PROJECT EOM – THE USE OF DIGITAL TOOLS FOR AN ACTIVATION OF CONCEPTUAL-CHANGE-PROCESSES AT MATHEMATICAL MISCONCEPTIONS

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Abstract

Project CODI – Conceptual Difficulties of functional relationships – by Nitsch [1] investigated typical learning difficulties in the field of linear and quadratic functions, especially with the transformation from graphical to situational descriptions. Nine systematic errors were found within more than 10% of the learners. Systematic errors are relatively stable and occur at every different task of the same type of question. The Graph as Picture error (GAP), as an example for the mentioned transformation, occurred again six months later at 43.3% of all students with this diagnosed misconception in the pre-test [2].

Intuitive images seem to affect initial solutions and interfere with mathematical ideas and patterns of mathematical acts. They so lead to stable misconceptions. To overcome this situation, Conceptual-Change-processes [3]) are going to be initiated by a digital feedback. That is one part of a digital given task with a special design: the DDTA – Digital Diagnostic Task [4].

My Project EOM – E-Feedback to Overcome Misconceptions – is connected to the running project of the DDTA and researches the possibilities to design computer-based feedback by the use of digital instruments to activate Conceptual-Change-processes.

This E-Feedback has to be fitted to the learner individually, it will appear automatically, uses different kinds of multimedia options and it should be able to activate Conceptual-Change-processes in the learner’s mind.

The long-dated aim of the project is an independent online-tool, which can be used by teachers for mathematical diagnosis but simultaneously stimulates the learning processes of the students. A proposal for an E-Feedback with the use of a video-tutorial will be presented.

Keywords: Misconceptions, learning difficulties, Conceptual-Change, digital media, video.

1 INTRODUCTION

“To make a diagnosis, to assess or score a performance and to support are major competences of teachers, who successfully teach their pupils these days” [5]. However, time is one of the greatest issues a teacher has to deal with. In Germany, the field of linear and square functions is taught in classes 8 or 9 for the first time [6]. Especially these topics are very important for further and successful learning in upper classes and to receive the higher education entrance qualification. These topics are therefore recapped in the beginnings of classes 9 and 10 to make sure, every student is at an equal level with similar competences in comparison to the others. Because of the pressure of time, this revision goes with teacher-centred lessons and without any internal differentiation. But exactly this differentiation is necessary [7]. Since 1982 and longer “it [became] a commonplace belief that learning is the result of the interaction between what [a] student is taught and his current ideas of concepts” [8], so every student has other requirements and competences.

The goal of the presented project EOM – E-Feedback to Overcome Misconceptions – is the development of learning environments to overcome misconceptions in the field of functional relations by the use of computer-based feedback. A basic feature of a tool called the Digital Diagnostic Task DDTA [4] is the usage of an individual feedback with options for further learning. This expands the field of usage of such exercises by the learning part. Project EOM concentrates on special feedback elements, that are individual fitted to the learner's behaviour, that appear automatically, that use different multimedia opportunities and that activate Conceptual-Change processes [3] at the learner.
2 CURRENT KNOWLEDGE ABOUT ERROR PATTERNS

Project EOM as well as project DDTA uses the results of Nitsch’s [1] project CODI – Conceptual Difficulties in the field of functional relationships. At the Technical University of Darmstadt, she developed an online-tool in 2015 to diagnose typical learning difficulties in the field of linear and square functions including an automatically evaluating plugin for both teachers and their students. Additionally, in this project she uses theoretical conceptions of the occurrence of error patterns.

One of her thematic focuses was the transformation from graphical to situational descriptions of mathematical functions. The tool consists of 24 different multiple-choice test items, each with defined types of errors. In her study Nitsch found nine systematic errors (Tab. 1) within more than 10% of the learners.

<table>
<thead>
<tr>
<th>Transformation</th>
<th>Field of function</th>
<th>Error-Code</th>
<th>Misconception</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA</td>
<td>Linear</td>
<td>FGAL3</td>
<td>Focus on points of interceptions with the axes</td>
<td>25.7</td>
</tr>
<tr>
<td>SA</td>
<td>Linear</td>
<td>FSAL1</td>
<td>Confusion of slope &amp; y-intercept</td>
<td>12.7</td>
</tr>
<tr>
<td>GA</td>
<td>Square</td>
<td>FGAQ2</td>
<td>Algebraic sign mistake at the shift in x-direction</td>
<td>11.6</td>
</tr>
<tr>
<td>GA</td>
<td>Square</td>
<td>FGAQ8</td>
<td>Parameter a hast been left out</td>
<td>13.4</td>
</tr>
<tr>
<td>SA</td>
<td>Square</td>
<td>FSAQ1</td>
<td>Wrong plug in of the coordinates of the vertex</td>
<td>13.4</td>
</tr>
<tr>
<td>SA</td>
<td>Square</td>
<td>FSAQ2</td>
<td>Algebraic sign mistake at the shift in x-direction</td>
<td>12.3</td>
</tr>
<tr>
<td>GS</td>
<td>-</td>
<td>FGAP1</td>
<td>Graph-as-picture-error</td>
<td>16.0</td>
</tr>
<tr>
<td>GS</td>
<td>-</td>
<td>FSHC1</td>
<td>Slope-height-error</td>
<td>10.0</td>
</tr>
<tr>
<td>GS</td>
<td>-</td>
<td>FSHC1/SHCR</td>
<td>Epistemological obstacle: slope at on single point</td>
<td>36.0</td>
</tr>
</tbody>
</table>

Systematic errors are relatively stable and occur at every different task of the same type of question. There are at least two items per specific error (distractor), so that there is a need to define systematic errors. Nitsch defined an error as an error pattern or systematic error, if a student makes the same mistake in at least either case. She concentrates on these learning difficulties that are related to conceptual knowledge and she assumes that they can be identified by analysing systematic errors in contrast to random errors. The reason is that misconceptions, as some kind of conceptual knowledge, reveal in consistent error patterns.

In the following picture a skier is skiling down the hill. Decide which of the given graphs describes the situation best.

The function value \( v(t) \) gives the velocity at the time \( t \).

\[
\begin{align*}
\text{Graph-as-picture misconception} & \quad 43.4\% \\
\text{Nitsch, 2015}
\end{align*}
\]

This article is going to focus on the Graph as Picture (GAP) misconception ([9], Fig. 1), as one example for one of the mentioned transformations from a situational to graphical description. It is
interesting, because 43.3% of all students, who had this misconceptions, made the same error in a post-test six months later again [2]. The GAP error happens, if the graph is interpreted as a real image of the situation. So, in this task, which asks for the velocity of the person with skis as a function of time, students choose the graph, that is most similar to the elevation profile of the slope. Interviews indicated, that especially in this transformation, there are everyday experiences that influence the student's concepts or “mental models” [10] and so their decisions.

This verifies the stability of that misconception and emphasizes the strong influences of everyday experiences. Because of the systematic nature of that misconceptions, they can be shown in test-exercises.

3 THEORETICAL BACKGROUND: CONCEPTUAL-CHANGE-THEORY

The Conceptual-Change Theory assumes that especially in the field of mathematics and scientific topics preconceptions of everyday life play an important part in influencing further learning [3].

First, there are different notions for the various facets of misconceptions because of the previous knowledge, all with different emphases. There are “misconceptions”, “initial models” [11] or “preconceptions” [12]. Nersessian characterises those “mental models” as follows:

“A mental model is a conceptual system representing the physical system that is being reasoned about. It is an abstraction – idealized and schematic in nature – that represents a physical situation by having surrogate objects of entities and properties, relations, behaviours, of functions of these that are in correspondence with it” [10, p. 409]

So, Conceptual-Change Theory springs from a constructivistically view of learning. The learning process is more likely a reorganization of pre-knowledge that is being linked to additional elements. There new knowledge-concepts enable students to do predetermined mental activities [13].

If there are incorrect or incomplete pre-concepts, they influence students’ behaviour in answering the test-items and patterns of error can be diagnosed. Mostly these students aren’t able to overcome those misconceptions for themselves. External factors have to initiate a conceptual change for example by causing a discrepancy [11] that can’t be solved anymore [14]. Sinatra et al. wrote:

“Learning about biological evolution presents particular challenges for students. Barriers to learning come in form of students’ prior conceptions that conflict with the scientific perspective of biological change. (...) Helping students understand evolution is not simply a matter of adding to their existing knowledge, but rather, it means helping them to see the world in new and different ways” [12].

In my project, Feedback is to be used as an external factor and impulse to initiate some kind of conceptual change processes.

4 DESIGN AND ELEMENTS OF PROJECT EOM

These feedback elements are going to be used within the frame of a DDTA, an online-diagnosis-tool that connects all mentioned elements: the diagnostic task, the clarification of students’ mistakes and the opportunity to give feedback to the students’ answers (Fig. 2).

![Figure 2. DDTA – Digital Diagnostic Task](image)

One additional feature of the DDTA is the use of devious task-routes for students, who make an error in a particular task. In this routes elemental mathematical elements of the prior given task are verified to improve the diagnosis of the learner [15, 16]. The other one is the use of the STACK question type plugin for the digital learning management system moodle, a “sophisticated assessment (…) with emphasis on formative assessment underpinned by [a] computer algebra” [17] system. It is used to generate automatic feedback, that by now concentrates on a differentiating clarification of mistakes and the “knowledge of correct result (KCR)” [18]. Project EOM is going to link to that and extend the feedback in various ways.
Referring to different researchers, the most common classification for the different types of feedback is the differentiation between No-Feedback, Knowledge-of-Result (KOR), Answer-until-correct (AUC), Knowledge-of-Correct-Result (KCR) and Elaborated Feedback [18, 19]. Within the mentioned online-situation of E-Feedback, that is meant to initiate any conceptual change, E-Feedback in project EOM is more likely to be elaborated feedback including more elements than right or wrong. So E-Feedback in EOM is going to look like

“Feedback = Verification + Elaboration (Type, Form, Load)” [19].

For being an “effective feedback” [20] or “formative feedback” [21] a few things have to be considered. Hattie and Timperley [20] said, that feedback has to answer 3 questions at 4 different levels:

<table>
<thead>
<tr>
<th>Questions</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Where am I going?</td>
<td>1. Task level</td>
</tr>
<tr>
<td>4. Self level</td>
<td></td>
</tr>
</tbody>
</table>

In addition with the literature research of Shute [21] and her features of formative feedback, different E-Feedback-designs will be evaluated (see also Fig. 3). Therefore in addition to the decision whether to use immediate or delayed feedback, one important part will be the influences of the personal and performance characteristics of the learners, according to the “learner’s initial state” of Bangert-Drowns et al. [22] or Shute [21].

Therefore, in a pilot study for EOM, various E-Feedback elements are focalized. They all differ in the use of different media such as videotapes, animations, interactive plugins such as Geogebra and so on. **How do students react to the different medial implementations and which one is the best for a special type of learner are only two of more unanswered questions.** A first try of an E-Feedback for the
GAP misconception was implemented in the form of a video. This video first tries to generate contradictions with the concept of a student and then provides different other views of the topic. The experiences of the students with those Feedback elements are supposed to be collected by the help of interviews analyzed after that.

The objective is to apply an automatic E-Feedback in the main study that is individual fitted to the respective students, that uses different multimedia implementations according to which type of misconceptions was diagnosed and that initiates Conceptual-Change processes. To answer my research question if it is possible to develop a special learning environment by the use of computer-based feedback to overcome misconceptions in the field of functional relationships there are still a few unsolved issues I have to deal with.

The main problem will be to individualize the automatic feedback elements. There must be gathered information about the traits and beliefs of test-subject to do so, but it is possible to identify them distinctly? If it is possible, which of the different media implementations is the best one for a specific characteristic? Are there any differences anyway?

Another important question is, how it will be possible to proof, if conceptual changes were activated or initiated exactly by the implemented E-Feedback elements. There is a first idea to administer the test three times, a second time just after the prime one and a third time a while later to verify long-time effects.

In the end an online-tool shall be formed that used by teachers or students autonomously.

REFERENCES


[18] Dr. Bernhard Jacobs, “Aufgaben stellen und Feedback geben,”


