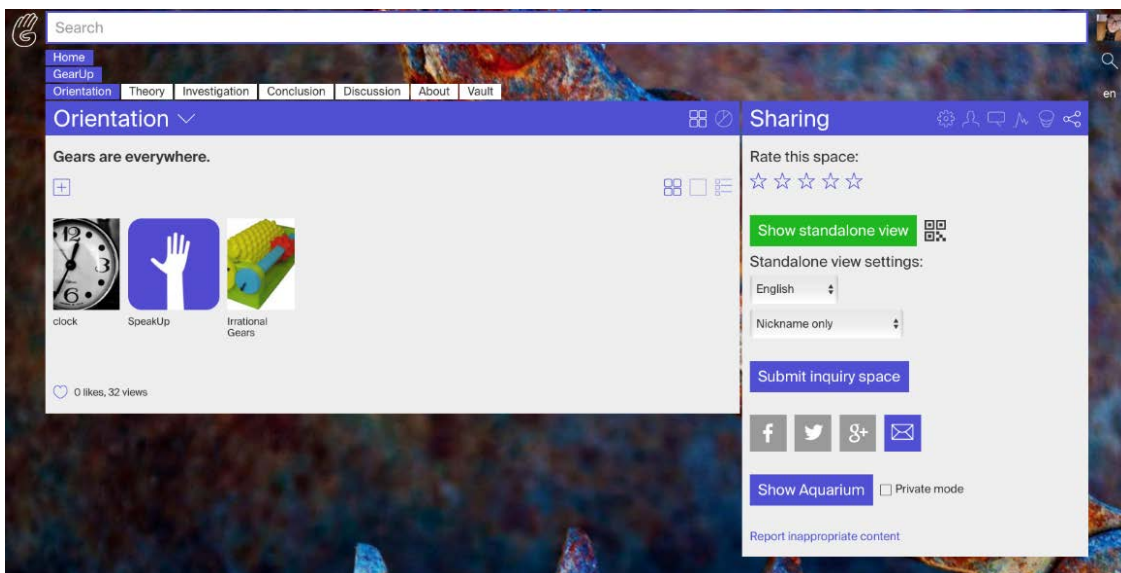**Figure 23. Student option to create an ePortfolio out of an ILS (Step 1)**

Figure 24. The student ILS gets persisted to Graasp, in a similar view to the teacher authoring view (Step 2)
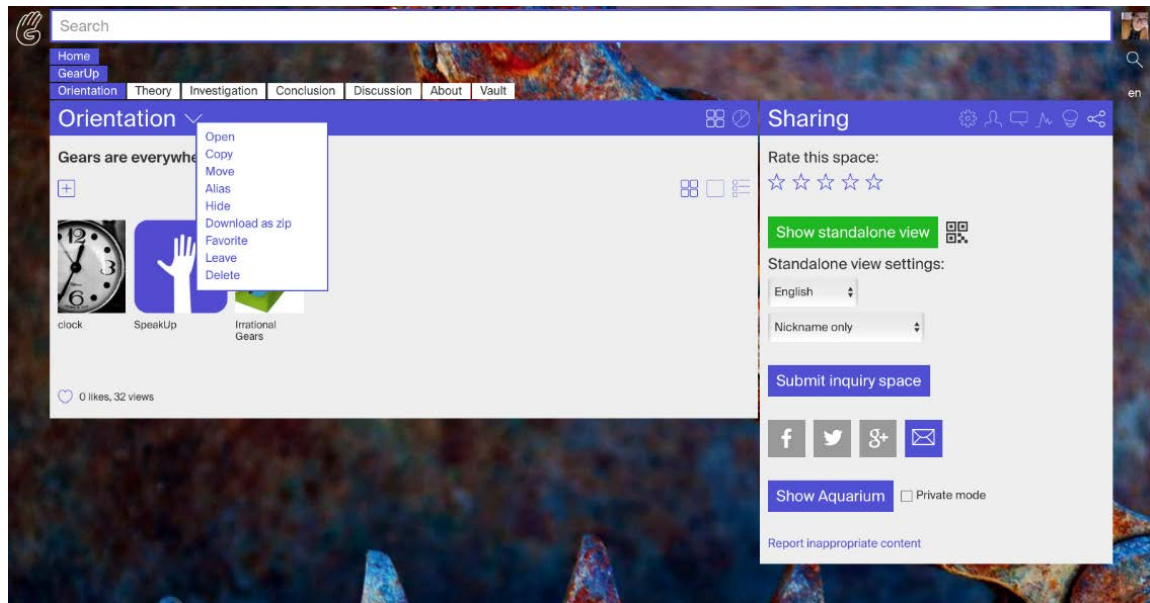
Figure 25. The student can further download the content offline as a zip (Step 3)

4.3 Outlook

There are several challenges associated with the implantation of the export and archiving features in terms of European privacy regulation compliance (can students below 18 year old create accounts on open educational platforms), ethics (who has temporary or permanent access to the content created by students in the context of a class (teachers, parents, hosting institutions, ...), who is managing the accesses (the teachers, the parents or the students themselves), how rights are transferred why students reach their age of majority, how to retrieve and store online content and apps integrated in inquiry learning spaces while complying with their various licenses, how to store the learning outcome of collaborative learning activities and handle its ownership, how to move from the anonymous exploitation scheme based on contextual nicknames to a sustainable access for identified users with permanent credentials (independent from institutional identity), how to guarantee the durability of information, just to mention a few dimensions. We will work on use in different contexts, including science education at school and teacher training at university.

More details regarding the usage of *Graasp* as ePorfolio have been published in [8].

4.4 References

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5. Modelling App

The modelling app allows students to create models of scientific phenomena from various domains, such as physics, biology, economics etc. These models are built by means of a graphical modelling language, and can be simulated to compare the expected behaviour with the model's behaviour. The models can be used to describe and simulate complex and emergent behaviour, such as predator-prey systems or the glucose-insulin regulatory system of the human body. In the following section, a set of requirements and specifications will be presented that have been carried together in the design of a Next-Lab modelling app. Section 5.2 describes the current state of the modelling app prototype, after which future developments are presented in an outlook.

5.1   Requirements and Specifications

For an easy adoption, the modelling app (in the following called "GoModel") should be based on the graph-based, visual modelling language System Dynamics, as described by (Forrester, 1968). System Dynamics – as a modelling language – is well known and already used in many curricular activities and contexts.

> *R1) The modelling app is based on the System Dynamics modelling approach.*

For intuitive functionalities and increased familiarity, the GoModel interface and modelling approach should be based on existing technology and applications, like Stella, Vensim, PowerSim, or SCYDynamics. These applications build upon a Stock-Flow notation, which can be specified with standard mathematical formulas. The model can be simulated and its output can be visualized as graphs.

> *R2) The modelling app's interface and user experience builds upon existing technology and modelling apps, e.g. on SCYDynamics or other existing System Dynamics modelling tools.*

> *R3) The learner-generated Stock-Flow models can be mathematically evaluated, and the results can be visualized as graphs.*

As modelling can be challenging and difficult to master for students, the modelling app needs to incorporate comprehensive and context-aware support features. For example, a mathematical expression might be invalid, the graph layout might not match the variables used in mathematical expressions, or the model might contain duplicate names. These problems (among others) can be easily detected and reflected back to the students.

> *R4) The modelling app supports the creation of a model by giving detailed feedback messages to the learner.*

To enable interoperability with other tools, and to be able to compare the modelling results with other data from physical experiments or with data from given datasets, the modelling app needs to be able to export simulation data – preferably in a format the is already been used in other Next-Lab apps.

> *R5) The modelling app can export simulation data. The data format is a "dataset", as it is already used e.g. in the TableTool or the Data Viewer app.*

To allow for a rich set of supported modelling activities, the modelling app should be configurable (by the teacher) in various ways. E.g., the modelling app could be configured to start with a given model, which can be incomplete, erroneous, or complete and correct. Also, the app might be configured towards a "simulation only"-mode, where students can simulate the model, possibly change variables, investigate the graphs and data, but not change the underlying model.

> *R6) The modelling app can be configured towards different starting models and modelling modes (like "simulation only").*

With respect to 21st century apps (see above), the modelling app is one candidate for synchronized collaboration, i.e., two or more students can co-construct a model simultaneously. A particular challenge in the realization of synchronized collaboration within the modelling app lies in its rather complex user interface (with modal dialogs and multiple tabs to show the model, the equations, or the graphs).

> *R7) The modelling app supports the co-construction of model through synchronous collaboration.*

5.2   Prototype

At the time of writing this deliverable, a prototype of the modelling app, called "GoModel" was already in a functional state[6] and has been used in participatory design activities, workshops, and Summer Schools. A first round of participatory design activities has returned useful results and suggestions for improvements, which have been included in this prototype (see Next-Lab deliverable D4.1, Section 7.1.1).

This section describes the current state of this prototype, along with screenshots, functionalities, and their relation to the requirements from the previous section.

The following screenshot (Figure 26) depicts the modelling tool's main interface. It shows the use of stocks, auxiliaries, constants, flows, and relations, as known from other System Dynamics modelling tools. The elements can be dragged from the menu bar to the left into the main modelling space, and double-clicked to change their properties (like name, colour, initial value, mathematical expression). Figure 26 shows a simple model of the exponential growth of a population.

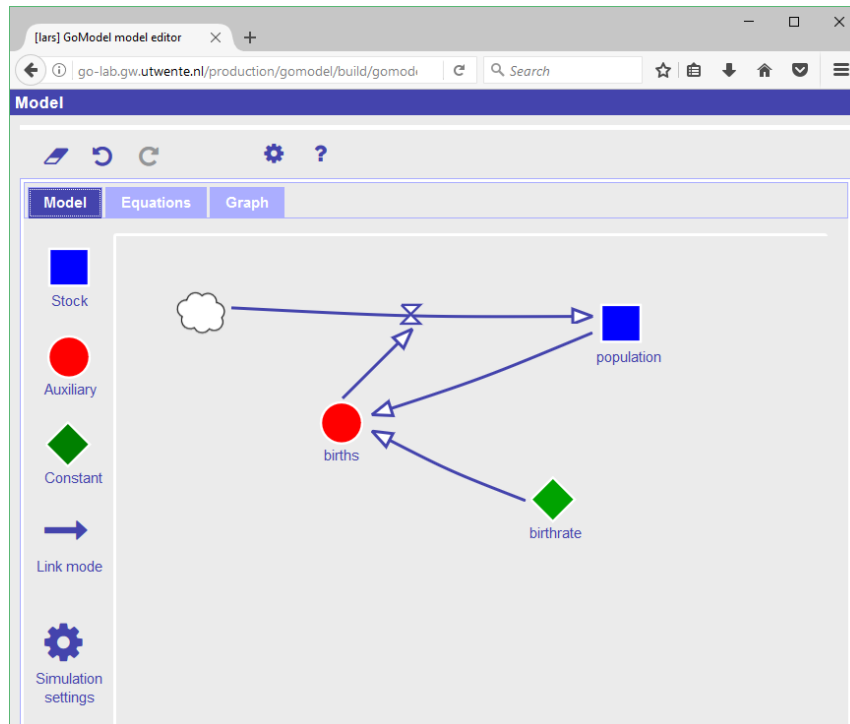[6]   The current state of GoModel is accessible at http://www.golabz.eu/apps/gomodel

Figure 26. GoModel main interface

The next screenshot (Figure 27) shows the graph which is created from this model. Each stock node and each auxiliary variable is shown as an individual plot in the according node's colour (in this example, blue for "population", red for "births"). A mouse-over information dialog shows the exact values in the graph.
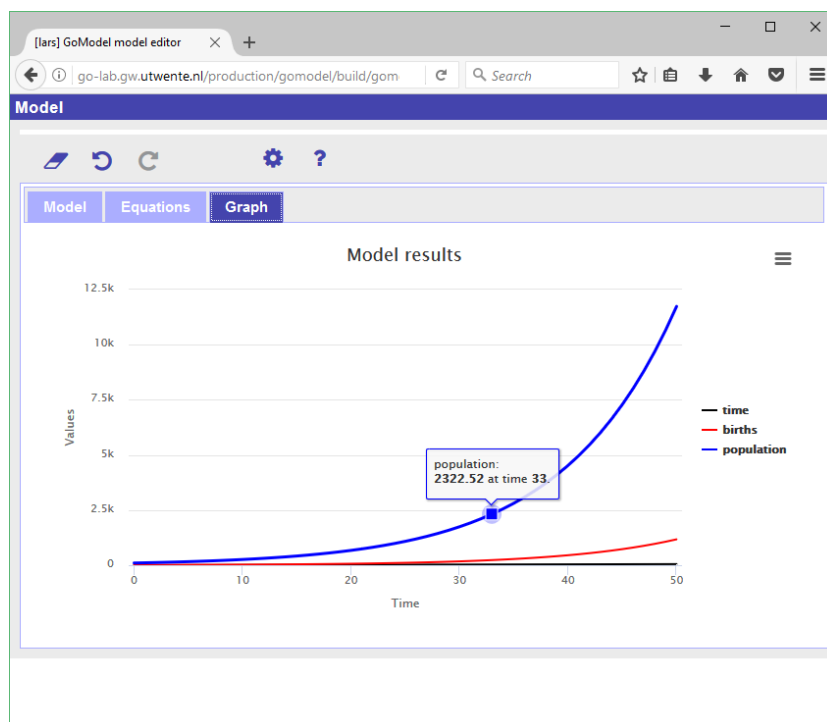

Figure 27. Graph created from the current model

The main modelling interface and the graph visualization cover the requirements R1, R2, and R3 (see section 5.1).

The following screenshot exemplifies the supportive feedback mechanism. In the settings dialog, the "Expression" field has a red border (indicating a problem or error in the model), and the mouse over message informs the user about a missing link in the model (from 'birthrate' to 'births').
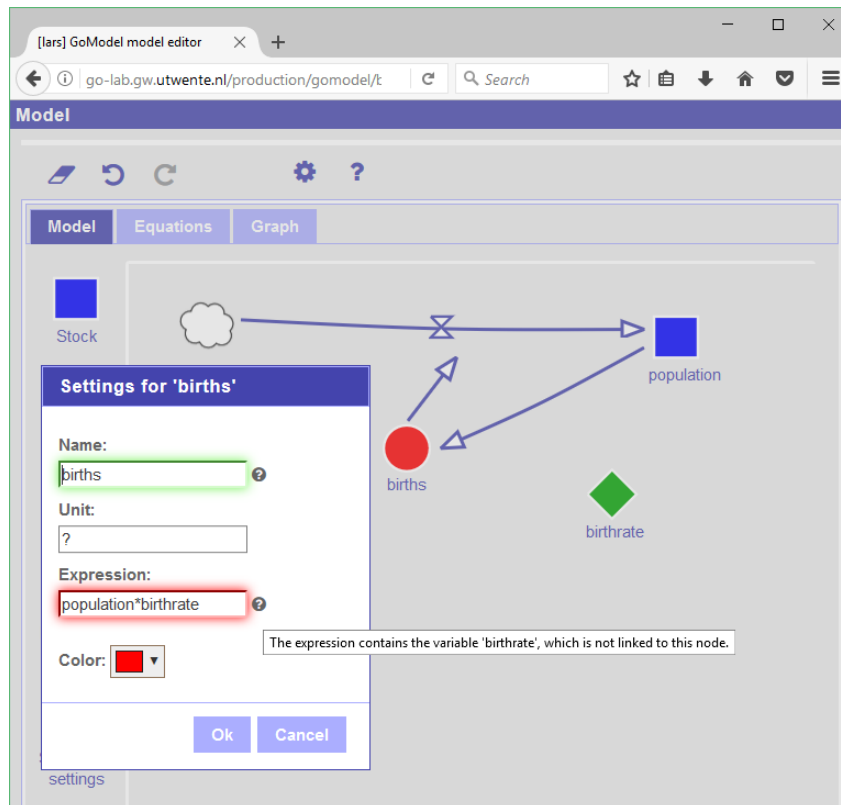

Figure 28. Supportive feedback messages during model construction

5.3   Outlook

Currently, the requirements R5 (export numerical data) and R7 (synchronous collaboration) are not implemented and will be added in future. Requirement R6 (configuration) is partly implemented, as it is already possible to define starting models for students (e.g. partial, complete, or erroneous models).

In certain circumstances, the simulation of complex models fails, which will be fixed in future.

Future results and experiences from participatory design activities, workshops, Summer Schools etc. will be used to further improve the set of features and usability of the modelling app.