Conjecture Maps in der Praxis: Planung, Durchführung und Bewertung von Educational Design Research

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Zusammenfassung

Im Kontext von Educational Design Research nimmt Conjecture Mapping (Sandoval, 2014) eine Schlüsselrolle ein, sowohl bezüglich der Klärung von Design-Annahmen, die in verschiedenen Forschungsphasen gemacht werden, als auch hinsichtlich der Visualisierung des typischerweise komplexen Beziehungsgeflechts. In diesem Beitrag werden drei Anwendungsbeispiele von Conjecture Maps vorgestellt, wobei deren Grenzen und vielfältige Vorteile für die Durchführung von Educational Design Research hervorgehoben werden.

Conjecture Maps dans la pratique: planification, réalisation et évaluation de l' Educational Design Research

Résumé

Le Conjecture Mapping (Sandoval, 2014) joue un rôle clé dans l'Educational Design Research pour clarifier les hypothèses faites à différentes étapes de la recherche et pour visualiser le réseau complexe de relations. Dans cet article, trois exemples d'utilisation de Conjecture Maps sont présentés, mettant en évidence les limites et les multiples avantages de cet outil lorsqu'il est mis en pratique.

Conjecture maps in practice: planning, conducting and assessing educational design research

Abstract

Conjecture Mapping, introduced by Sandoval (2014), embodies a key role in Educational Design Research, namely to clarify the various assumptions made at different stages of the research and to visualize the typically complex web of relations. This paper presents three cases of using Conjecture Maps. It highlights their limitations and their multiple benefits for conducting Educational Design Research.

1 Introduction[1]

In the last issue of this journal Schmiedebach & Wegner (2021) introduced design-based research (DBR), also known as educational design research (EDR) (McKenney & Reeves, 2021), as a key research approach to close the gap between scientific knowledge and educational practice in educational research. The term EDR collects a multitude of studies that aim to solve relevant problems in real educational settings while also advancing theoretical knowledge about important phenomena. EDR can make use of a variety of methods, including quantitative, qualitative and mixed-method designs. What is characteristic for EDR, however, is that educational actors are not only the addressees of the research but become active research partners by contributing to the iterative process of design, intervention and evaluation. Corresponding to the main theme discussed in this journal, this paper explores challenges and opportunities of such research-practice collaboration with special focus on the use of Conjecture Maps.

1.1 Background, research problem and purpose of the study

As EDR encompasses such a variety of settings, methods, design interventions and theoretical concerns, researchers who are working on EDR projects are often confronted with the challenge of communicating their research in a coherent and efficient way. This challenge ties into the general discourse on theory-practice transfer in empirical educational research (Brown, 1992). In response to this gap, William Sandoval (2014) proposed and defined so-called Conjecture Maps (CMs) that serve as a systematic tool to visualize practice-based and theory-based goals (conjectures) and how these interrelate.

Since the publication of Sandoval's proposal in 2014 many authors have been using CMs. Thus, a variety of secondary literature emerged and is still emerging with explicit reference to Sandoval's work (e.g. Ma & Van Aalst, 2014; Wozniak, 2015; Wu & Chen, 2018; Chen & Wu, 2019; Reimann & Thompson, 2021). Various authors made an argument for CMing as a tool to (1) structure research (Ryoo, 2014), (2) structure the intervention design (Euler, 2014), (3) structure theory building (Boelens et al., 2020), (4) structure experimentation and data gathering (Lee et al., 2018) and (5) to communicate research (Lee et al., 2018; Boelens et al., 2020). In this article, the current discourse on CMs is introduced with main reference to Sandoval´s original terminology and outline. This is motivated by the fact that CMing remains a relatively recent innovation in EDR that is well discussed by a variety of authors, as indicated above, but hasn´t been significantly refined yet. In this paper, however, we relate the various theoretical claims to the benefits and issues that commonly arise when implementing CMing in research practice.

The intention of CMs according to Sandoval is "to organize design research by focusing researchers' attention on the aspects of a designed learning environment considered theoretically salient" (ibid., p. 27). Hence, CMs are made to display assumptions about design characteristics (embodiment), mediating processes and consequent outcomes in learning settings. This way they make the process of theorizing about the relations between these elements

[1] This article is the result of a shared collective effort. In formal terms, the paragraphs 2 and 3.2 have been authored by M. Garzetti, the paragraphs 4 and 3.1 have been authored by F. L. Deister and the paragraphs 1, 3.3 and 5 by M. Schlauch.

more transparent. Over the course of a research project, CMs change or develop into a sequence of CMs. As such, they are not only a way of representation, but also a tool for inquiry and reflection: they force researchers "to be specific not just about what [they are] trying to design but also about what particular features of the design are expected to do, how they are expected to work together, and what they ought to produce." (ibid., p. 27).

As the authors of this paper are working on different EDR projects, we experienced that CMing is not a straightforward process. CMs are only able to represent a section of a complex web of relations in learning settings. Therefore, in this paper, we illustrate how CMing was used in three ongoing research projects and highlight common issues that have arisen.

1.2 Problem Outline

EDR has the dual goal of advancing theoretical understanding of learning and teaching processes and of designing instructional interventions to address issues or needs that arise in real educational settings. So, it “seeks to create and improve effective solutions to serious education problems as well as identify new knowledge related to those problems, often in the form of reusable design principles related to teaching, learning, and performance.” (McKenney & Reeves, 2021, p. 273).

We then speak of theoretical development and maturing intervention that occur through cycles of analysis, design, implementation, and evaluation of implementation. EDR in this sense isn´t considered a research methodology, but rather a research genre that links design to related learning hypotheses. These are reviewed and assessed through the implementation of the design itself. This link between the design of a learning intervention and the advancement of related theories of learning is fundamental to the design of an EDR project. Therefore, it becomes crucial to make the argumentative grammar of EDR explicit, namely “the logic that guides the use of a method and that supports reasoning about its data” (Kelly, 2004, p. 118). In particular, two kinds of relations need to be made explicit; those between the design and expected enacted processes and those between the enacted processes and the expected outcomes. William Sandoval (2014) refers to these relations as design conjectures and theoretical conjectures. In order to visualize the structuring of the research around these two types of conjectures, Sandoval proposes CMs. He describes their fundamental scope as follows:

“I propose conjecture mapping as a method for articulating the joint design and theoretical ideas embodied in a learning environment in a way that supports choices about the means for testing them. Thus, conjecture maps clarify how a research team views the concurrent effort of practical improvement and theoretical refinement in terms that include at least some elements of an argumentative grammar.” (Sandoval, 2014, p. 20).

Thus, CMing is a systematic technique that helps coordinate the interaction of “prospective and reflexive components” of EDR (Bakker, 2018, p. 18). In particular, it allows to structure the deep link between theory and practice, which is necessary to address complex problems in real contexts of educational practice. In the process of creating a CM to structure one's EDR-project, useful combinations of theoretical and practical knowledge may occur. Researchers, for example, initially tend to focus more on theoretical conjectures that are discussed in literature. Thus, they ground their conjectures rather on explanatory and descriptive knowledge (Reinmann, 2021). At the same time, practitioners tend to draw more on their procedural, practice-based knowledge and can provide valuable insights and hints about

design conjectures based on their practical experience. By coordinating the respective knowledge of researchers and practitioners, CMs endow them with the possibility to jointly elaborate a CM without necessarily re-informing each other's knowledge from scratch (Ryoo, 2014). This way, the conceptual distinctions introduced when applying the technique of CMing also helps to facilitate collaboration between researchers and practitioners (Boelens et al., 2020).

2 Conjecture Maps as a research tool

Having presented CMs as a heuristic tool for planning, reflecting and refining research steps in EDR, the following section outlines in more detail Sandoval's ideas on how CMs are composed and can be used. Section 2.1 also presents an excursus on the functions CMing can have in EDR by considering later re-elaboration of Sandoval's proposal.

2.1 Theoretical Underpinning

Sandoval (2014, p. 19) describes CMing as "a means of specifying theoretically salient features of a learning environment design and mapping out how they are predicted to work together to produce desired outcomes. Furthermore, he points out how important the relation between the ideas that inform how learning shall happen and the design of the actual interventions is: "As researchers (and not just designers) we have an obligation to be as explicit as possible, in advance, about what those ideas are" (Sandoval, 2014, p. 20). In order to do so, Sandoval proposes four main elements of a CM, namely the high-level conjectures, the embodiment, the mediating processes and the outcomes, which are depicted in the following figure:

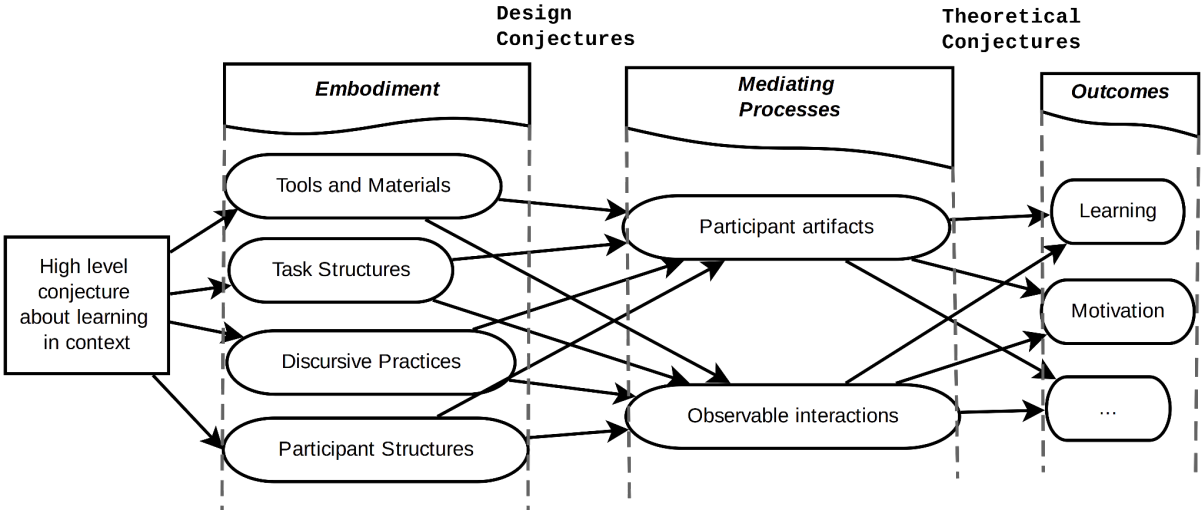

Fig. 1: *Generalized Conjecture Map for educational design research (adapted from Sandoval (2014, p. 21), own figure)*

CMing allows the visualization of the conjectures made, which helps to formalize and structure the theoretical underpinning of the study and to shape the empirical work. As shown by the arrows, each element visible in the map is interwoven with another and represents an empirical relation. High-level conjectures mark the starting point of the map. They derive from

theory on how to support learning in some context and thus need to be made specific, even if they tend to be rather general in the initial phase of an EDR. Then the embodiment of the high-level conjectures follows. This signifies the translation of the high-level conjectures into design features. According to Sandoval, such embodiment can occur within four different kinds of elements of learning environments; namely the *tools and materials* used (e.g. instruments and other resources), *task structures* (e.g. task goals and task criteria), *participant structures* (e.g. different roles and responsibilities) as well as the processes of communication related to the intervention, so-called *discursive practices*. Given that EDR takes place within natural and thus complex and heterogeneous learning settings, the types of embodiments and their naming may differ depending on the focus of the study, as illustrated in section 3. The processes occurring during enactment of embodiments of high-level conjectures are called *mediating processes*. As suggested by Sandoval, they can be examined in two ways, both as *observable interactions* with the designed environment and as *participant artifacts* produced during/ through the intervention. The definition of mediating processes as observable processes is introduced by Sandoval (2014), together with the complexity related to their selection in an educational environment. The relations between the embodiment and the expected processes in the third column are named design conjectures. Furthermore, Sandoval (ibid., p. 30) indicates that the mediating processes should directly affect learning and thus lead to *outcomes*. However, considering the complexity of educational practice concerns arise regarding the causality of learning outcomes. Therefore Sandoval (ibid., p. 30), with reference to Salomon (1996), outlined that a CM "should not be read as a set of factors leading to effects but as the specification of process relations, as a pattern of change". Finally, theoretical conjectures about how learning processes take place link the mediating processes to the learning outcomes expected by the implementation of the design.

To provide an overview of the different functions of CMs as originally intended by Sandoval and enriched by further authors, the following list summarizes the main aspects:

- To structure the research (Sandoval, 2014):
  - giving shape to the direction of an EDR project in its initial phases;
  - making explicit the distinction between hypotheses about educative interventions and hypotheses about learning with an increasingly high-level of precision;
  - focusing attention on certain aspects of the project that have yet to be defined or addressed.
- To structure the intervention design (Sandoval, 2014):
  - clarifying what processes are expected during the implementation of an educational intervention, highlighting the link with the intervention itself.
- To structure the theory building (Boelens et al., 2020):
  - clarifying what kind of learning is expected in relation to defined processes and design;
  - synthetically showing the theoretical underpinning of each research step and decision.
- To structure experimentation and data gathering (Lee et al., 2018):

- building explicit connections between design, processes and learning that can be examined in the course of experimentation, individually or in their mutual relationship;
- highlighting which conjectures have not yet been verified during previous phases of the research.

• To communicate research (Sandoval, 2014; Lee et al., 2018; Boelens et al., 2020):

- supporting clarity in the communication of the main characters and assumptions of the research;
- providing a common tool for EDR researchers, it allows structured confrontations among projects.

Nevertheless, Reimann & Thompson (2021, p. 3f.) state that:

> "[i]t is important to keep in mind what a conjecture map is not: It is neither a fully developed learning design nor a fully-fledged research design. It is, rather, a technique to build bridges between the practices of learning design and learning research."

In addition to that, CMing shall not be considered as the only research technique used in EDR. Still, we want to emphasize its very crucial function. Namely, it allows tracing the evolution over time of both the researchers' and practitioners' assumptions about the EDR. Furthermore, it allows tracing the designed intervention itself, as well as the theories from which they are drawn and their mutual relationships. As highlighted by Sandoval, this allows the clarification and separation of different assumptions that are intended to be tested at different stages of a research project. Specifically, many projects that pursue classroom interventions tend to overlap design conjectures and theoretical conjectures. In other words, there are two types of hypotheses. One is about the processes that the intervention will initiate in the context in which it is introduced. The second one concerns hypotheses about the link between these processes and the expected learning outcomes. Each of these aspects and hypothesized relationships must be verified and discussed in an EDR, and, more importantly, must be made explicit so that they won't get lost in the long process that characterizes this type of research.

2.2 Relevant questions when working with Conjecture Maps

The use of CMs is quite widespread amongst researchers and practitioners working with EDR. However, it requires clarification of its effective uses in different phases of EDR projects in a variety of educational domains and of related issues that arise in practice (e.g. on how to relate the different items of the map to each other, how to frame the most relevant items, how much a CM is subject to individual needs and can be customized etc.). We face those issues by giving some practical examples taken from three different research projects: KULKOM (on music education), OPEN-MATH (on mathematics education), and MEKIDS (on media education). Through the description of each project, we illustrate how we understood, implemented and modified CMing in each, and we highlight the commonalities and differences among these three approaches.

3 Conjecture Mapping in practice: Three case studies

The three research projects are suitable to examine the practical application of Conjecture Maps for both substantive and research pragmatic reasons. These relate to their connection to K12 education, participatory research and to their multi-year duration. As the studies were conducted by the three authors of this article, not only comprehensive access to data but moreover in-depth knowledge regarding each EDR phase of analysis, design and implementation and evaluation is available. Considering that all projects were discussed multiple times in regular research group meetings since their beginning, a solid self-reflective perspective of each author can be ensured, also with regard to obstacles and limitations encountered. In correspondence with the theoretical and methodological advancement of the studies, an in-depth case study approach was used for each example. In addition, the different versions of CMs (including annotations and comments) were evaluated over the course of the last 2 years. Based on this, each author responds to the research question of how CMing did shape the outline and definition of the EDR project. The uses of the maps recall the list of section 2.1 to highlight both specific aspects of different projects and transversal functions of this technique.

3.1 KULKOM, Kulturkomplizen (Cultural Accomplices) in music education through transprofessional cooperation

The EDR study KULKOM inquires the cooperation and potential accomplicity of professional musicians and primary school teachers for introducing music instruments in primary education. By following the approach of transprofessional cooperation according to Oberhaus & Eller (2018) the research project aims for mutual professionalization of the actors involved in the course of joint lesson design and implementation over several months. At the student level, KULKOM aims to introduce instrumental playing as aesthetic-artistic action and experience as well as a social practice by demonstrating the learning objects in presence of the musicians. At both levels, musical and music pedagogical competence shall be promoted and further developed with special focus on posture, tone production and basic knowledge of the instruments present.

The study took place in South Tyrol, Italy, where music lessons of three German-speaking classes (4th/5th grade, 15 pupils each) have been transprofessionally designed and implemented by their teacher and four external musicians. This was researched in a three-part study in the course of a parallel management of theory generation and practice implementation (Aigner, 2017). First, a theory-based and empirical needs analysis took place by means of literature review and participatory classroom observations. Subsequently, in a workshop phase the teacher and the musicians co-designed five targeted modules for receptive and productive encounters of the pupils with string and wind instruments, making use of transprofessional cooperation elements such as an open structure and expertise-based task assignment. The modules developed were piloted in class A in a series of seven lessons. After formative evaluation based on the content structuring qualitative content analysis (Kuckartz, 2018) of questionnaires, project journals, intervention protocols and interviews, the five modules were refined, and a second cycle followed in classes B and C. The last part of the study regards the summative evaluation of the interventions and processing of the research results for further educational and scientific practice.

The aim of the study is to derive a local resource for transprofessional cooperation, with which interested teachers and musicians can expand their own (teaching) practice and structure their cooperation. Therefore, KULKOM has a dual focus: namely on an empirically based teaching-learning arrangement for the introduction of and engagement with string and wind instruments in primary school music lessons, and at the same time on the cooperation strategy of the actors involved that stimulates processes of reciprocal professionalization. The main conjectures and this dual focus are visualized in the CM below, which was last updated at the beginning of the evaluation phase.

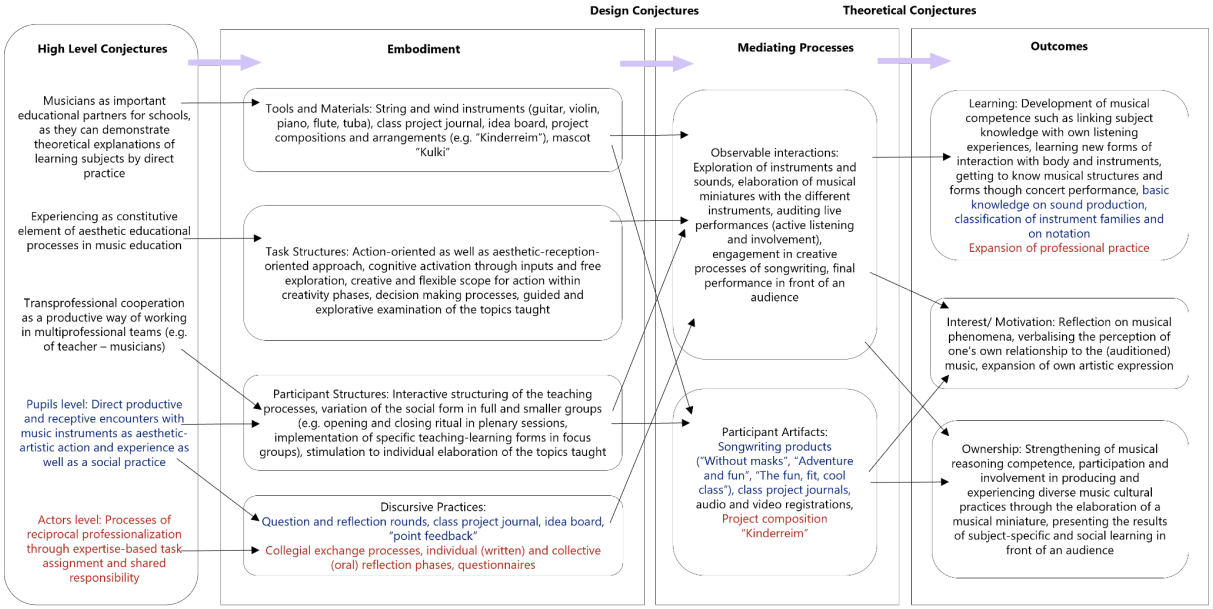

Fig. 2: *Conjecture Map KULKOM, Adaptation of Sandoval (2014), own figure*

To organize and clarify the dual focus of KULKOM throughout the process of mapping and remapping, different colours were used. Items marked in blue refer to the actors' level (teacher and musicians) only, whilst items marked in brown are linked to the level of the pupils involved. Black items relate to both levels and thereby visualize that, even though the project follows a dual focus, both the actors' and the pupils' level are connected and interdependent regarding most of the aspects of KULKOM, hence why one CM for all levels was devised.

In line with the organization of the study into three research phases, the process of CMing was able to fulfil three different functions: first, the map required a clear formulation of the high-level conjectures and the intended outcomes, which had to be defined in the analysis and exploration phase based on the literature review and field observations. Only through the (step-by-step) selection of the tools and materials, the task structures etc. it became possible to establish a more tangible connection between the high-level conjectures and the desired outcomes. The main items of that version of the CM and their connections were provided to the musicians and teachers in the workshop phase in the form of moderation cards with one item each (classified by colours as objectives, contents, resources, social and work forms, artifacts, structure, other). Those cards served as building blocks for a co-design process in which different combinations of the elements, sequences and focal points were discussed and (musically) tested. Finally, this led to a solid structure of the classroom interventions and in turn allowed for the clear formulation and operationalisation of five resulting modules. Through the iteration of the modules in the three classes, the assumptions about embodiment and mediating processes were informed and enriched by practice (e.g. with regard to

participant artifacts such as the project compositions or the project journals), which enabled a shift from rather general to specific design conjectures. These processes must be considered in the evaluation phase, because these (albeit small) changes allow important conclusions to be drawn about the practicability of the various modules (with various target groups). Furthermore, in the third course of CMing it became apparent that the actual outcomes of the three classes regarding subject-specific learning, involvement and social learning outcomes strongly overlap (although they represent three different groups composed by individual learners). However, it should be noted that these outcomes describe more general items, the differentiation of which on the individual level of the single pupil still needs to be clarified in the ongoing analysis phase.

3.2 OPEN-MATH, Learning mathematics in an inclusive environment

The research project OPEN-MATH aims at defining design principles to enhance inclusive mathematics education in Italian middle schools. To do so, two research fields need to be networked: that of inclusive pedagogy and that of mathematics education. Educational Design Research (McKenney & Reeves, 2019) allows to build the network on a theoretical, practical, and methodological level.

The theoretical foundation of OPEN-MATH refers to a broad definition of inclusion given by Ainscow (2016), which not only encompasses the presence of all students in school without separations due to ability levels (which in Italy has been established by law since 1977) but aims at participation and meaningful learning opportunities for all. With this respect the philosophy of didactical differentiation (Tomlinson, 2014) offers several strategies to manage classrooms looking at differences among students as a resource for learning that values individual characteristics. Looking specifically at mathematics education, the main background theory considered is the Theory of Objectification (Radford, 2021). Referring to the latter, teaching activities shall be designed to provide rich and meaningful situations that allow students to perceive different levels of conceptualisation in mathematics through the interaction with others, supported by artifacts, intended as bearers of mathematical meanings. The high-level conjecture that originates from the two mentioned perspectives is that inclusive mathematics education is situated at the intersection of the social and individual dimension of learning. This means that the designed cycle of activities must balance the attention between mathematics as a discipline mediated by cultural artifacts discovered through social interaction and the valorisation of the specific characteristics of each student in learning. Thus, the classroom interventions combine individual moments in which tasks are differentiated, group work, and discussions with the entire class. Moreover, attention to multimodality of mathematical learning and to discursive practices and form of participation in the classroom is given. This also refers to specific strategies for help-requests and collaboration in small groups to enhance positive interdependence among students.

The cycles of activities have been defined and developed during a school year in five different interventions with one class of grade 7. The main characteristics of the cycle are defined by the embodiment column in the map. A phase of evaluation of the current cycle was held in February and March 2022 with the same class. The map depicted in figure 3 is the current CM of the project.

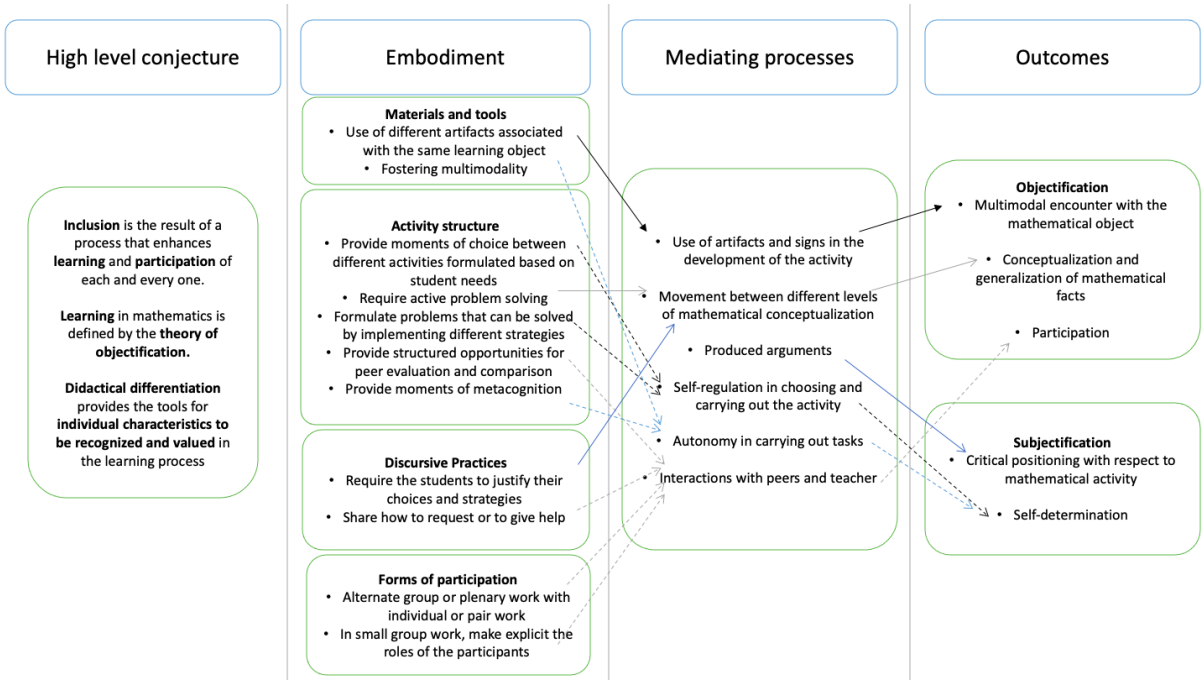

Fig. 3: *Conjecture Map of OPEN-MATH, Adaptation of Sandoval (2014), own figure. Each set of similar arrows represents a hypothesis that leads from the embodiment to a specific outcome*

The first CM of the project has been used to give direction to the project in its initial phases and to structure the initial cycle of activities. Theory building in the first map was mainly related to the definition of the high-level conjecture in relation to the theory of objectification and to didactical differentiation.

Thereafter the data collection and the fieldwork allowed for the redefinition of the intervention. This resulted in a better specification of the second and third column, in particular concerning the link between the two. The map shown in figure 3 is the schematic result of this second part of the work: the mediating processes have been defined in terms of observable processes in the classroom and connected to specific characteristics of the proposed design. The next phase of research will be dedicated to the evaluation of the design conjectures made in the map. Thus, recalling the list in section 2.1, CMing was used within OPEN-MATH as a technique that has allowed to:

- build explicit connections between design, processes and learning that can be examined in the course of experimentation, individually or in their mutual relationship;
- highlight which conjectures have not yet been verified during previous phases of the research.

One last remark concerning the CM of OPEN-MATH: there is a strong connection between the first and the fourth column. The assumptions made at the beginning of the project, called high-level conjectures, have been directly associated with the learning outcomes. This association has been informed by the CM, and thus made tangible in the educational interventions.

3.3 MEKIDS, Media Education with Kids through Interactive Digital Storytelling

This doctoral research project explores the use of interactive narrative and digital storytelling as a way to introduce elements of media education in learning settings with young children (8-11 years). Specifically, a hypertextual interactive tool (’Fantanomio’) was developed to facilitate creative storytelling with young children about subjects that can be curated by their educators. Inspired by "carte in favola" and other creative storytelling techniques with children (Rodari, 1973, ch. 23), the tool consists of story elements and characters (represented as images with captions) within various categories that can be edited either individually or as a group-based activity via an online spreadsheet. Each time they add a story element to an overall image sequence, children are able to choose autonomously one out of three algorithmically selected story elements. This way, the resulting image sequence acts as a scaffold for the oral/written or theatrical production of a simple story. During the first experimentation sequence, that took place in a Montessori school, groups of 4 children collaboratively created multiple stories and chose to write the preferred one in a word processor, which led to conversations about expected or planned story subjects according to the elements given (e.g. use of technology).

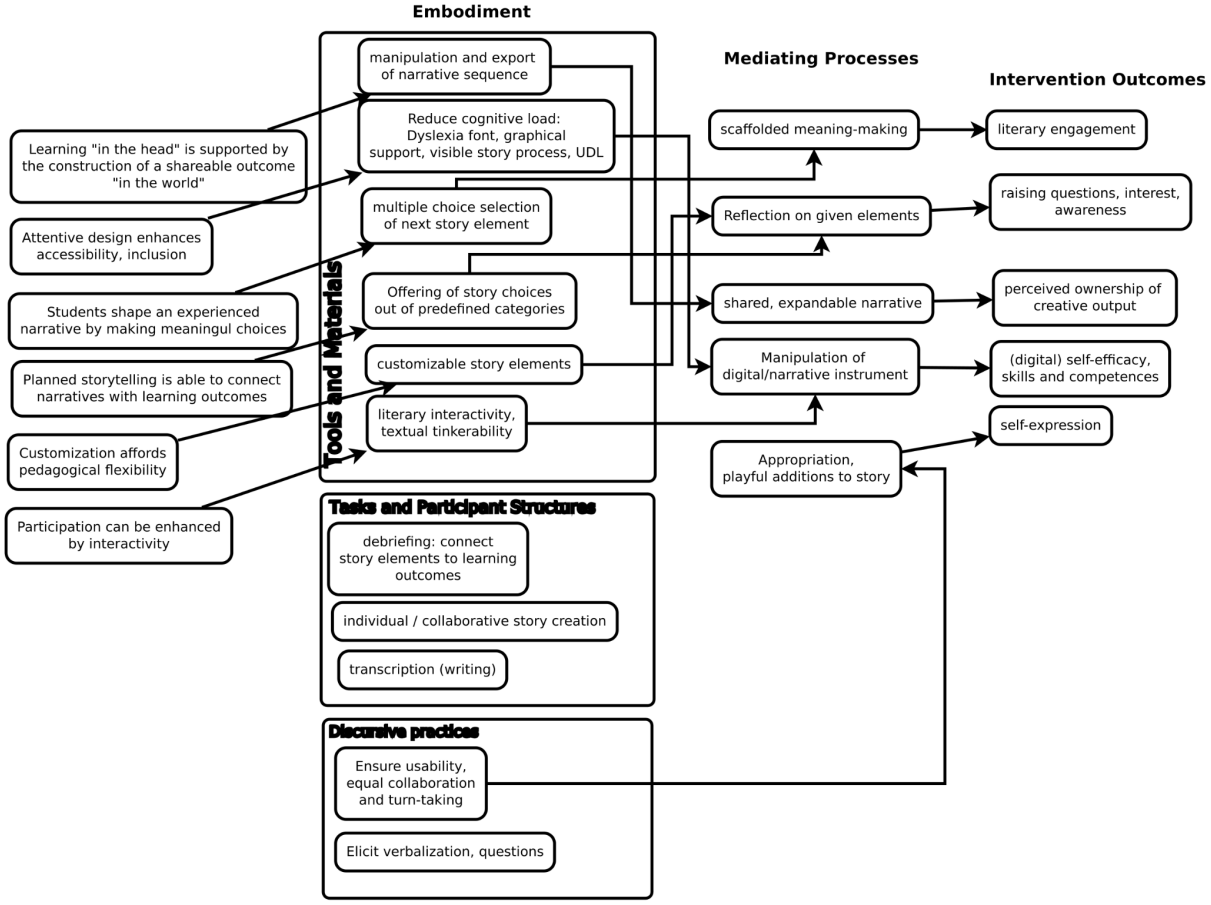

Fig. 4: *Conjecture Map of MEKIDS, Adaptation of Sandoval (2014), own figure*

Figure 4 displays the CM in its current form at the end of the design and construction phase. On the left we can see higher level conjectures that derive from learning theories like constructionism and existing research about storybook apps and digital storytelling. Educational technology is often criticized for diminishing the role of the teacher by prescribing and

consolidating a specific way of teaching. Taking this into account we can retrace an exemplary path through the map. Starting from the high-level conjecture “customization affords pedagogical flexibility”, we can see that the aim of maintaining pedagogical flexibility is expressed through the design characteristic “customizable story elements”. In other words, the elements can be changed, selected or renamed beforehand according to the intentions of the teacher, attending to the needs of the children in the specific context. This can result in linguistic or curricular adaptations, for example. A design conjecture leads from these customized story elements to the mediating process where children are invited to choose among them and integrate them in their own narrative, spurring “reflection on given elements”. The target outcome consists in the fact that children exit the process with a raised level of “questions, interest or awareness” to discuss a certain subject.

In the beginning of the research the type of tool to support storytelling was not yet clearly defined and comprised multiple options, ranging from the adaptation of interactive fairy tales to the composition of preformulated phrases. Conjecture mapping contributed to the process of stabilizing the design by specifying and distinguishing theoretical conjectures and mediating processes based on high-level theoretical assumptions. Earlier versions of the CMs were tailored to a different kind of tool or embodiment. Nevertheless, much of the knowledge gained through the making of the initial CMs has been reused in later versions. Contemporarily, additional mediating processes have been accounted for and have informed the decision about the most fitting embodiment.

4 Discussion

In the previous sections we illustrated how CMs have been customized and used to structure various research projects in K12 education. Several of the uses listed in section 2.1 were echoed in each description of the researcher's journey. What emerges in the three paths is the effectiveness of constructing a CM from the beginning of the research path to define the high-level conjectures and one's educational goals. During this process the need becomes clear to work in greater detail on the second and third columns of the CM, and on the connections that one wants to investigate empirically. In this regard, CMing forces the researcher to select lines of investigation in the form of relationships between an educational intervention, its implementation, and expected learning goals among the several possibilities. For instance, in the OPEN-MATH project, CM helped to clarify which aspects of the design were most related to individuals' self-determination, participation or learning, and thus to focus on their mutual relationships in the definition of student inclusion. This can be retraced in figure 3 by each set of similar arrows that represents a line of investigation. Regarding KULKOM, those lines of investigation were processed as building blocks and made available to the practitioners involved, who, in their role as research partners, used them as a basis for co-designing the different modules. This way the final design was informed by multiple deeply connected sources. These concern the theoretical foundations of the research, recalled in the map, as well as the results of the empirical needs analysis and the practitioner’s knowledge and competences. Another aspect of interest while working with CM when conducting EDR are the commonalities between the maps presented. These relate to cross-cutting skills in education, as for instance self-determination and collaboration, as well as the importance of a rich environment capable of taking into account the characteristics of the individual and its self-expression. Among the three case studies a more specific set of categories for the learning outcomes can be proposed, namely relating to informal, general and subject-specific learning, agency,

motivation and participation. These two interconnected aspects, related to the use of CMing and to the structure of CMs in educational projects are developed in the following subsections, where some functions of CMs are underlined together with further issues that did arise while approaching this technique.

4.1 Further functions of Conjecture Maps in the course of Educational Design Research

As illustrated by the three projects KULKOM, OPEN-MATH and MEKIDS, CMing can serve as an effective technique to structure and communicate EDR endeavours. Yet, not only during, but also after having concluded the core phases of an EDR, the different variations of a CM allow retracing the whole research process "back to the design, and evaluate the linkages between each component of the conjecture map" (Wozniak, 2015, p. 608). Therefore, CMing can also be used when reporting the research itself. By comparing different versions of CMs during the progression of a project it is possible to see how conjectures were modified. This allows the identification of which decisions have been made according to which conjectures. For example, in MEKIDS design conjectures about discursive practices have been added at a later stage of implementation to address the pedagogical support needed for the use of the tool. Here CMing is a suitable tool for documenting EDR processes which are usually too complex to be outlined in a few pages. To make such reasons for changes in the research structure or in the intervention design explicit is a further quality criterion of empirical research.

Over the course of applying CMing in the three projects presented in this paper, CM also turned out as a "planning and evaluation framework [... that] reveals unexpected findings" (Wozniak, 2015, p. 607). Herewith the author refers to CMing as a tool for finding blind spots related to several aspects of the research process, e.g. characteristics of the design that were not visible or tangible and thus overlooked. For instance, in the first interventions related to the project OPEN-MATH, inclusion was defined as participation and learning, but learning in mathematics was not operationalized, and CMing has helped within that process by making explicit the distinction between design conjectures and theoretical conjectures.

Consequently, by creating and refining the CM, central conjectures are to be verified, whilst unexpected findings may also arise. Thus, the process of visualizing the high-level conjectures that inform a research project from the very beginning is a crucial tool to structure, communicate and reflect on one's EDR. Based on this claim, we encourage fellow researchers to already make use of CMing in the early phases of their research. Even if their map won´t be particularly mature in such early research phases, CMing itself will support the advancement of the research design and allow re-information within the practical iterations of the research process.

4.2 Issues arising while working with Conjecture Maps

Various authors have already suggested revising the original proposal of Sandoval's CM to increase the clarity and practicability of individual aspects (e.g. Chen & Wu, 2019). In this light the mediating processes claim the focus of attention. It was pointed out that a distinction should be made between CMs as a research tool and CMs as a tool to communicate research. We would like to endorse this statement and use the example of mediating processes to point out that in the context of using CMs as a research tool, it is important that the mediating

processes are very specific and that the researcher needs to be able to operationalize them, also by giving examples from her/his data. However, for the communication of the research, it is useful to synthesize the mediating processes in the CM in order to keep the map readable and to rather define precise trajectories of conjectures that are linking the different aspects of the EDR and the different design conjectures. Hence, the three maps presented in this paper made use of synthesizing the mediating processes by more general terms, whilst they appear more complex in the implementation of the research.

With respect to the complexity of the implementation of EDR interventions, issues also arise when considering the different perspectives and professional categories of people involved in the research process. By its nature, EDR combines practice and research. Hence the collaboration of educational practitioners, such as teachers, and researchers is substantial. Accordingly, as many interventions follow the dual objective of both teacher and participant/pupil qualification (so teaching development and learning of pupils), besides the level of the pupils (as well as of other stakeholders involved in the EDR), also the learning processes of the teachers' merit consideration. This is why some projects may require multiple CMs or, as depicted in figure 2 with regard to KULKOM, some CMs make use of various colours to display this dual focus and make the different levels and perspectives transparent.

4.3 Outlook on the relation of High-level Conjectures and Outcomes

As already affirmed, CMing represents the endeavour to make the argumentative grammar of EDR explicit. The form taken from CMs is itself that of an argumentation, as highlighted by Reiman & Thompson (2021). The idea behind the use of the word conjecture is nevertheless related to the fact that conjectures presented in the CM still need to be verified through intervention and data analysis: Thus a conjecture, as introduced by Reiman and Thompson, is an initial research guiding assumption to be tested in the course of the research. If the high-level conjectures are considered as deriving from the research problem faced and from researchers' knowledge of the problem, they are a first statement related to its solution. So, they can be considered as the first claim that the researcher wants to address *through* the designed intervention. The embodiment of the high-level conjecture represents exactly this step-in research, and the mediating processes expected from the participants during the educational intervention should be related to the outcomes in a way that helps to characterize the high-level conjecture in the specific context of the designed embodiment. That is why the learning outcomes related to the intervention could be considered a refined claim about the initial conjecture, that must be proved, or at least addressed, through it. In OPEN-MATH for example, the two main theoretical frameworks chosen are considered two separate high-level conjectures and do not allow inclusion in mathematics to be defined in specific terms. In the last column, student inclusion is instead characterized by combining the two initial approaches: participation and self-determination become deeply related to mathematical content and to the theory of objectification.

Design conjectures and theoretical conjectures could therefore be seen as the characterization of the high-level conjecture in the designed intervention, and the learning outcomes should consequently be strongly related with them. That is why we could consider the map as a cylinder, connecting the starting point with the fourth column and vice versa, so that not only the high-level conjectures lead to the outcomes, but that the outcomes also allow conclusions to be drawn about the high-level conjectures and thus about theory building in the

course of the EDR. Consequently, a modification of the CM proposed by Sandoval to a cylindrical shape is an outlook whose practicality and benefits need to be explored through future discussion by fellow practitioners and researchers.

5 Final remarks and limitations

In this paper CMs have been presented as a valuable tool for EDR, where research is deeply connected with educational practice. This process can be complex and unpredictable sometimes, and CMing helps to ensure clarity in EDR. Typical elements of a CM were described and its use in three different research projects has been illustrated. The distinction between design conjectures and theoretical conjectures makes it possible to differentiate assumptions regarding the relations between design characteristics (e.g. the embodiment) and observable information from assumptions regarding the relations between observable information and outcomes. It has been shown how CMing can be useful in a variety of educational domains, with different types of designed interventions. The process of working with CMs, however, is contingent on the knowledge and intentions of the researcher. As illustrated, CMs are also dependent on which perspective towards participants has been taken. Arguably, a research project can entail multiple CMs. While there is an active debate on proposals to modify aspects of the CM idea, these ideas must be backed up by looking at the research practice. Nonetheless some insights on the process of CMing have been provided, it remains necessary to review a broader range of EDR projects that apply CMing for drawing conclusions about specific questions that have emerged. For example, it needs to be explored whether outcomes of design interventions can be organized along a set of typical, commonly occurring categories (e.g. tacit/informal learning). Also, it is unclear whether projects make use of the possibility to check for consistency by relating outcomes in the 4th column back to the high-level conjectures. Yet, as we have seen, CMs provide multiple potential advantages for the challenge of doing research within, rather than about, educational practice.

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