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Executive Summary

This deliverable describes the pedagogical intervention model (cf. Mazziotti, Loibl, & Rummel, in press) underlying the technical development within the iTalk2Learn project (cf. D2.2.1 for sequencing and support, D3.1 for speech recognition, and D4.2.1 for the platform development), and thus accomplishes milestone MS4 (pedagogical interventions). With our intervention model we aim to help students develop robust knowledge about fractions. In order to develop robust knowledge, students need to gain procedural *and* conceptual knowledge, which evolve differently and require different types of instructional support (cf. D1.1). Procedural knowledge can be acquired through repeated practice and deepening of problem-solving procedures. In contrast, conceptual knowledge can be facilitated by providing students with exploratory learning activities and encouraging reflection. Therefore, students need to be provided with structured *and* exploratory learning activities for developing complete robust knowledge. In order to provide students with these different types of learning activities one of the main innovations within the iTalk2Learn project is to combine in our platform Intelligent Tutoring Systems (ITS) (suited for structured practice activities) with exploratory learning environments (ELE) (suited for exploratory learning activities). While we incorporate existing ITSs, we develop a new ELE as a second innovation of our project. D3.4.1 provides the technical details of the developed ELE; D1.2 describes the tasks provided in the ELE.

Combining these different learning activities within the different computer-supported learning environments is expected to have a high impact on pedagogical theory and practice. In particular, the combination of both learning activities aims to overcome the problem that learning just within either ITS or ELE tends to foster just one type of knowledge (i.e., conceptual *or* procedural knowledge). In particular, in the case of ITSs the criticism has been raised that due to the high degree of guidance and the “drill-and-practice” approach students gain procedural knowledge, but do not conceptually understand why they solved the structured practice task in the way they did. Our pedagogical intervention model that is presented in this deliverable forms the basis for the technical developments within the iTalk2Learn project by providing a guideline about how to combine structured practice (within ITS) with exploratory learning activities (within ELE). More specifically, the intervention model aims to shed light on the following three issues: First, should students start with a structured practice or an exploratory learning activity? Second, when to alternate between the different types of learning activities? And third, how to support students as they solve structured practice and exploratory learning tasks? In addition to providing a guideline for the optimal combination of exploratory learning activities and structured practice activities and their support features, this deliverable gives an outlook on the next steps in the iTalk2Learn project regarding pedagogical interventions that will be included in our platform. For instance, we are currently working on the possibility to provide students with so called task-independent support. The task-independent support that we are aiming to develop within iTalk2Learn goes beyond combining the two types of learning activities in order to optimize cognitive processes and addresses students’ attitudes and emotions during the learning process (cf. D2.2.1).

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List of Abbreviations

ELE Exploratory learning environment

FL Fractions Lab

FT Fractions Tutor

ITS Intelligent Tutoring System

LO Learning Objective

1. General Introduction

In iTalk2Learn the student interacts with a web-based learning environment to develop robust knowledge, which consists of procedural and conceptual knowledge. These two types of knowledge evolve differently and require different forms of instructional support (cf. D1.1). Within the iTalk2Learn environment students are asked to solve structured practice activities in an Intelligent Tutoring System (ITS) for enhancing procedural knowledge and to tackle exploratory activities in an exploratory learning environment (ELE) for gaining conceptual knowledge. While we develop the ELE, called Fractions Lab (FL), within the iTalk2Learn project, we incorporate existing ITSs for providing students with structured practice activities. As ITSs the iTlk2Learn platform integrates Fractions Tutor (FT) for German students and Maths-Whizz for English students. The built-in help functionalities (e.g., error feedback, hints) of these two ITSs (Maths-Whizz and FT) are also integrated in the platform and form one part of the task-dependent support. The help functionalities within the ELE, which we develop within the project, constitute the other part of the task-dependent support. While the combination of exploratory learning activities and structured practice activities (including their task-dependent support functionalities) focus on cognitive processes, we are currently investigating the possibility to further enhance the learning process by providing task-independent support that stresses students' attitudes and emotions. The just described client side of the architecture is displayed in Figure 1.

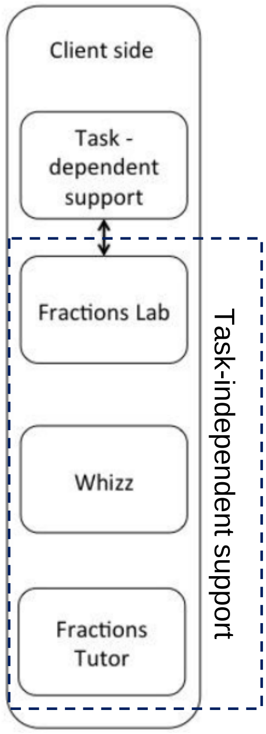

Fig. 1: Client side of the architecture of the iTalk2Learn platform

Since prior work in the learning sciences and educational technology has focused on fostering *either* procedural knowledge with structured practice activities (within ITSs) *or* conceptual knowledge with

exploratory activities (within ELEs), our pedagogical intervention model presented in this deliverables aims to exceed the existing literature by proposing to combine both learning activities. In doing so, the intervention model aims to facilitate both types of knowledge simultaneously and thus to gain complete robust student knowledge (as presented in Mazziotti et al., in press). Apart from providing the basis for combining both types of activities, the intervention model also includes the question of how to adapt support in such a combined setting. Thereby this deliverable strongly contributes to theory development in education. At the same time, this deliverable forms the pedagogical foundation for the technical developments within the iTalk2Learn project. In this way, the project puts educational research and theory development at its core and aims to go beyond showing prove of concept that the components of the developed platform work from a technical perspective.
In the following subsection we discuss the relationship of our pedagogical intervention model to the project in more details. In Section 2 we present the intervention model. We first briefly revisit how different types of knowledge can be fostered by different learning activities in ITSs and ELEs, we then give an overview and present the theoretical rational of the intervention model before illustrating the intervention model with case studies. Section 3 presents the conclusion, summarizes the key innovations and indicates the next steps that this deliverable enables to tackle.

1.1. Relationship to the project and innovations

One key innovation of iTalk2Learn is the combination of structured practice activities provided by an ITS and exploratory activities in an ELE. This combination poses two challenges for the project:

1. iTalk2Learn works on the technical implementation of integrating both learning environments, smoothly presenting them in one interface, and allowing students to switch between the activities of these learning environments without interrupting the process (WP4).
2. Combining two different types of learning activities also presents a major educational key innovation of the project. This challenge is addressed in the present deliverable.

Combining both learning activities is therefore at the same time promising and challenging. This pedagogical challenge on how to adaptively support both types of knowledge by defining a sequence for the different activities is tackled in the intervention model presented in this deliverable. In this regard, we address three open questions: How should students start when learning fractions with iTalk2Learn - with an exploratory FL activity or with a structured Maths-Whizz/FT activity? When should students switch between both types of activities? How to support students as they solve structured practice and exploratory learning tasks (i.e., task-dependent support)? Answering these questions achieves the milestone MS4 (pedagogical interventions). While the combination of the different learning activities including the task-dependent support focuses on cognitive processes, we are currently investigating whether an additional intervention which based on speech recordings focusses on students' attitudes and emotions can be integrated in the intervention model. This additional intervention is not linked directly to a specific task, but rather supports learners in their general learning process and is therefore called task-independent support. As it is not fully integrated in the intervention model yet, it is discussed at the very end of this deliverable under further steps.

2. Intervention model

2.1. Computer-supported learning environments to support robust learning

The two mentioned types of knowledge, procedural knowledge and conceptual knowledge, form the basis of robust learning (e.g., Rittle-Johnson, Siegler, & Alibali, 2001; for more detail see also D1.1). Both types of knowledge develop over the same period of time (e.g., LeFevre et al., 2006). They develop iteratively: increases in one type of knowledge lead to gains in the other type of knowledge, which in turn leads to increases in the first type of knowledge (cf. Rittle-Johnson et al., 2001). Since the development of the two types of knowledge relies on different types of activities and therefore requires different kinds of instructional support (Koedinger, Corbett, & Perfetti, 2012), we enable students to learn with different computer-supported learning environments (i.e. ITSs, ELE) suited for the different required activities. In the following sections we describe briefly how ITSs and ELE can help students to gain robust knowledge and how especially the task-dependent support of FL under development has the potential to further enhance students learning.

As described in detail in D 1.1 *procedural knowledge* can be acquired through repeated (structured) practice and deepening of problem-solving procedures (Anderson, Boyle, Corbett, & Lewis, 1990). Intelligent Tutoring Systems (ITS), for instance, offer students efficient instructional support for practicing problem-solving procedures, because within ITSs students are enabled to solve problems step-by-step, receive immediate feedback and hence can automatize the problem-solving procedure bit by bit (e.g., Anderson & Lebiere, 1998). In the context of the iTalk2Learn project we will integrate Maths-Whizz for UK students and FT for German students as ITSs to foster procedural knowledge. Both ITS and their build-in functionalities (e.g., feedback, hints) are described in detail in D1.1. In a nutshell, Maths-Wizz first presents a short introduction how to complete the following exercise successfully. Afterwards, students work through the exercise and receive feedback according to their answers and errors. In FT students solve fraction problems step-by-step and they receive immediate feedback (correct or incorrect) to each step. Students can ask for hints to get support. Both ITSs ensure that students receive the correct answer in the end. For structured practice tasks we integrate Maths-Whizz and FT including their build-in task-dependent support (i.e., feedback and hints as described in D1.1).

D1.1 and D3.2 described how by providing students with exploratory learning activities and by encouraging reflection and self-explanation, students are supported to abstract information, construct schemata, and hence develop *conceptual knowledge* (e.g., Koedinger et al., 2012). The iTalk2learn project has developed the ELE Fractions Lab (FL) with this in mind. The main objective of FL is to enable students to inspect and manipulate various fractions representations, investigate their relationships, explore the concept of equivalence and challenge their misconceptions on addition and subtraction. Example tasks with FL are provided in D1.2. D1.1 briefly summarised that the richness of ELEs comes at the cost of the necessary pedagogical support. This is usually provided in one-to-one or small-group settings making the integration of ELEs in the classroom difficult. D2.1 and D2.2.1 provide technical details of how support can be provided by an intelligent system in order to enable the implementation in a classroom (i.e., with several students at a time). As summarized in D1.1 a major challenge lies in how to guide students towards beneficial interactions with the ELE without compromising the exploratory potential. Therefore we develop task-dependent support for FL. The task-dependent support for FL is developed in iterative design and test cycles as described in D5.1. Our pilot studies with FL tasks confirm both the importance of the pedagogical strategies mentioned in D1.1 and Pólya's reasoning stages (Pólya, 1945) that emerged from the literature review in D2.1. These stages resemble the recursive and iterative problem solving processes involved in exploratory tasks, and they also reflect the strategies required to develop the conceptual basis necessary for robust mathematical knowledge (Schoenfeld, 1992). As described in D2.1, the different reasoning stages include:

1. *Understanding the problem and formulation of goals*
   Based on the understanding of the problem, goals have to be formulated in order to manage the exploration of the ELE. The formulation of goals determines the focus of the exploration.
2. *Devising a plan that includes certain tasks in order to achieve goal(s)*
   Once goals have been formulated, strategies for achieving them need to be devised, such as how to explore the ELE, including projected sequences of actions.
3. *Carrying out the plan/ tasks*
   This stage involves the execution of the plan or strategy to achieve the goals. It refers to a goal-driven exploration of the ELE.
4. *Reflecting on the plan and outcome*
   This stage involves reflecting on the effectiveness of the exploration, including whether the plan of action to achieve the goal worked well, or a new plan is needed. It also includes reflection on new knowledge which has been learned through the exploration. This could lead to new goal formulation due to the additional knowledge gathered concerning the problem domain.

The aim of the task-dependent support is to provide feedback according to these different reasoning stages. Accordingly, each of the tasks descriptions delivered under D1.2 provides the required information for developing the task-dependent support. The use case looks as follows: The student is confronted with a particular learning task. He or she reads and listens to the task and tries to understand the next steps necessary to deal with it. In order to come up with a plan of action, the student refers to his/her knowledge of the task. Let's assume the student has low knowledge of the task and struggles to formulate a plan of action. The task-dependent support then can provide some feedback to help the student formulate a plan of action, which takes into account the student's knowledge state. In an ideal case, the student would then carry out the plan. While the student is interacting with FL, the task-dependent support detects a misconception, based on certain actions undertaken. This is then used to provide support during the carrying out the plan phase. The student is, again ideally, able to overcome the misconception and finishes the plan of actions, also completing the learning task. At the end of each task, the student is asked by the task-dependent support to reflect on his / her performance, taking into account the misconception.

With respect to the intervention model presented in this deliverable the challenge is to use the task-dependent support within FL not only to provide help to the students directly during the task but as additional information for sequencing the tasks (both within FL, but also between FL and Maths-Whizz/FT). As task-dependent support is designed to help the student overcome some difficulties or misconceptions, the information that they receive help but have not managed to solve a task is pertinent in deciding either to provide another exploratory task that addresses a particular misconception or a structured task that can help with procedural knowledge. Therefore, in order to allow FL to provide information to the rest of the platform and particularly the sequencing and switching, there was a need to design the system in a way that provides access to sufficient unambiguous information in order to enable inference based on students' interactions (see D3.4.1 for more details).

2.2. Pedagogical interventions

As indicated in the introduction, the theoretical intervention model underlying the iTalk2Learn learning platform aims to answer three core questions:

1. Should students start with structured practice or with exploratory learning activities when learning fractions (equivalence, addition, and subtraction)?
2. How should the different types of learning activities be sequenced in this content area?
3. And how to support student when learning with the different activities?

Our intervention model for the iTalk2Learn platform addresses these issues. The first two questions are also discussed in a paper to be presented at the EARLI SIG 6 & 7 Meeting (Instructional Design & Learning and Instruction with Computers) 2014.

The flowchart (see Figure 2) below provides an overview of the different paths in the learning process. Note the following abbreviations in the flowchart: Fractions Lab (FL), Fractions Tutor (FT), Maths-Whizz (Whizz), and learning objective (LO).

2.2.1. How to start when learning fractions?

As Figure 2 indicates the student first needs to be familiarized with the platform and the tools at hand before starting with the learning tasks.

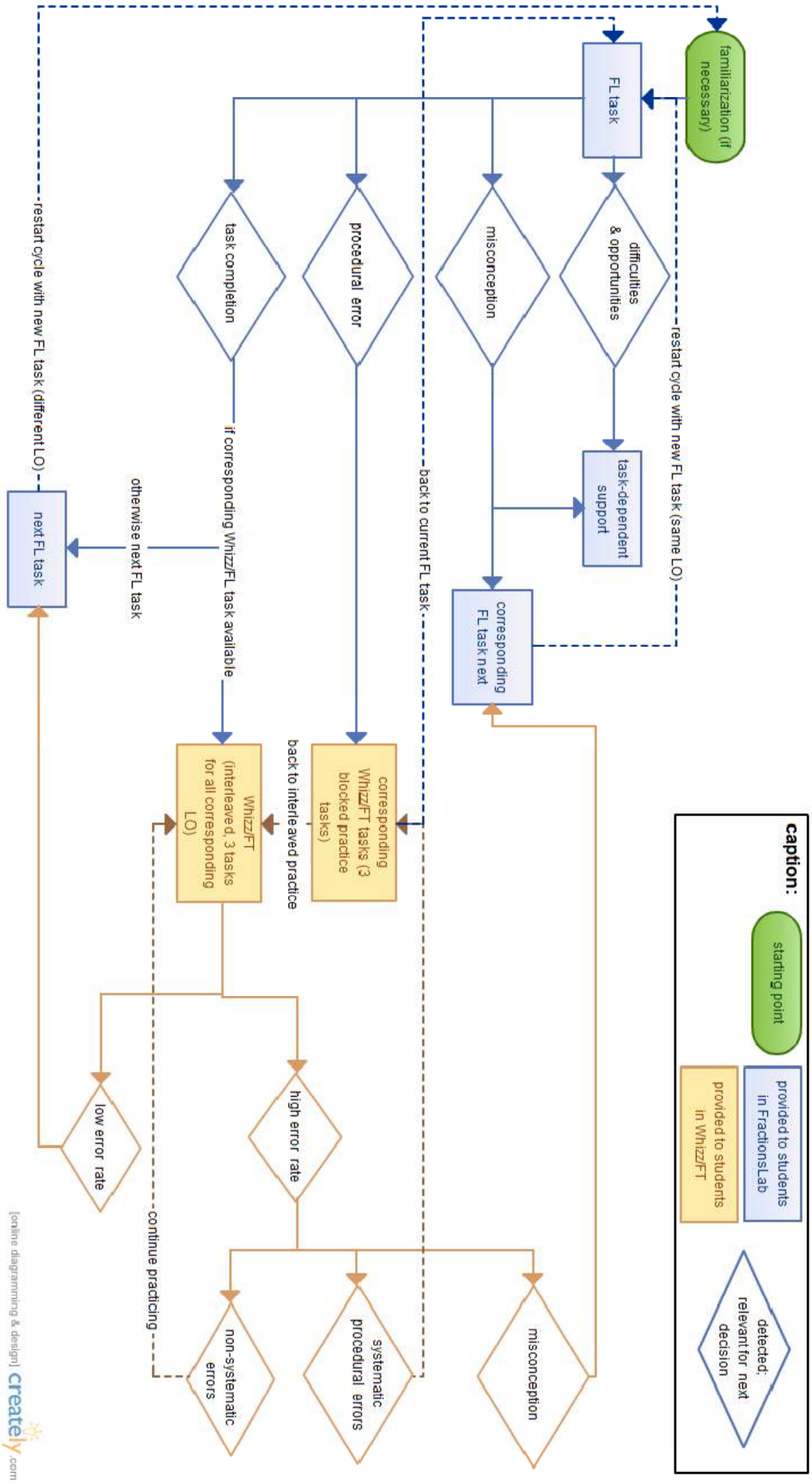

Fig. 2: Learning paths in the iTalk2Learn intervention model

Then the interesting question whether to start with a structured practice or an exploratory learning task comes into play. Based on the results of the Rational Number Project (RNP; e.g., Cramer, Behr & Lesh, 1997) - a research project about learning and teaching fractions - starting with an exploratory learning tasks should be favoured in this context. In over 20 years of research the RNP elicited four essential beliefs about how to best support students' learning fractions (e.g., Cramer, Post & delMas, 2002). One of these essential beliefs is that "teaching materials for fractions should focus on the development of conceptual knowledge prior to formal work with symbols and algorithms (Cramer et al., 1997)" (Cramer & Henry, 2002, p. 41). Since our exploratory learning tasks are designed to foster conceptual knowledge and the formal work with symbols and algorithms are comparable with structured practice activities in Maths-Whizz or FT, we argue that starting with an exploratory learning activity facilitates students' acquisition of conceptual knowledge. This conclusion is supported by findings on learning approaches, in which students explore the target concepts prior to receiving explicit instruction (e.g., Productive Failure: Kapur, 2012). These approaches have been proven effective for acquiring conceptual knowledge without inferring with the acquisition of procedural knowledge. Students' initial exploring is comparable with the exploratory learning activities within FL. Due to the high degree of guidance of the structured practice activities (i.e., direct feedback, hints), the explicit instructions of the above mentioned learning approaches can be aligned to the structured practice activities of the iTalk2Learn platform. In summary, we argue that students should start with an exploratory learning task when learning fractions in order to first facilitate the acquisition of conceptual knowledge without hampering the acquisition of procedural knowledge in the subsequent learning process.

2.2.2. How to sequence and how to support the different learning activities?

While students solve the exploratory learning task we monitor the student's progress. We aim at detecting difficulties, misconceptions, and procedural errors in order to provide students with a high degree of individualized support.

a) If we detect **difficulties** when students solve an exploratory task, we provide **task-dependent support** as described above.
b) If we detect a **misconception**, we also provide **task-dependent support** or for more severe misconceptions we select **another exploratory learning task which addresses this misconception**.
c) If we detect a **procedural error** (e.g., adding across numerator and denominator), the student is send to **Maths-Whizz or FT** for structured practice on this procedure. The student solves about three isomorphic tasks in Maths-Whizz or FT. The number of tasks to be solved will be adapted using performance prediction. Once the performance prediction predicts a high score on this type of task, the student returns to the exploratory learning tasks which they were working on.

Once the student successfully completes the exploratory learning task and presses the next-button the next task is selected. If there are no Maths-Whizz or FT tasks that correspond to the learning objectives of the just completed exploratory learning task, then the student continues with the next exploratory learning task targeting the next learning objectives. However, if there are structured practice tasks that correspond to the same learning objectives as the completed exploratory learning task, the student gets a structured practice task (from Maths-Whizz or FT) to practice the corresponding procedure. The decision to prioritize structured practice after the completion of an exploratory task is based on the mutual dependence of the acquisition of conceptual and procedural knowledge (Rittle-Johnson et al., 2001) and the aim to foster both types of knowledge iteratively. Thus, students should switch from exploratory learning activities to structured practice activities when procedural errors are detected or students have completed the exploratory task. In this practice phase different tasks that all correspond to different learning objectives are presented in an interleaved sequence (i.e., one task of each type followed by again one task of each type etc.) for the following reasons.

In light of the ACT-R theory (Anderson & Lebiere, 1998) and the power-law-of-practice (Newell & Rosenbloom, 1981), students should be provided with more than a single structured practice task, because students need more practice to become fluent in the application of the problem-solving procedure. However, Rohrer and Taylor (2006) could show that nine in comparison to three practice problems only lead to very little benefit. As a first approach, we therefore propose to provide students with a set of three isomorphic structured practice tasks after each exploratory learning task. If the previous exploratory learning tasks addresses several learning objectives (which usually seems to be the case), than we have interleaved practice of structured tasks that fit these learning objectives (Roherer & Taylor, 2006; Schmidt & Bjork, 1992; Rau, Aleven & Rummel 2013). Interleaved practice has been shown to yield more robust learning (e.g., Rohrer, 2009). Only if we detected a specific errors or knowledge gap which is procedural in nature or can be resolved with practice, we first provide blocked practice of tasks that fit this error/knowledge gap. Blocked practice results in quick (but less robust) learning (e.g., Rohrer, 2009).

In iTalk2Learn, the precise sequence of the tasks is selected by the machine-learning performance prediction described in D 2.2.1. The performance prediction also helps to select the next steps.

a) If the performance prediction predicts **low scores for only one specific type of task** (i.e., systematic errors), the student moves to a **blocked sequence** of this specific type of task as described above. After mastering this type of task, the student continues with interleaved practice.
b) If the performance prediction shows **low scores overall**, we try to distinguish between misconceptions and non-systematic procedural errors. If we detect a **misconception** that hampers the performance on these procedural tasks, the student is send to an **exploratory learning tasks that addresses this concept**. Whereas, if the student makes **non-systematic procedural errors**, he or she **continues practising**.
c) Once the performance prediction predicts **high scores for all** these tasks, the student continues with an **exploratory learning tasks on the next learning objectives**. If this task requires the use of different tools, the students first receives a short familiarization with these tools before working on the task.

So students should switch from structured practice to exploratory learning tasks if the student lacks the conceptual knowledge needed for successfully working on the structured practice task (cf. b) In doing so, the student is able to re-explore the concept prior to solving further structured practice tasks. This assumption again is supported by the above-mentioned belief of the RNP (e.g., Cramer & Henry, 2002) that the development of conceptual knowledge should precede formal work with symbols and algorithms (comparable with the problem-solving procedure applied in the structured practice activities). With "sending" the student back to the exploratory learning tasks when encountering misconceptions (cf. b) or successfully solving the structured tasks successfully (cf. c), the circle of combining structured practice and exploratory learning activities restarts.

2.3. Case studies illustrating the different interventions

Based on our observations during our formative trials (the outcome of the trials will be described in detail in D5.2) we describe three case studies reflecting "typical" students. The names of the students do not correspond to actual students. As explained above all students start with an exploratory learning activity.

Student 1: Tim
During an exploratory task Tim demonstrates a conceptual misconception and is given another exploratory task to address this misconception.

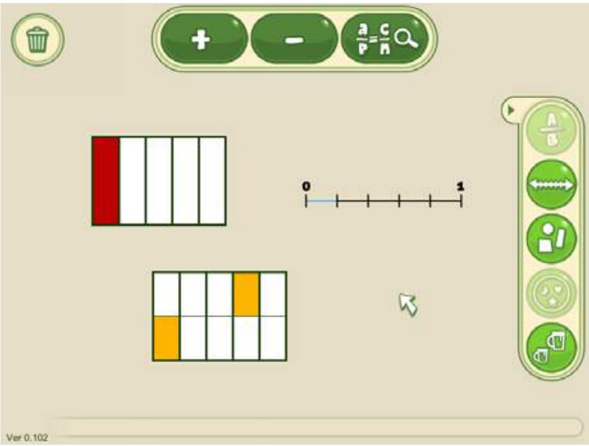

Fig. 3: Example 1 for an exploratory learning task

Tim's exploratory task (see figure 3) is to make three fractions equivalent to ¼ (cf. Coarse Goal 2 in D 1.2). However, he has produced three fractions that are equivalent to 1/5. This indicates a possible misconception where Tim does not take into account that the denominator shows the total number of divisions in the whole. Instead, he is showing 1 part to 4 parts (ratio interpretation) rather than 1 part out of four parts (part-whole interpretation) (see Appendix D1.2 for further discussion). In order to address Tim's misconception he should be provided with a further exploratory task helping him to overcome this misconception. Therefore, this next tasks (see figure 4) encourages Tim to develop his conceptual understanding in fractions as part of a whole (cf. Coarse Goal 1 in D 1.2).The exploratory task asks Tim to make 1/3 using each of the representations. Tim produces the following:

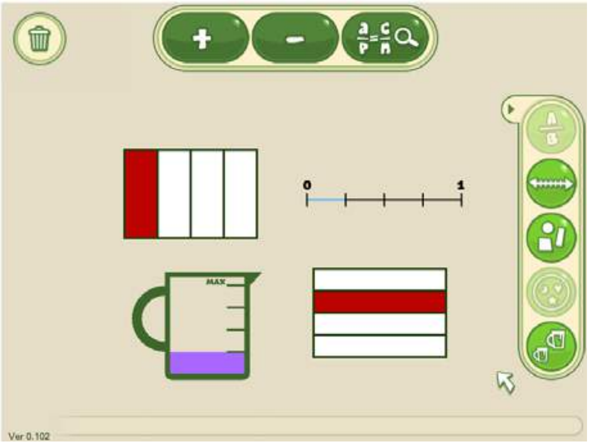

Fig. 4: Example 2 for an exploratory learning task

Again, Tim's misconception is observable. Task-dependent feedback is given to him and he amends the fractions, reflecting verbally on his change in thinking.

Student 2: Laura

During an exploratory task Laura makes procedural errors and is given a structured task to address this.

Laura is completing an exploratory task that requires her to identify how full a jug was before a certain amount was poured out (cf. Coarse Goal 3a in D 1.2).

The expected solution involves o – p = r, where o = original amount, p = amount poured out and r = remaining amount and o is the unknown. However, instead of finding the correct solution she erroneously subtracts: p – r = o. This is a procedural error related to solving the problem and not a misconception. This is a procedural error and not a misconception, because Laura struggles with applying the problem-solving procedure (an not the concept) correctly. Laura receives a structured practice task that supports her understanding of finding the missing fraction in subtraction.

Student 3: Ruth

Ruth successfully completes the exploratory learning task, with some task-dependent feedback, and is given some related structured practice tasks that are interleaved (= set of structured practice tasks addressing different learning goals, e.g., subtraction, equivalence, addition).

Ruth receives first the following exploratory learning task (see figure 5) (cf. Coarse Goal 3b+ in D 1.2): "Clara used number lines to add fractions. She made the fraction here using two fractions. Can you make it too, using the 'join' tool?"

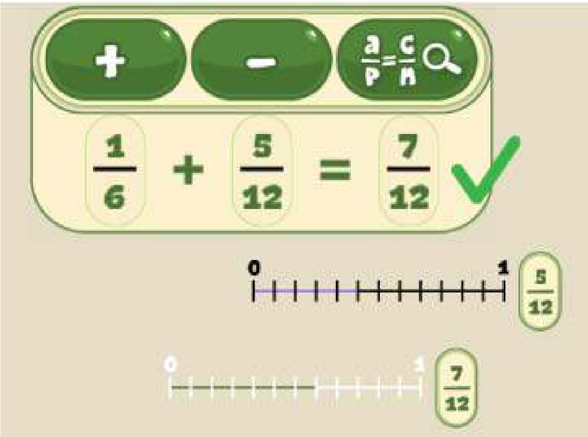

Fig. 5: Example 3 for an exploratory learning task

Initially Ruth constructs two fractions on number lines: 1/6 and 5/12 and attempts to add them together. She receives task-dependent feedback reminding her that the two fractions she is trying to add need to share the same denominator. Ruth quickly changes 1/6 to 2/12 using the partition tool in FL and goes on to find the solution.

She receives a set of Maths-Whizz structured practice tasks (see figure 5 to 11) that are interleaved to enable further practice:

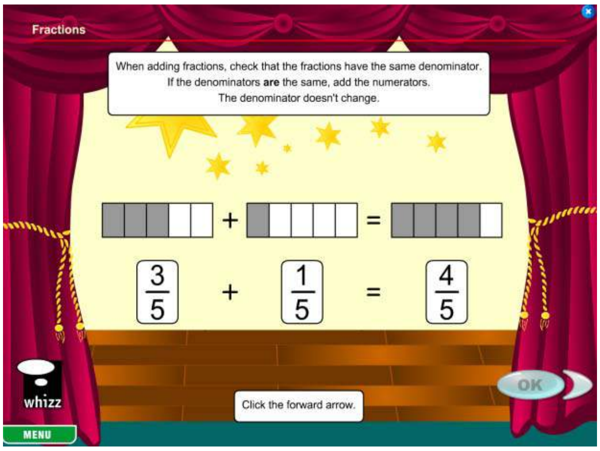

Fig. 6: Example 1 for a structured practice task within Maths-Whizz

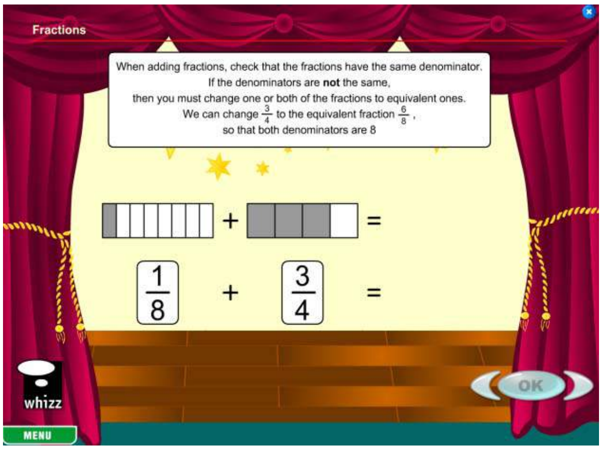

Fig. 7: Example 2 for a structured practice task within Maths-Whizz

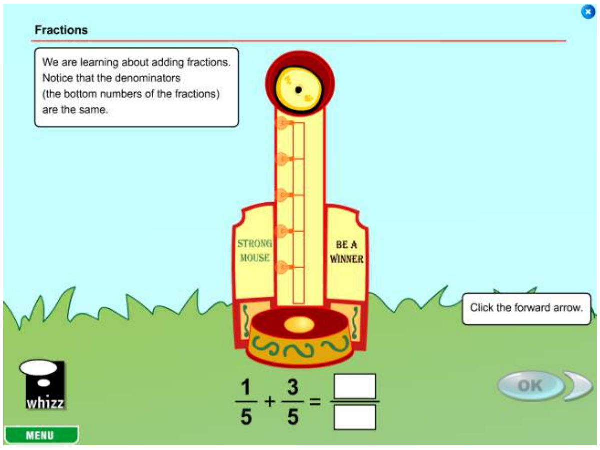

Fig. 8: Example 3 for a structured practice task within Maths-Whizz

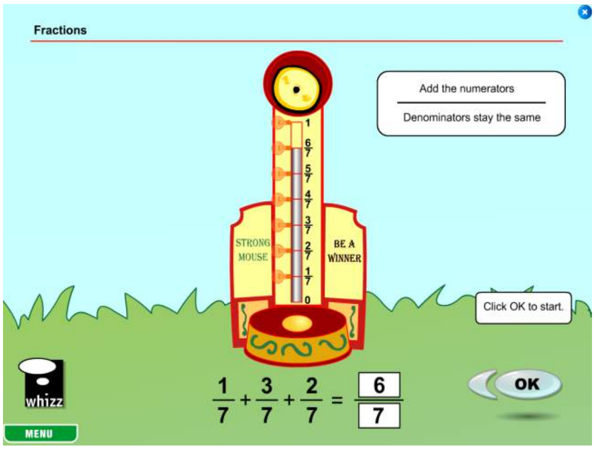

Fig. 9: Example 4 for a structured practice task within Maths-Whizz

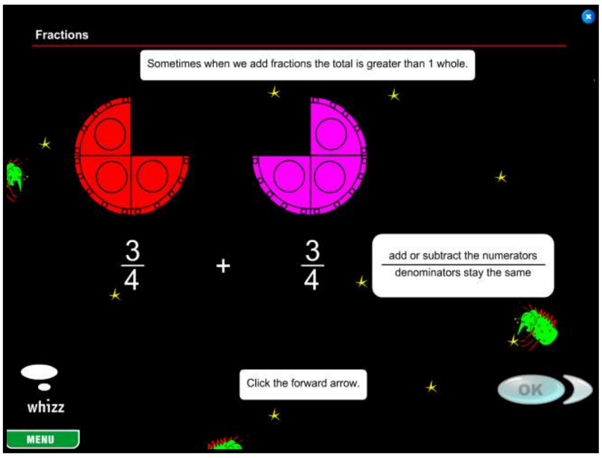

Fig. 10: Example 5 for a structured practice task within Maths-Whizz

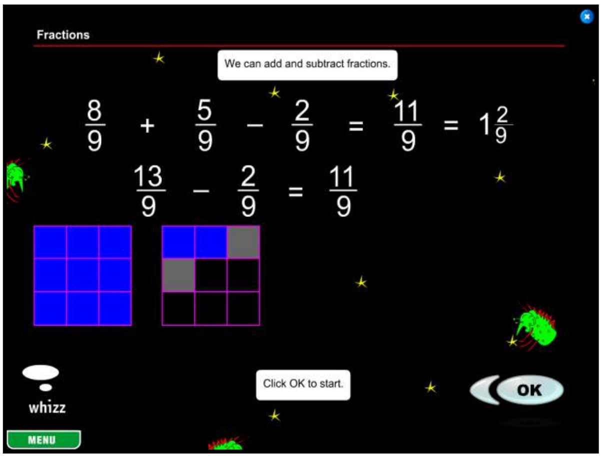

Fig. 11: Example 6 for a structured practice task within Maths-Whizz

The three case studies illustrate different interventions that can be selected when students encounter difficulties when working on an exploratory learning task. These interventions depend on the type of students' difficulty. Ruth received task-dependent support, Laura moved to structured practice tasks to learn a specific procedure and Tim received a different exploratory task to tackle a misconception. Similar students receive different interventions when working on structured practice tasks: they receive hints and feedback from the ITS when entering a wrong answer or getting stuck, they receive blocked practice to practice specific procedures or they move to an exploratory task to tackle a misconception. As indicated in the flowchart, the whole process is a cycle that restarts with new learning objectives once students master the current learning objective.

3. General conclusion and implications for iTalk2Learn

3.1. Strengths and innovations

Our intervention model provides an overview of how to combine exploratory learning with structured practice activities. In particular, we shed light on the following three issues. How to start when learning fractions: With structured or exploratory learning activities? When to alternate between exploratory learning and structured practice activities? Additionally, the intervention model focuses on how students can be supported while they solve structured or exploratory learning tasks (i.e., task-dependent support). With regard to the structured practice tasks we revert to the support which already exists in Maths-Whizz and FT (i.e., error feedback, hints). For the exploratory learning tasks in FL we develop support within the ELE.

Based on students' performances our innovative intervention model allows us to provide students with individualized support on two different levels:

1. The first level concentrates on the optimal task selection. Indeed, students are provided with tasks or learning activities, which exactly address students' individual knowledge gaps. In doing so, the iTalk2learn intervention model considers when and how many tasks of specific type (i.e., structured or exploratory learning tasks) helps students to overcome their individual knowledge gaps. For example, if a student still needs to practice more intensively the problem-solving procedure for adding two fractions he or she will be provided with additional structured practice tasks targeting this problem-solving procedure. Furthermore, if we detect a conceptual misconception as students solve structured practice tasks the respective student will be provided with an exploratory learning tasks in order to (re-)explore the concept underlying the particular problem-solving procedure.
2. The second level, in which individualized support comes into play, is the task-dependent support within Maths-Whizz, FT, and FL. The commonality across the task-dependent support of all of the iTalk2Learn components lies in the possibility to receive just-in-time feedback and to ask for hints. So also on this finer grained level of interaction students are provided with individualized support.

Combining these levels reflects one of the key innovations of the iTalk2Learn platform and has a high impact on theory development. In particular, the question of how structured practice and explorative learning activities should be combined and sequenced in order to effectively foster robust learning is central to instructional design research. Furthermore combining both learning activities addresses the more general criticism towards students learning with ITSs. Since most of ITSs allow students to solve problems step-by-step and to receive immediate feedback, they tend to foster procedural knowledge more efficiently than conceptual knowledge. As we have mentioned earlier, fostering procedural knowledge is just one side of the robust knowledge coin. With addressing also the other side of the coin, namely fostering conceptual knowledge by providing students with exploratory learning activities, we aim to overcome this criticism. Since already existing ITSs are nearly as effective as human tutors (Van Lehn, 2011), we expect that our iTalk2Learn platform with its particular strengths may be even more effective.

3.2. Next steps

3.2.1. Technical implementation

While the pedagogical intervention model described in this deliverable already forms a strong contribution to educational research and theory development, for the iTalk2Learn project the next crucial step is the technical implementation. As described in D5.1 and in line with the design based research approach we integrate and test single components of the iTalk2Learn platform iteratively. Therefore, we plan to conduct Wizard-of-Oz studies in the next weeks and months. These Wizard-of-Oz studies aim to simulate the system's adaptivity regarding especially the task-dependent support for the exploratory learning activities and the selection of tasks. The results of these studies together with the theoretical intervention model provide the basis for the technical realization of the integrated platform.

3.2.2. Task-independent support

Additionally, we investigate whether task-independent support that addresses students' attitudes and emotions can further enhance the learning process. The aim of the task-independent support is to use the children's speech (while they solve structured or exploratory tasks) to detect students' attitudes and emotions and to provide feedback accordingly. We further investigate how this task-independent support can be integrated in the intervention model which so far focuses on cognitive processes.

As described in Kort et al. (2001) emotions interact with and influence the learning process. While positive emotions such as awe, satisfaction or curiosity contribute towards constructive learning, negative ones including frustration or disillusionment (for example when realising misconceptions) can lead to difficulties. The learning process includes a range and combination of positive and negative emotions. For example, a student is motivated and expresses curiosity in exploring a particular learning goal; however, he or she might have some misconceptions, generating a need to reconsider her/his knowledge. This can evoke frustration and/or disappointment. However, the negative emotion can be transformed into curiosity again, if the student develops a new idea on how to solve the learning task. The different emotions expressed in learning can be linked to the learner's personal goals. For example, Ahmed et al. (2013) describes how a match between personal goals and learning tasks produces positive emotions such as enjoyment, whereas a mismatch produces negative emotions, such as boredom. Additionally, the understanding and knowledge of the learning task can influence the setting of a personal goal. For example, if the student has high knowledge of the learning task, he or she might experience low challenge in formulating a plan of action to perform that task, and this could lead to boredom. In contrast, if a student's knowledge is matched to task demands, the personal goal might be better aligned with the task and the student could enjoy the activity as a result. Boekaerts (2007) describes how positive affect and positive self-appraisal leads to effort, which can enhance performance.

In the task-independent support we focus on emotions that arise during a learning situation. The emotion detector is based on the achievement emotions described in Pekrun (2006). Achievement emotions are emotions that are linked to learning, instruction, and achievement. Emotions are classified into prospective, retrospective and activity emotions. For the task-independent support we concentrate on the activity emotions that arise during learning. They can be positive or negative. A positive activity emotion is enjoyment, while a negative activity emotion is anger, frustration, or boredom. From a Wizard of Oz study (described in D5.1) we detected two additional emotions (surprise and confusion) which were not included in Pekrun's activity emotions, but seem relevant for the task-independent support. The negative activity emotion anger from Pekrun's classification could not be detected. Therefore, the following five emotions are included for the task-independent support: enjoyment, surprise, confusion, frustration and boredom.

The task-independent support aims to change a negative emotion, such as frustration or boredom, into a positive emotion, like enjoyment by boosting emotional confidence in structured tasks (Maths-Whizz and FT) and in supporting alignment of the student's personal goal with the learning task in exploratory learning tasks (FL). In order to do so we provide students with hint messages like "It may be hard, but keep going.". So far, the task-independent support focusing on students' attitudes and emotions works on the top of our cognitive intervention model. However, students' attitudes and emotions may also be relevant to decide on the next intervention selection (e.g., providing a structured activity, if students get too frustrated or bored with the exploratory activity and vice versa). By investigating how the task-independent support can be integrated in the intervention model, iTalk2Learn takes at the same time emotional *and* cognitive processes into account. This approach represents an additional innovation of the project.

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