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► To cite this version:

Sophie Tittel, Karina Höveler, Franziska Tilke. Developing digital scaffolding modules to support oral description skills - Results of a teacher survey. Twelfth Congress of the European Society for Research in Mathematics Education (CERME12), Feb 2022, Bozen-Bolzano, Italy. hal-03748983

HAL Id: hal-03748983

<https://hal.science/hal-03748983v1>

Submitted on 10 Aug 2022

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Developing digital scaffolding modules to support oral description skills – Results of a teacher survey

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Oral descriptions of mathematic phenomena are indispensable for mathematic conversations in primary school but pose challenges for learners on a conceptual and linguistical level. Digital media offers potential to foster the oral descriptive skills, but the application of digital language scaffolding in mathematics has not been researched yet. Therefore, a digital scaffolding tool addressing primary school learners' oral descriptions of mathematical patterns and structures using the app 'Book Creator' is being developed in a design research project following the Integrative Learning Design Framework. This paper reports on teachers' evaluation of a prototype and its already implemented design principles, in order to identify implications and suggestions for the development in further micro-cycles. Results show that the current version is considered to be fruitful for primary school learners already but should be revised concerning the linguistic level and the cognitive activation.

Keywords: Digital scaffolding, Language in mathematics education, Design research.

Introduction

Oral descriptions are a very important part of communication in primary school mathematics as they lay the foundation for sharing different approaches to solve problems, explanatory statements and lines of reasoning, however, the necessary linguistic and conceptual requirements are challenging for many learners (Maisano, 2019). One possibility to promote language – including oral descriptions – in the mathematic classroom is by providing scaffolds according to the learners' needs. It has been shown that digital scaffolding that focusses on both the language and the mathematical content has positive effects on the students' math test scores and their math self-efficacy (Freeman, 2012). However, there are no findings yet whether digital scaffolding also has a positive impact on the students' language use in the mathematic classroom as seen from a commognitive perspective (Sfard, 2008). To fill this research gap, our design research project 'DeScriBe', following the Integrative Learning Design Framework (Bannan, 2013), aims at micro-cyclically developing and researching a digital scaffolding tool to promote the learners' descriptive skills with the app 'Book Creator' (<https://bookcreator.com>). This paper presents the development process of prototypical digital language supportive modules as well as results of a Local Impact Evaluation (Bannan, 2013) by teachers to assess the language supportive modules' technology-specific design principles' (DPs) fruitfulness for the learners' learning processes as well as the usability of the digital scaffolding tool.

Implications of oral descriptive skills for mathematical learning

Oral descriptions in the primary mathematics classroom can verbalize observable patterns and structures and therefore promote the children's understanding of the mathematic contents while simultaneously promoting the language skills themselves (cf. Lüken & Tiedemann, 2019). According to Sfard's (2008) commognition framework both thinking and talking about mathematics are communication processes, the former on an intrapersonal level, the latter on an interpersonal level.

This fusion of cognitive and communicative processes shows that language is required to both think and talk about mathematics and that communication is an integral part of doing mathematics. As such, communication is subject to determined routines in the process of mathematizing between the interlocutors (Sfard, 2008). A long-term-goal of mathematics education is to enable learners to explain mathematical patterns and structures. These explanations are based on the description of a mathematic phenomenon, the procedure of describing a phenomenon therefore needs to be established as a routine in the classroom. Since there exists a relation between the proficiency in the academic language and the access to knowledge and a successful education respectively, there is a mathematic educational interest in fostering the school or technical register (Tiedemann, 2015). Functional and generalized descriptions cannot be expressed in an everyday register (cf. Prediger & Wessel, 2013). The necessity to use a school or technical register to express these descriptions can however be challenging, especially for primary school learners. A promotion of oral descriptions is therefore necessary to lay the foundations for future explanations and argumentations. Teachers should make their context-specific linguistic norms explicit (Tiedemann, 2015) and include the student's progress related to the educational code in self-evaluations and feedback (Hammond & Gibbons, 2005). Besides the linguistic demands, oral descriptions also require a conceptual understanding of the phenomenon that is to be described, therefore language promotion should always go hand in hand with the mathematic content (Prediger & Wessel, 2013).

Fostering oral descriptive skills - analogue and digital

Scaffolding consists of specific support measures provided by more experienced persons that help learners reach their zone of proximal development (Hammond & Gibbons, 2005). Successful analogue measures that can also serve as the basis for digital language supportive modules in an adapted form are – among others – the inclusion of the learners' progress related to the educational code in self-evaluations and feedback, provision of transparency of the expectations as well as the use of different representational means that help the learners to structure their learning process (Erath et al., 2021). A checklist allows an integration of these facets as it is both a tool to work with for the learners as well as a synopsis of important aspects of a good oral description. In relation to specific tasks, it has been proven to be useful to offer sentence phrases and guidelines for formulations as well as posters with the necessary vocabulary and thus provide linguistic models (Erath et al., 2021). However, the limit of the analogue fostering of the oral descriptive skills is reached when learners cannot use a written linguistic support due to an uncompleted acquisition of the written language or insufficient reading comprehension. This problem is pervasive in primary schools (Mullis et al., 2017).

Digital scaffolding generally uses the same strategies as analogue scaffolding but offers additional opportunities by using text-to-speech technology (TTS) or linked scaffolds in hypertexts. Both features support learners with difficulties in the written language (Dalton & Strangman, 2006). Referring to Mayer's (2007) cognitive theory of multimedia learning, the use of digital media, which enables the combination of different media, such as pictures, videos, texts, TTS and audio samples can help students to engage in meaningful cognitive processes. Audio recordings with the voice memo function of a tablet can be played back multiple times and therefore avoid that the volatility of oral utterances might hinder teachers and learners from precisely evaluating the descriptions.

The project ‘DeScriBe’

For the reasons given above, the project ‘DeScriBe – Digitale Sprachförderbausteine für das mündliche Beschreiben mathematischer Strukturen’ (digital language supportive modules for oral descriptions of mathematical structures) aims at developing and researching a digital scaffolding tool to foster oral descriptions of mathematic structures. To develop the ‘digital scaffolding’, the project follows the design research approach of the Integrative Learning Design Framework (Bannan, 2013). This framework encompasses the four phases of Informed Exploration, Enactment, Local Impact Evaluation and Broad Impact Evaluation that are conducted in iterative micro-cycles to cover “the entire scope of research from initial conceptualization to diffusion and adoption” (Bannan, 2013, p.116). While the Informed Exploration phase built the theoretical base for the development, in the Enactment phase design principles and a first prototype of the language supportive modules were developed. The current Local Impact Evaluation phase puts to test, whether the developed design is usable, accessible, efficient and supports learning, by having different stakeholders rate the design which may then lead to the next micro-cycle for improvement (Bannan, 2013). This paper presents the theory-based development of prototypical digital language supportive modules as well as results of a Local Impact Evaluation by four teachers. As experts and stakeholders for the future adoption of the digital language supportive modules in the classroom, they test and review the digital scaffolding tool as well as the potential and challenges of the already implemented DPs.

The analysed potential of digital tools for scaffolding oral descriptions led to the formulation of the following language supportive modules and corresponding technology-specific DPs (Table 1):

Table 1: Language Supportive Modules and Design Principles

Language Supportive Modules	Design Principles (DPs)
Digitalisation of a Checklist for a Good Oral Description (Module 1)	<ul style="list-style-type: none">• Interactive Feedback (DP 1.1)• Linking of Supportive Means (DP 1.1)
Digital Support for the Development of Meaning-Related Language (Module 2)	<ul style="list-style-type: none">• Multimedia-Based Relation of Different Representations (DP 2.1)• Digitalisation of Task-Specific Scaffolding Means (DP 2.2)• Digital Differentiation (DP 2.3)

Enactment phase – Functionality of the digital scaffolding and implemented design principles

The digital language supportive modules are realised in the app ‘Book Creator’, a tool for effortlessly creating and sharing digital books. ‘Book Creator’ has been chosen due to its degree of popularity in German primary schools and its features (<https://bookcreator.com/features/>) that offer opportunities to overcome the limits of analogue scaffolding by integrating different media, TTS, linking pages to avoid difficult orientation to find the desired scaffolds and sending scaffolds via Airdrop or a QR-Code which allows a use in the classrooms as well as in distance learning settings or for homework. In the current version of the scaffolding tool, two DPs have already been implemented: ‘Linking of Supportive Means’ (DP 1.2) and ‘Multimedia-Based Relation of Different Representations’ (DP 2.1). In the following we will outline the central features of the prototypical tool and how it can be used to support learners’ competencies in orally describing mathematic patterns and structures.

The DP ‘Linking of supportive means’ has got the subject-specific aim of providing scaffolding elements according to the learners’ personal needs to allow content- and language-integrated mathematical learning (Prediger & Wessel, 2013). This aim should be reached by using the digital potential of hyperlinks as well as dialoguing and controlling interactivity (Hillmayr et al., 2020). It is implemented in the language supportive module ‘digital checklist’ and realised through the button “Tips” that leads to specific scaffolds of the respective aspect of the checklist (Figure 1).

Checklist ✓
for a good description of mathematical structures

	This is important	This is how I think I'm doing	This is where I want to improve
Using mathematic terminology			
You are describing, <u>what</u> is changing in the structure.	😊	😐	😞
You are describing, <u>how</u> the structure is changing.	😊	😐	😞
You are using <u>mathematical terms</u> , that you learned in class or knew before already.	😊	😐	😞
Speaking in complete sentences			
You are speaking in <u>complete sentences</u> .	😊	😐	😞
You are using <u>different beginnings of the sentences</u> to make the order explicit.	😊	😐	😞
You are focussing on <u>what is happening</u> , and not on who is doing something	😊	😐	😞
Understanding the mathematical structure			
You are trying to make your description <u>it would be possible to transfer it to another situation</u> .	😊	😐	😞
You are describing <u>how the parts of the structure</u> are connected together.	😊	😐	😞
You are concentrating on <u>what is important</u> in the mathematical structure.	😊	😐	😞

Design-principle ,Linking of supportive Means‘
Immediate offer of fitting support

Design Principle ,Multimedia-Based Integration of Different Representations‘
Integration of text-to-speech-technology, videos, pictures etc.

Describing links in the structure
Maybe it might help you for your description to have a look at what has been considered while solving the task.

Try to find the missing numbers.

0 | 48 | 6 | 32 | 42 | 36 | 30
0 | 18 | 4 | 12 | 2 | 6

6 + 6 = 12

Figure 1: Implementation of DPs in the Digital Scaffolding Tool (translated screenshots)

The DP ‘Multimedia-Based Relation of Different Representations’ aims at the subject-specific goal of changing and relating registers (Prediger & Wessel, 2013). This aim should be reached by using the digital potential of the TTS (Dalton & Strangman, 2006), multiple external and linked representations (Walter, 2018) and by shifting learning processes to allow more capacities to focus on the mathematical content (cf. “cognitive load theory” in Chandler & Sweller, 1991). This DP is realised by enriching the digital checklist and scaffolds (that could generally also be used in an analogue form) via different related media, like audio samples, videos, TTS etc. (Figure 1).

Research questions and methods of the Local Impact Evaluation

The main goals of this Local Impact Evaluation were to assess the fruitfulness of the implemented DPs as well as to check the usability of the basic functions already available in the language supportive modules to compile aspects that should be considered when developing digital language scaffolds and to improve the design of the digital tool in the following micro-cycles. Teachers were interviewed as experts since they are competent in rating the helpfulness of (digital) scaffolding measures according to their learners’ needs. In addition, it was expected that as stakeholders they could think about possible extensions of the scaffolding tool on a meta level and therefore provide useful ideas for the future development. The following questions were leading: (1) What potential and challenges do teachers see in the implemented DPs? (2) How do teachers rate the usability of

the basic functions in regards to their learners' experiences with digital tools? (3) Which additional functions are desired and suggested by teachers with regard to the support of oral descriptive skills?

The data collection was based on semi-structured guided interviews (Galletta, 2013) with a total of four teachers in which the teachers first used the scaffolding tool themselves and then answered open questions that asked whether the teachers would rate aspects of a respective DP, like TTS, videos or links as supportive for their learners and explain their assessment. Their answers were then analysed with a qualitative content analysis (Kuckartz, 2019). The resulting categories of the content analysis have been subdivided into positively and negatively connotated categories, named 'potential' and 'challenges'.

Results

(1) Potential and challenges of the digital scaffolding tool

The four teachers were asked to evaluate the usability and practicability of the digital language supportive modules in the scaffolding tool. A synopsis of the categories generated via qualitative content analysis, complemented with some exemplifications, can be found in the following Table 2.

Table 2: Assessment of the Digital Scaffolding Tool

Potential	Challenges
<ul style="list-style-type: none"> • Informative with regard to the aspects of an oral description • Intuitive handling • Very well arranged due to the use of different colours, underlined important words and the use of smileys for self-evaluation • Well suitable for primary school learners • Allows a versatile use in the mathematics classroom • Linguistic level well suitable for children with good knowledge of German 	<ul style="list-style-type: none"> • Linguistic level might be too high for learners with little knowledge of German • Very extensive – might lead to an overload of weaker learners • Requires the skill to self-assess one's description • Requires previous experience with checklists • Some buttons do not function properly yet • 'Book Creator's' function to turn over pages might lead to difficulties in the classroom when learners accidentally use this function

These categories indicate that in general, the teachers see opportunities for the use of the digital scaffolding tool in the primary mathematics classroom since they assess it to expatiate on the context-specific linguistic norms as claimed by (Tiedemann, 2015). While they rate the checklist as being well arranged and the digital aspects as being intuitive, it also has to be summarized that the teachers see challenges in including the student's progress related to the educational code in this form of self-evaluations that is based on Hammond and Gibbons (2005) claims, since self-evaluation requires additional skills of self-reflection that need to be acquired before working with this tool. However, all teachers claimed that this challenge can only be solved by a change of the socio- and sociomathematical norms and not by the digital language supportive modules themselves. When applying Sfard's (2008) idea of discursive routines on the 'rules' that are being set in the checklist, it might be concluded from the teachers' assessment that the routine that is supposed to be established with this tool might be not accessible for all learners yet due to the high linguistic level and the extent of the language supportive module. The technical issues reported as challenges will be revised.

(2) Potential and challenges of the implemented design principles

In addition to the assessment of the digital scaffolding tool, the teachers were also asked to evaluate the language supportive modules with a focus on the respective DPs' estimated fruitfulness for their students. The consolidated results of their assessment can be found in the following Table 3.

Table 3: Assessment of Potential and Challenges of the Implemented DPs

Design Principle	Potential	Challenges
Linking of supportive means	<ul style="list-style-type: none"> • Immediate reaction to the self-evaluation • Does not require posters and/or tip cards • Helps the learners to decide where support is needed • Use of links in the checklist before evaluation can help to get a better idea of the statement 	<ul style="list-style-type: none"> • Risk of students' unfocussed use of all the linked elements due to easy accessibility
Multimedia-Based Relation of Different Representations	<ul style="list-style-type: none"> • Video that relates verbal, symbolic and (animated) iconic representations is very helpful for both the linguistic and conceptual understanding • TTS is particularly useful for weaker readers • Relation of different media caters for different types of learners • Related verbal and non-animated iconic representations in audio samples can be supportive for the learning process (mixed review) 	<ul style="list-style-type: none"> • Related verbal and non-animated iconic representations in audio samples can be hard to follow (mixed review) • Headphones need to be used to make full use of the media • Risk of students' unfocussed use of TTS due to easy accessibility

The teachers' assessment of the DPs' current realization supports Dalton and Strangman's (2006) statement that TTS and linked scaffolds support learners with difficulties in the written language. Their positive evaluation of the implementation of different media second Erath et al.'s (2021) suggested support measure to use different representational means that help the learners to structure their learning process of language for mathematics. However, the mixed review of the relation between audio samples and non-animated representations points out that the use of different representations is not perceived as helpful in general, but only when fitted exactly to the different learners' needs. The teachers' ideas to improve this relation of representations are presented in the section 'Suggested additional functions'. The perceived challenges mostly consider the practical use of digital media in the classroom and can be traced back to the reported insufficient equipment of and experiences with digital media in primary schools.

(3) Suggested additional functions

To collect input for the future development in the next micro cycle of the integrative learning design, the teachers were asked to propose additional functions on both the level of the DP 'Multimedia-Based Relation of Different Representations' and the practicability for using the digital language supportive modules in their classrooms. Concerning the first aspect, they propose a stronger inclusion of the typical non-verbal illustrative and representational means like arrows, colours or magnifying glasses to help the students develop a conceptual understanding. Even though they already appreciated the video as a relation of different representations, they suggest to make even more use

of the digital potential by linking the spoken text in the video and the visual stimuli closer together – e.g. while saying “the sum in the roof” the respective number should simultaneously be enlarged and accentuated. They also propose an interactive design of the video to include the students more and avoid passive watching. All these features could be summarized under the quality criteria of cognitive activation that is supported by the media design (Korntruff & Prediger, 2021).

Conclusion and Outlook

In this paper we discussed the Enactment and Local Impact Evaluation of a learning design’s development addressing digital scaffolding using the app ‘Book Creator’. The outcome of the Enactment phase is a prototype of the digital language supportive modules which can be used in order to support oral descriptions of mathematical structures. Given that language promotion is always supposed to go hand in hand with the mathematic content (Prediger & Wessel, 2013), it needs to be considered that this digital scaffolding tool can only be used to accompany the mathematics lessons and not to promote the mathematical content on its own. The results of the Local Impact Evaluation indicate that the general idea of a digital language scaffolding tool is well accepted by the teachers and their list of perceived potential (Tables 1 and 2) is long. In the following micro-cycles revisions of the current language supportive modules will be necessary to better align their linguistic standards with the primary school learners’ competencies. To allow a digital differentiation that helps learners reach their zone of proximal development, it is necessary to analyse the competencies learners need in order to perform good descriptions of mathematic structures. This analysis will be undertaken in the PhD-project of Sophie Tittel. The teachers’ suggestions for improving the videos by stronger linking the visual and auditive stimuli will be implemented in the future and may also be applied in other projects and explanatory videos. In addition, it is planned to further implement the DPs ‘Interactive Feedback’, ‘Digitalisation of Task-Specific Scaffolding Means’ and ‘Digital Differentiation’ on the basis of teachers’ feedback in the next iterative micro cycle and evaluate their local and broader impact.

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