A Multimodal Approach to the Analysis of Complex Collaborative Learning Environments: Using Complementary Methods of Analysis to Synthesize New Trends in Scaffolding Research

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Abstract: Synthesis research is a method utilized in the field of ecology, and involves bringing together experts in different areas to address a research question that cannot be entirely answered by a single perspective. This symposium explores the application of this model to the learning sciences, specifically to scaffolding of computer supported collaborative learning. The symposium brings together expert researchers (working on different, related perspectives of scaffolding) to discuss their analysis of processes of learning in relation to discursive psychology and gesture analysis; conversation analysis; and multimodal interaction analysis. Each presenter will analyze and discuss the same corpus of data. These streams of data analysis are then brought together in the fourth presentation, with a discussion of visualizing and synthesizing the findings, piecing together an elaborated understanding of scaffolding. The final presentation includes the whole panel and addresses some of the challenges of conducting research this way in the learning sciences.

Introduction

As CSCL interventions become more integrated, and the availability, and sharing, of 'big data' more commonplace, the need for frameworks to make sense of the data from complex collaborative learning environments is evident. The overall focus of the symposium is to contribute to the discussion about the design of methods for analyzing and assessing collaborative learning. Synthesis research has been adopted in ecology in response to similar circumstances to those facing the learning sciences: (1) a sudden increase in available data, (2) a search for coherence, (3) an interest in applying the data for management of resources, (4) the complexity of the challenges faced, and (5) the need to train new scientists to solve these problems (Kemp & Boynton, 2011). Used for almost twenty years, synthesis research has contributed to some of the most influential studies in areas such as climate change and river ecology and management (Kemp & Boynton, 2011). Synthesis research is inherently interdisciplinary, as experts from different fields come together, bringing their data and perspective, to develop a new explanatory model that accounts for how diverse observations work together (Kemp & Boynton, 2011). The synthesis approach is aligned with the multidisciplinary perspective of the CSCL paradigm (see Stahl, Koschmann & Suthers, 2013; Koschmann, 2008), as well as other studies adopting multi-perspective data analysis (e.g. Stahl, 2014; Stahl, Jeong, Ludvigsen, Sawyer & Suthers, 2013). It is this focus on developing a new model to explain observed patterns, developed from the analysis of multiple data sets, that distinguishes synthesis from other approaches that attempt to align findings. Synthesis can be seen as both a challenge and an opportunity to create new understandings of existing problems (Kemp & Boynton, 2011).

Scaffolding was identified as an area in the CSCL community with a long history of work, and one in which many perspectives have been considered, but usually not coordinated. One issue with research on the processes of learning is the lack of a framework in which to place the results of the research (Goodyear, Jones & Thompson, 2013). This is particularly important given our focus on the application of the synthesis approach. Carvalho & Goodyear's (2014) framework for the analysis of complex learning environments formed the basis

for our study in two principal ways. First, the framework provides the structure for the design of the study, where different scaffolds are offered to three groups of learners, as they complete the same educational design task. Second, the framework provides the basis for synthesizing the multiple streams of data collected and analyses conducted. The framework suggests that in complex learning environments, there are elements that can be designed (set, epistemic, social, discussed in more detail below) and some that cannot (the learners' activity).

Three groups of postgraduate students were brought together to discuss the design of an educational resource about a socio-environmental issue. Learning by design has been used previously as an example of a complex learning scenario in which multiple scaffolds would be needed (Tabak, 2004). Participants were asked to design an educational blog about a complex socio-environmental system in Australia. They were expected to access multiple websites (resources) to explore the given problem and design a potential solution (e.g. education resources to address the large number of stakeholder groups). After 60 minutes participants were expected to produce a short statement with ideas for their design concept, and after a further 30 minutes, they were expected to produce a sketch or brief outline of their design solution, which they then presented to two of the researchers.

A group of twelve researchers (from Australia, Spain, Indonesia, Germany, France and USA) have adopted six different perspectives to analyse a complex dataset, which included video, audio, transcripts, and the physical artifacts produced by participants. The group collaborated on the design of the project, and collection and extraction of the data. Each sub-group analysed the data according to their methodological perspective (orchestration, multimodal interaction analysis, conversational turns, process mining, conversation analysis and discursive psychology and gesture), and then the synthesis step was performed as a group. Previous work, particularly in the field of multivocality (Suthers, et al., 2011) has been at the forefront of the application of combinations of methods of analysis. This symposium is the first to explicitly take the synthesis model, apply it to multiple streams of data collected specifically to examine the interplay of task, technology and social interactions, and use the tools developed for the field of multivocality, with experts in a variety of fields. In this symposium, presenters will apply frameworks for Discursive Psychology and Gestures (Hepburn & Wiggins, 2005), Conversation Analysis (Sacks, 1992) and Multimodal Interaction Analysis (Norris, 2004) to describe the co-configuration and co-creation behaviour of learners. The first presentation (Thompson & Carvalho) provides detailed background to the theoretical and analytical underpinnings of the project. Presentations 2 (Evans), 3 (Khoserhonejad, Reimann & Aditomo), and 4 (Wardak, Thompson, Carvalho & Goodyear) focus on individual perspectives. They discuss existing work that has led them to form particular assumptions about the role of scaffolding in their area of expertise, as it relates to the behaviour of learners. Each then outlines the methods used to analyse the dataset collected as part of this study. The fifth presentation (Thompson, Carvalho & Dyke) will include visualizations of the multiple streams of data using Tatiana, as well as a conceptual analysis of the combination of three methods and perspectives of analysis. The final presentation will include the whole project team to discuss the implications of doing research using the synthesis approach. While these presentations are all related, this symposium is of interest beyond the immediate reporting of results. As datasets become more complex, and more easily shared, a framework with which to understand the results is necessary. A discussion of the practical realities of team science in relation to the demonstration of real, theoretical findings, should be of interest to the CSCL community.

Background and framework
Kate Thompson and Lucila Carvalho

Scaffolding is an issue that is of particular importance in computer supported collaborative learning, and one that is in constant discussion in conferences and journals. Most current research agrees that students need to be scaffolded in their collaborative activities (Maloney & Simon, 2006; Hmelo-Silver, 2013; Nivala, Saljo, Rystedt, Knronqvist & Lehtinen, 2012). The concept of scaffolding involves providing support to learners in various ways, as these learners undertake complex or difficult learning tasks (Wood, Burner & Ross, 1976). Many studies have focused on scaffolding, and these could be classified under one or more of the three areas of Carvalho & Goodyear's (2014) framework: set design, epistemic design or social design. Technology scaffolding (set design) can include information about how to use a tool for the learning activity (see Davis & Linn, 2000). The context in which the learning experience occurs is of relevance when considering scaffolding. The Ecology of Resources Approach (Luckin, 2010) emerged in recent years as a learner-centred framework for the use of technology to scaffold learning. Collaboration scripts have often been used to scaffold the social processes of collaborative learning, such as Hogan & Pressley, 1997. Recent work on scaffolding has focused on combining scaffolds, and identifying scaffolding synergy such as technology- and social-focused in language learning in Singapore (Chen, Looi, & Wen, 2011), or social- and epistemic-focused collaboration scripts (El-Rifai, Kollar & Fischer, 2011). By using complementary scaffolds, multiple potential blocks to student learning

were overcome. Tabak (2004) was the first to refer to 'scaffolding synergy' while exploring the notion that multiple scaffolds that address the same learning need, in different ways, produce a robust support for learners.

What is lacking in the field of scaffolding is an examination of differences in the *processes* of learning as a result of specific scaffolds, and in the field of process analysis, a framework in which to place methods and analysis. The synthesis approach to analyzing complex collaborative environments presented in this symposium achieves these, and in doing so, will contribute to a deeper understanding of the processes of learning in complex learning environments. Kemp & Boynton (2011) identify five steps in synthesis research: problem identification; data assembly; data integration; explanatory model development; and testing model validity.

The authors purposefully designed a study in order to explore the application of a synthesis model of research to the topic of scaffolding in computer supported collaborative learning, underpinned by an analytical framework proposed by Carvalho and Goodyear (2014). The framework is concerned with how the relationships between the different elements in what has been designed/set in place in a given learning environment, combine to support the activity that ensues, the focus here being on how structure supports function. The framework proposes the examination of complex learning environments under four analytical dimensions: *set design*, *social design, epistemic design* and *co-creation and co-configuration activities*. Set design relates to the material and/or digital elements - the tools, resources, artefacts and affordances of place - that compose the setting for the activity of learners. Epistemic design relates to the proposed learning tasks, for example, their structuring, sequencing, pacing and the way tasks are planned to happen. The social design relates to social arrangements and roles, divisions of labour or who is expected to do what. The fourth dimension, the co-creation and co-configuration activities, relates the above components to learners' activities, acknowledging that learners re-arrange and reconfigure the designed learning space, proposed tasks and social roles.

The data collection was carried out in the Design Studio at the University of Sydney. This dedicated space for researching the processes of design gives participants access to tools (digital and physical) to aid in the process of design. The space is also equipped with multiple video and digital cameras, audio recorders, and the ability to capture log files of computer-based interaction. Three groups of three postgraduate students completed the task: Group 1 (Tools) - scaffold tool use; Group 2 (Design Process) – scaffold the design process; and Group 3 (Social) – scaffold (multidisciplinary design team (roles). We recorded the actions (physical and digital), conversation, and collected artefacts produced during the study. The data collected has been analysed from six perspectives: orchestration; multimodal interaction analysis (MIA) of the role of inscriptions; analysis of collaborative design behavior through conversational turns; conversation analysis (CA) and the impact of positioning in social interactions; process mining – decision-making and the design process; and discursive psychology and gesture. Three will be presented in the symposium: DP and gesture; CA and the impact of positioning in social interactions; and MIA of the role of inscriptions. These three were chosen because of the potential overlaps that will be examined – both DP and MIA examine the role of gesture, and CA and MIA examine key moments of negotiation, but with different focus and purpose to the analysis. In addition, these three approaches address the three designable elements – the tool use, epistemic and social interactions. Examining how they come together, and discovering what this tells us about the way we understand the role of scaffolding of complex collaborative learning environments, will lead us to develop a new explanatory model.

Analysis of scaffolding using a discursive psychology approach
Michael A. Evans and Lixiao Huang

In this presentation, we describe and characterize scaffolding through interactions among participants, analyzing video data from collaborative learning efforts. We are interested not only in learning outcomes from collaborative activity, but also in how the approaches used by learners influenced the ways in which collaborators made meaning of the project and engaged in the design process. To understand the role that talk plays in guiding learning, we employ a discursive psychology (DP) approach (Hepburn & Wiggins, 2005). DP is deemed a valuable framework as it assists us to understand how elicitation strategies of scaffolding influence the ways participants discursively construct understandings guided by the design process.

DP differs from other psychological analyses in that the focus is not centrally on psychological processes in a decontextualized form, but more on the ways that those processes are represented contextually in social interactions. DP explores socially situated and embodied forms of talk to understand psychological constructs like emotion (Hepburn, 2004) cognition (Molder & Potter, 2005) and beliefs (Barwell, 2005). As a primary advocate, Potter (2004) defines four ways in which DP can be used: 1) it assists analysts to better understand institutional practices; 2) it assists us to uncover the construction and meaning of "facts"; 3) it allows for the re-specification of cognitive constructs; and 4) it allows for the exploration of ideology and assumptions. DP frameworks identify discourse as "a type of action or work through which the social field of interaction itself

is constituted" (Freisen, 2009, p.133). Discourse is action-oriented, socially constructed, and situated, such that cognitive constructs are embedded in and expressed through talk and action (Potter, 2005). In using a DP perspective we see social interactions as a means of taking "discourse and its pragmatic realization for the purpose at hand as topics rather than language and linguistic structure per se" (Roth, 2008, p 46.). That is, discourse is viewed as a form of social action, rather than simply a means of sharing or outputting information.

While cognitive science has for many years recognized thinking as situated within a social environment (Lave, 1988), and as culturally mediated (Vygotsky, 1978), thinking and learning are still often described in terms of extrapolating mental processes. Rather than "assuming an underlying explanation for why people say or think as they do, DP assumes that mental states, motives, and thoughts are all features that are situated in and made visible through interaction (e.g., verbal and nonverbal communication)" (Lester, 2011, p.4). We used DP as a lens for understanding how scaffolding influences talk and helps to construct ideas about design. Our challenge is to characterize indicators of engagement through the talk and actions of participants, and to understand how the prompts provided by tools, context, and social support influence that engagement. Hsu & Roth (2008) explore science conceptions and motivation through a DP framework. They analyze interviews to understand youth's future career interests, but rather than analyzing what jobs are talked about, they focus on how language is used in the interview. In doing so, they discern how participants make consensus, revise their perspectives, and differentiate cognitive and affective processes. In a separate study, Roth (2007) outlines the ways that scientific conceptions are formed through talk, rather than simply being expressed by talk. He notes that the formulation of conceptions is filled with "mumbles, stumbles, malapropisms, pauses, stupidities, and solecisms" (p 36), all of which are important components of the discourse that are often overlooked. In addition to the verbal interactions, we applied a scheme for describing gesture and physical position of objects to capture the interactions among tools, scaffolds, and social support. Notation for physical interactions includes position of learners (who is in physical contact with it and for what duration) position and movement. Gestures included movements that indicate a directive (e.g. pointing), or describing a concept (e.g. lifting hands to show air flow).

Conversation analysis and the impact of position on social interactions
Maryam Khosronejad, Peter Reimann, and Anindito Aditomo

In this presentation we apply conversation analysis (CA), informed by positioning theory, in order to take an in-depth look at the interactional talk during the design session. Conversation analysis was developed by Harvey Sacks, Emanuel Schegloff, and Gail Jefferson (1974; Sacks, 1992) as a method for the study of conversation, focusing on understanding the regularities of talk-in-interaction applied by participants in conversations. We applied these ideas in the analysis of design group work, seeing such work as the interactional accomplishment of collective action. In our analysis, we focus on solution development of a design process, as a communicative activity and as an ongoing joint interactional achievement of the participants involved (Heritage, 1984). Conversation analysis allows us to investigate how transitions between different phases of solution development are accomplished at the micro level of talk. Our analysis focuses on different phases of solution development, such as solution analysis, solution suggestion, elaboration, evaluation, confirmation/disagreement and implementation (as suggested by the Decision Function Coding Scheme or DFCS, Poole & Holmes, 1995). In addition, we studied how alternative solutions were introduced and followed up through conversational patterns.

Conducting CA through the lenses of positioning theory, we also investigated participants' positioning of one another during conversation (Harré & Van Langenhove, 1999). Positioning theory looks at how people position themselves and others in a conversation by analysing conversation as consisting of tri-polar storylines, speech acts, and positioning (Harré & Van Langenhove, 1999). We investigated if and how positioning practices influenced patterns of conversation and transitions between stages of solution development, exploring whether these help to establish and preserve mutual agreement during design group work.

Our analysis suggests that three main categories of positioning were practiced by participants, each having consequences on the sequence of talk in conversation. These include positioning of oneself in relation to the task as an outsider or insider, positioning of oneself in relation to the researchers of the study, and positioning of oneself in relation to other group members. The first two categories of positioning happened at the beginning of the collaboration and as the group moved towards different phases of solution development, positioning practices were limited to the third category. Our analysis shows how one type of positioning led to rejecting, at least during the collaboration analysed, the scaffolds in the environment and as such contributes to an understanding of the difference between the collaboration environment as designed and as used.

Multimodal interaction analysis (MIA) of the role of inscriptions in design
Dewa Wardak, Kate Thompson, Lucila Carvalho, and Peter Goodyear

Ehrenstrasser and Spreicer (2012) state that "when designing technologies with tangible user interface, we need to enhance our understanding of modalities. We need to better scrutinize how space is used and organized, and furthermore, how users interact with different types of objects" (p. 1), including inscriptions. In order to inform the design of scaffolds for collaborative learning, a rich description of the activities of the learners is necessary. The role of inscriptions and representations has been researched in other studies of learning (e.g. Zhang, 1997; Medina & Suthers, 2013) however, not with a focus on collaborative *design*, instead in specific subject areas such as mathematics or science. Multimodal Interaction Analysis (MIA) takes the action rather than utterance as the unit of analysis (Norris, 2004). Creating and attending to the way in which visual marks, images, sketches and drawings embody a particular type of communicative practice requires a multimodal analytic framework. Spontaneously created visual representations can facilitate, bridge, or anchor communication. Visual communication plays a unique role providing opportunities for a person to employ certain modes of communicative practices (Snyder, 2013). Snyder (2013) illustrates how multimodal interaction analysis techniques can enable the researcher to investigate the role of drawing in face-to-face conversation. The transcriptions of MIA move beyond the focus on discourse, and depend on the analytical categories defined by the researcher. Based on these categories, the researcher defines the communicative modes to be included in the transcription of specific events. In this study certain communicative modes were transcribed because they were deemed important for describing the specific events and actions in the presence of inscriptions. The multimodal system of analysis in this study has at its centre the sketching and drawing practices of the participants. The participants' interaction is transcribed so that it illuminates the inscription-related interaction of the participants. Gestures are included when they are relevant to the analysis. That means, when gestures are produced in relation to the inscriptions and when the gesture is part of the meaning-making process of the participants.

Participants' use of both verbal and nonverbal interaction in relation to visual representations was considered. Inscriptions drawn during the design sessions by the participants in order to communicate and explain their ideas to their team members were analyzed in relation to the context in which they were used. For example, when a team was discussing an issue using indexical terms such as "this", "that", "here", "there", or "this one" and "that one", the inscriptions provided the essential context to understand what was being discussed. As such, the inscriptions serve as the background against which verbal and non-verbal communication can make sense (Roth & McGinn, 1998). The multimodal perspective will illuminate how participants were drawing and using the inscriptions they drew, as well as how they were interacting with each other in the presence of inscriptions.

Synthesis

Kate Thompson, Lucila Carvalho, Gregory Dyke, Michael A. Evans, Lixiao Huang, Maryam Khosronejad, Peter Reimann, Anindito Aditomo, Dewa Wardak, and Peter Goodyear

In this presentation we piece together the analytical contributions of each symposium participant, to compose our understanding of the scaffolding of learners and its influence on the learners' behaviour. First, we discuss the structure of our study, which allowed our exploration of part-whole relationships; we then show ways of visualizing how these different elements come together to explain the unique insights the synthesis analysis adds to our understanding of scaffolding in CSCL. As previously stated, the structure of the study follows the analytical dimensions in Carvalho and Goodyear's (2014) framework. We will discuss the results of the three analytical presentations in the context of the framework.

We used Tatiana (Trace Analysis Tool for Interaction ANAlysts) (Dyke et al., 2009) to provide a visual representation of the data and analyses considered. Tatiana is an environment (and an underlying conceptual framework) designed for manipulating various kinds of analytic representations, in particular those that present a view on event-based data, be it the original data or subsequent analyses thereof. We call these representations replayables, because they can be replayed in a similar fashion to a video. Tatiana replayables comprise a sequence of events and benefit from Tatiana's four core functionalities: transformation, enrichment, visualization and synchronization. Replayables can be *transformed* to create new replayables whose events might be a subset, an abstraction or a combination of events from other replayables. Adding annotations and categories is called *enrichment*, and Tatiana also provides a graph enrichment allowing researchers to annotate relationships between events. All replayables within Tatiana can be visualized in different viewers, such as a table with rows and columns, and several forms of graphical timelines, including a sliding window visualization (Dyke, Kumar, Ai, & Rosé, 2012), which affords the visualization of how indicators change over time and at different granularities. Finally, all visualizations of replayables in Tatiana can be synchronized with each other. This functionality allows data to be examined simultaneously from different angles. Because of Tatiana's

extensibility, and its ability to manipulate multiple analytic representations it is ideally suited both to accommodating analyses from the multiple perspectives addressed in this symposium, and to allow new insights to emerge when combining these multiple analytic perspectives. It has been successfully used in the past to highlight the agreements and disagreements of analyses from different epistemological positions (interaction analysis, content analysis, and cognitive analysis), not only allowing researchers to achieve common ground in their analysis, but also highlighting how different analytic traditions can achieve productive multivocality.

Recent research has focused on the interplay between social interactions, the design process, and the use of tools in the Design Studio (Thompson, Ashe, Carvalho, Goodyear, Kelly & Parisio, 2013; Thompson, Ashe, Wardak, Yeoman, & Parisio, 2013). Multiple streams of data are collected, processed, and presented to researchers to combine video, audio and image files. Initial studies have shown that the use of Carvalho & Goodyear's framework to structure the analysis of complex data results in rich descriptions of the context as well as the processes of learning. In these studies, we have also combined methods of analysis, such as video, conversation and sketch analysis, and process analysis and conversation analysis. Examining the interplay between the social, tools and epistemic processes can show patterns otherwise unable to be detected.

The analysis of the processes of learning using DP and gestures focused on the epistemic and the social. DP and gestures were used to understand scaffolding in relation to the development of talk and helped to construct ideas about design. Emphasis was given to understanding how the prompts provided by tools, context and social support influenced engagement and the group's trajectory was contextualized in relation to the scaffold. The use of CA and positioning theory also highlighted epistemic elements in a different way that includes social negotiations between participants. MIA of inscriptions offered insights related to the role of artefacts as resources for the participants in achieving a shared understanding of the problem at hand. Thus, in terms of Carvalho and Goodyear's framework, the focus is on how participants use the resources at hand and the role of their inscriptions and the artefacts produced so as to facilitate the groups' social interactions and communication. When these analyses were combined in Tatiana, we gained insight into the complexity of interacting processes of learning.

Reflections on the process
Entire panel

The purpose of this symposium is to demonstrate the results and processes of a synthetic approach to research of a computer supported collaborative learning task. In order to carry out the project, a team of twelve researchers in the learning sciences has come together to synthesize their perspectives in terms of methods of analysis as well as theoretical perspectives. This presentation will give all the participants the opportunity to discuss the challenges and solutions involved in conducting research of this type including: sharing data; managing the social; shared objectives; and future directions. Throughout this process, the research team has had to address the challenges of shared data in the social sciences. The files were made available to all, however the data extracted was unique to each participating researcher. There were three main challenges the team faced: what data was to be extracted, to what purpose; how would this data be visualized so that patterns and overlap could be noticed by researchers; and how would we present the findings coherently. Maintaining regular contact with the project team was important, and making time for virtual meetings was valued. We also held presentation meetings, during which initial results were discussed. Another important social aspect was the mix of established scholars, mid and early-career researchers as well as research students in the team. The students grounded the ongoing progress of the group, as they had specific deadlines for the development of their own work. Early-career and research students both had opportunities to have their emergent research ideas recognized as part of a larger group of researchers, and established and mid-career scholars gained insights into these new ideas. The development of shared objectives, particularly around research output has been crucial, offering concrete short-term goals for the ongoing progress. They helped to guide our work, and maintained the engagement and interest of the group. We have produced symposium proposals, a journal article (Thompson et al., in progress), and a data paper (Thompson et al., submitted). We hope that the discussion of the challenges presented in this symposium will aid in the application of this method to other areas of the learning sciences research, helping scholars in the field to gain richer insights in issues related to complex learning environments.

Even using a subset for this proof of concept, we will demonstrate findings in key areas associated with the processes of learning as well as the role of the design process scaffold. The use of the tools of synthesis – the framework as well as the visualization – are key in bringing these findings together. Without the analysis tool Tatiana, understanding and describing the interactions between perspectives in relation to processes of learning over time would have been far more challenging. The analytic framework was essential for making sense of the multimodal data collected, as well as contextualizing the findings. In future work we plan to incorporate all the

perspectives, and present these analyses in full. Other work has already been done synthesising three perspectives (Thompson et al., in progress). While the conclusions are preliminary, the initial findings show that there are identifiable moments of the interplay of tools, task and social interactions, after which shifts occur in patterns of tool use, social interaction or the design process. It appears that there are some key moments of intersecting processes that can affect the trajectory of a group's behaviour. The addition of further perspectives are expected to identify further moments of intersection, as well as other changes to the behaviour of the group.

The ultimate aim of this synthesis research, as opposed to other multidisciplinary research, is to develop a new model to understand the interplay of tools, task and social interaction in response to scaffolds in a complex collaborative learning environment. Unlike ecology, there is not an existing model against which to test the model. This research is focused on model development, and because of this, we are interested in opening up the research to more perspectives, to incorporate them into the model we are developing. To that end, we have submitted a data paper to a special issue of the *British Journal of Educational Technology,* and we are open to sharing the data further. As learning scientists we aim to understand how and why students learn in particular learning environments, given specific tools, tasks, and social interactions. These are complex scenarios that have yet to be fully explained with the current set of analytic and methodological tools. Borrowing methods from other fields, more suited to dealing with large datasets and complexity, and describing the complexity with a tool adapted from educational design, shows promise for unpacking some of this complexity, to begin to make sense of the interactions between the design, the processes of learning, and their effects on learning outcomes.

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