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# Bridging Diagnosis and Learning for Mathematics Education in Classroom Settings

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## Abstract
Research on digital learning environments has recently advanced in two directions: diagnosis driven approaches and approaches that allow for flexible learning opportunities through open interaction formats. Prior research regarded both dimensions independently. However, a linkage of the two approaches is highly desired for every day classroom settings. We contribute a concept for an integrated diagnosis and interaction-centered environment that makes use of the existing social classroom network. We derive research questions and describe both the planned evaluation and future work.

## Keywords
Classroom setting, diagnosis and learning, mathematics, knowledge sharing, peer feedback

## ACM Classification Keywords
K.3.1 Computer Uses in Education: Computer-assisted learning (CAI).

## General Terms
Design, Human Factors

## Introduction
Quite a number of learning systems for mathematics have been developed to support classroom learning in mathematics. Some of these systems are experimental environments that leave lots of freedom to the students but cannot track the students' performance [6]. They are useful for initial learning processes, taking into account both depth and complexity of a domain and promote conceptual and competence-oriented learning. Other systems focus on learning of a very narrow part of a competence, like specific mathematical skills that are trained in interaction between a learner and a computer and are assessed step by step [8]. In the latter case, an Intelligent Tutoring System operating on a knowledge base checks the students' solutions, e.g. numerical inputs or predefined choices. These systems do not go beyond practicing skills and abilities of a domain. Moreover the assessment results of such systems remain unconnected to instructional adaptation. Finally most of the systems are designed for the interaction between a single learner and a computer.

However, learning research shows that a vivid learning and achieving of mathematical competence is complex. Beside individual work with the content, it requires the interaction between (a) students and teachers and (b) among students to develop procedural skills, flexible knowledge and understanding [9]. In order to support rich and connected learning, teachers need to track the students' individual development to make adequate didactic decisions. In learning research this type of diagnosis is called formative assessment [2]. In order to support interactive learning that goes beyond single-learner settings learning environments need to allow for the integration of the classroom setting.

Current computer-based tools for educational support that allow for diagnostic assessment lack (i) the integration of depth and complexity of a domain, (ii) the support for interaction between students and teachers and among peers and (iii) the flexible adaptation to specific classroom's situation [8,10]. In order to address those shortcomings, three requirements can be deduced: (1) concepts that address a rich concept of learning while keeping track of the student's performance, (2) beneficial integration of computer-based and human-based activities and (3) flexible entanglement of diagnosis and instruction.

In this paper, we contribute PEDALE (Peer-based Diagnostic And Learning Environment), an integrated concept for teaching and learning of "Functions and Graphs" [1] in intermediate level mathematics education that addresses the aforementioned requirements. The rest of this paper is structured as follows: first we outline the concept of PEDALE and discuss its characteristics. We then deduce open research questions and conclude the paper with outlining an evaluation concept.

## Concept

PEDALE, a peer-based diagnostic and learning environment, aims at bridging diagnosis and learning in computer-supported classroom settings. It uses a sophisticated model for the diagnosis and development of competencies of "Functions and Graphs" as a fundament. The characteristics of PEDALE are aligned alongside three different design dimensions:

*(1) A rich learning concept while keeping track of the students' performance*

A model of competence development and diagnosis is used as a fundament for the computer-supported learning environment. The model results from a 3-year research project and is carefully reviewed and empirically validated. It covers the competence development of lower secondary class students in the domain of "Functions and Graphs" [1]. The focus is on the heuristic use of basal mathematical representations, i.e. numeric, graphic, algebraic and verbal representation (*n*, *g*, *a*, *v*) and the transfer between them as a key to mathematical problem-solving and modeling. The model covers the competence of transferring between mathematical representations on different levels of activity. The HEUREKO model was worked out according to extensive empirical research based on a pool of 80 task items tested with a sample of 872 students. Rasch analyses showed that a four-dimensional model (*n*, *g*, *a*, *v*) with three levels of activity (identifying, realizing and explaining & reasoning) serves as the best predictor [1]. The first two levels of activity (identifying and realizing) can be automatically analyzed by a computer.

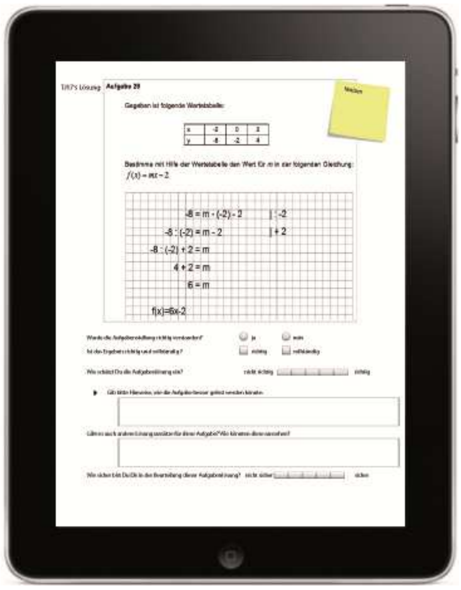


Figure 1: Peer-assessment interface with a solved problem and a review template. The template contains both open and closed questions. Moreover, it allows peers to directly comment on the sketched approach.

*(2) Entanglement of individual learning, teacher-student interaction and peer interaction*

The higher level questions (explaining & reasoning) cannot be assessed automatically. Tasks of that level are generated from the previous tasks and are given to peers as so-called solved problems [5]. This new type of task is an enhancement of the existing item pool and competence model. It prompts students to compare and evaluate the peers' solutions regarding quality, correctness and alternative solutions. This can be carried out directly in-class using for instance novel mobile devices. Featuring a large screen and convenient input capabilities, such devices allow peers to efficiently interact with the overall system even in-situ. Figure 1 shows an interface mock-up for the iPad. Previous task solutions are now given to the students for a review (see Fig. 2).

Peer review allows for open question formats and the expression of students' individual concepts of mathematical content. This further supports teachers diagnosing deeply and individually by documenting students' reflection on solved problems. Teachers can re-trospect students' answers on two diagnostic levels (problem solution and evaluation of a peer's problem solution).

For learning, there are three more benefits: First, learning takes place while viewing other student's solutions and reflecting the own approaches. Second, the own knowledge can be set in relation to others' know-ledge and to a problem solution a student was not aware of. While being taught by peers and by teaching peers, students practice Learning by Teaching [4]. Third, students gain higher skills in self-regulated learning and social competencies by giving and recei-ving feedback, sharing knowledge and using group structures.

*(3) Bridging of diagnoses and corresponding instruction*

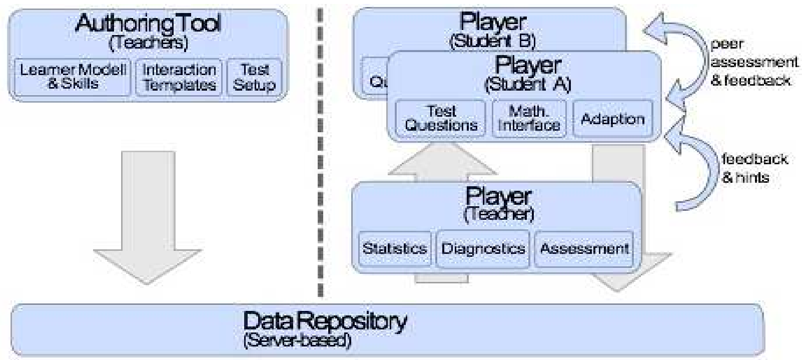


Figure 2: The model of interaction with PEDALE

PEDALE aggregates relevant diagnostic data to help teachers decide the next instructional steps. The technical environment allows for diagnosis and diagnostic documentation as well as learning units within one application. Our solution is an authoring software (based on StoryTec [3]) that allows teachers without programming skills to create own content for test units. The application's behaviour can be configured for different requirements of the target class (e.g. types of tasks and adaption behaviour). The application comes with a player (BatCave [7]) for running the environment, the user data and providing individual quantitative measures and qualitative information to teachers.

## Conclusion and Future Work

PEDALE is a novel peer-based diagnostic and learning environment. While previous work focused either on automatic diagnosis or on flexible learning through open interaction in the classroom, PEDALE bridges this gap by providing adaptive instructional data and utilizing peer-assessment. We plan to evaluate PEDALE in a repeated measure design which will be lead by two main scientific interests:

1. Does the tool work as a reliable and valid formative diagnostic instrument? Does it generate data that is meaningful for teacher's instructional decisions?
2. Does the tool help foster learning, regarding the domain-specific learning? Does it teach while it assesses? Are there benefits regarding social, self-regulated learning and student motivation?

The diagnostic quality of the tool will be investigated using measures of validity in relation to the paper-pencil test in a control-group design. The learning progress after using the tool will be evaluated by pre-, posttests and student interviews. The effects of social relations for giving and receiving feedback will be finally assessed by Social Network Analysis.

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