

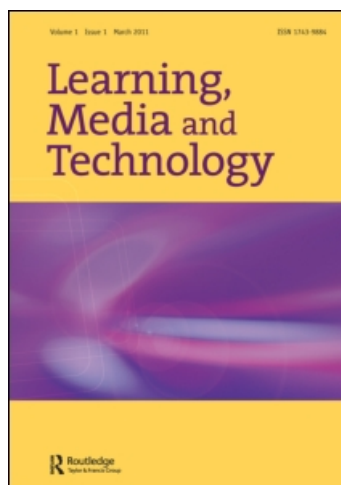
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Researching design practices and design cognition: contexts, experiences and pedagogical knowledge-in-pieces

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If research and development in the field of learning design is to have a serious and sustained impact on education, then technological innovation needs to be accompanied – and probably guided – by good empirical studies of the design practices and design thinking of those who develop these innovations. This article synthesises two related lines of research into teachers' design thinking. We draw attention to the importance of context in working on the solution of design problems and introduce the idea that some pedagogical knowledge can best be understood as 'knowledge in pieces', rather than as a coherent system of pedagogical beliefs.

Keywords: learning design; design practices; design cognition; design knowledge; teachers' knowledge; knowledge-in-pieces; intuitive pedagogy; personal epistemology

Introduction

Research and development in the broad field of learning design – including work on learning object repositories, reuse of designs and objects, design patterns, and design principles – has put significantly more effort into 'supply-side' issues than into 'demand-side' issues. That is, much more attention has been paid to the development of tools, standards, software and infrastructure than to establishing what users – primarily teachers who design technology-enhanced learning activities – actually need. Such technology-led ventures take the risk that they will produce tools and resources that get disappointing levels of take-up, in part because the developments are based on untested assumptions about what users do, how they think and the contexts in which they work and use these tools (Norman and Draper 1986; Pirolli and Russell 1990; Goodyear 1993; van Rosmalen et al. 2006; Laurillard 2008).

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We believe that future progress in learning design R&D will require more and better research on users, their needs, contexts of use and the affordances of the various tools and resources that are meant to improve their design activity. There will have to be a more productive interaction between (1) creating and testing new tools, and resources; and (2) carrying out well-conceptualised empirical research to inform better specifications for these tools. Such empirical work is not straightforward. It is no use if it is inherently conservative – we expect the introduction of new tools to change practices and personal capabilities for the better. But neither can it ignore the social practices of design nor can it ignore the mental resources and constraints involved in design cognition.

From this perspective, the broader enterprise of learning design R&D needs to develop, and be informed by, plausible theories of how intended users will come to take up new tools and resources. At a macro- or organisational level, such theory needs to account for why teaching, as a profession, might be expected to shift its attention towards the upstream work of design (Goodyear and Retalis 2010a). At a meso- or practice level, it also needs to help us create convincing scenarios of future use – including work practices and divisions of labour – such that the tools and resources being created fit into a credible ecology of use (Laurillard 2008). At a micro- or user level, it needs to explain the situated nature of design cognition – at least to the point where we have a clear idea of what kinds of design thinking teachers find easy and difficult, and where performance support from suitable tools – including methods upon which they draw – might make most difference (Markauskaite and Goodyear 2009).

In this article, we synthesise some lessons learned from two parallel strands of empirical research on teachers' design activity, when 'teachers' are referred to in a very broad manner. One strand has been examining learning processes of school teachers who participated in a semester-long course in educational technology design, as part of their graduate studies in education (Ronen-Fuhrmann and Kali 2010). The other has been investigating the nature and evolution of a university teacher's design thinking, over a one-semester course, focussing particularly on the variety of mental resources activated in her accounts of activity designs (Goodyear and Markauskaite 2009; Markauskaite and Goodyear, under review). In both study settings, teachers designed learning activities which required their students to collaborate with each other and to make extensive use of technology. In this article, we want to (1) extend and illustrate some of the arguments about the value of empirical research into teachers' design activity; (2) use this as a way of examining some influential assumptions about the nature of teachers' personal pedagogical knowledge and design cognition; and (3) examine some related issues concerning the role of *context* in design.

This work is part of a larger interest we have in design-based research, teaching-as-design, design principles, design patterns and pattern languages,

and design cognition (see Goodyear 2000, 2005; Kali 2006, 2008; Goodyear and Markauskaite 2009; Kali, Levin-Peled, and Dori 2009; Goodyear and Retalis 2010b). We have come to attach particular importance to the ways in which design thinking has to move back and forth between macro-, meso- and micro-level considerations and has to deal in an integrated way with at least four design components, involving tasks, people, tools and regulations. Design cognition and design practices, in the field of education, take on distinctive qualities because of the need to travel between high-level pedagogical theory and the minutiae of learning activities, using various kinds and levels of intermediate representation to do so (Goodyear 2005; Ruthven et al. 2009). We have also found that translating abstract design ideas and pedagogy into concrete design artefacts is a process with which many novices in learning design have difficulties (Ronen-Fuhrmann and Kali 2010). Similarly, seeing common instructional principles and articulating conceptual similarities between specific learning activities encountered in different teaching and learning contexts or maintaining pedagogical coherence across all activities in the same course was a demanding task even for a knowledgeable teacher (Markauskaite and Goodyear, under review). Educational design is a social construction. As such, it is both an epistemic activity and practical action that takes place in specific, yet multiple, contexts and specific, yet multiple, circumstances. Such tasks provide multiple solutions; neither the process of design nor the final solution could be accounted by one 'expert' practice. While being complex from a social perspective and non-reducible to a simple cognitive step-by-step description, design thinking deserves much more precise examination (and more flexible theorisation) that can account for and provide articulated insight into the richness and structure of expert thinking.

Lessons learned from instructional design research

A substantial body of research on teachers' thinking, decision-making and beliefs has emerged over the last 20–30 years. For summaries, see Clark and Peterson (1986), Calderhead (1996), Hativa and Goodyear (2002) and Postar-eff et al. (2008). A subset of this research has focussed on teachers' planning activities (e.g., Stark 2000; Eley 2006; McAlpine et al. 2006). There has also been a somewhat separate line of research involving empirical studies of instructional design – sometimes involving school or tertiary education teachers, sometimes novice and expert professional instructional designers (e.g., Kerr 1983; Rowland 1992; Hoogveld et al. 2001, 2002; Kirschner et al. 2002; Ertmer et al. 2008, 2009). Some studies link between the two by trying to assess the extent to which experienced and/or successful teachers make use of instructional design methods (e.g., Moallem 1998; Young et al. 1998). Studies of how teachers use learning designs, design tools, design principles and design patterns are still rather rare (Uduma and Morrison 2007; Bennett et al.

2008, 2009; Levy, Aiyegbayot, and Little 2009; Masterman, Jameson, and Walker 2009).

Kerr's (1983) pioneering study of relatively inexperienced instructional designers highlighted some important features of their design thinking. First, most novice designers had difficulty in entertaining multiple candidate solutions to their design problem – rival solutions tended to be culled at a very early stage in the design process. Second, a tendency to make a premature jump to the solution was often evident. For instance, one study participant wondered 'how to design a project when you already know what you want to use' (1983, 54). Third, novice designers tended to accept the constraints of the envisaged instructional situation as fixed and rigid, rather than as open to change. This appeared to be accompanied by a wariness about trying new instructional approaches. Fourth, the novice designers made very limited use of representational aids (such as sketches, diagrams etc.) in their design process. Fifth, they rarely used explicit criteria for stopping their design work (other than 'running out of time'). That is, the novice designers in the study were ill-equipped to judge whether their design had been elaborated to the point where it was right to stop. Finally, they showed few signs of engaging in design metacognition (self-awareness, self-monitoring, reflexivity etc.). Kerr's study is useful, for our purposes, in that it begins to suggest areas of weakness in the activity of novice designers, with clear possibilities for improved performance with the help of appropriate tools and methods. As our own research shows, many of these issues are still relevant.

Rowland (1992), in a comparative study of expert and novice instructional designers, found that novices tended not to see the instructional design problem that they were given as being ill-structured – they assumed, instead, that the information provided was complete and well-specified. They also focused on the surface features of the problem presentation and rarely drew on other knowledge to make inferences that went beyond the information given. They shifted rapidly from problem analysis to problem solution and, as with Kerr's novices, did not give much consideration to alternative solutions. Expert designers, in contrast, tended to draw on rich experiential knowledge to construct a conceptual framework for exploring and solving the problem; they spent considerable time on analysis and only moved to generating candidate solutions when they were confident they understood the problem thoroughly.

Hoogveld et al. (2002) conducted a small-scale study working with 10 experienced teacher trainers. They used a variety of knowledge elicitation techniques, including repertory grid methods, in order to ascertain how these teachers went about the processes involved in designing or redesigning the courses that they taught. They compared the teachers' accounts of their design practices with the classic ADDIE (Analysis, Design, Development, Implementation, Evaluation) model (Dick, Carey, and Carey 2001) and observed that both Analysis and Evaluation were under-represented in the teachers' accounts. The teachers did not appear to spend much time on diagnosing their

students' learning needs, or on the complexities of analysing and defining intended learning outcomes. At the other end of the process, neither did they attend much to evaluating the success, or otherwise, of the learning activities that they implemented. The relative neglect of these 'diagnostician' and 'evaluator' roles was replicated in a larger sample study, once again with teacher trainers as the participants (Hoogveld et al. 2001).

More recently, Ertmer and colleagues (2008, 2009) have been studying expert–novice differences in the area of instructional design in order to improve the kinds of support available for novice designers. Ertmer's work has been particularly successful in helping novice designers do a more thorough job at the analysis stage, for example, by providing them with Analysis guidelines that scaffold their work and inhibit the tendency to jump to a premature solution.

To summarise, research shows that instructional design is cognitively complex and that novices are:

- unlikely to spend enough time and effort to analyse the problem properly;
- likely to jump very quickly from deciding on a learning goal to specifying the concrete details of lessons;
- unlikely to pay sufficient attention to alternative candidate solutions;
- likely to take the apparent constraints of the current learning situation as rigid and hard to change;
- unlikely to create helpful representations (e.g., sketches, notes etc.) of their problem and candidate solution(s); and
- poorly placed to reflect on their design work or to learn from evaluating its process or outcomes.

Thus, the lessons we can learn from empirical research on design, regarding how to develop tools and resources for assisting teachers in designing technology-enhanced learning activities, are that these tools (1) need to compensate for the above weaknesses; and (2) need to provide scaffolding that helps teachers progress on the path from novice to expert designer. For example, it may be better to offer tools that provoke teachers into thinking about new learning activities rather than equipping them to carry out pre-existing pedagogical intentions. It may be better to help them explore several candidate solutions to a problem than to fast-track to a premature solution. Some of these aspects have already been implemented in tools and resources designed for teachers, such as Compendium LD (Conole 2008), Cloudworks (Conole and Culver 2009), LAMS (Learning Activity Management System; Dalziel 2003), the Design Principles Database (Kali 2006, 2008), and Design Patterns (Goodyear and Retalis 2010b).

However, many novices in educational technology design find such tools difficult to use (McAndrew and Goodyear 2007; Ronen-Fuhrmann and Kali

2008). We claim that more in-depth analysis of the situated nature of teachers' design cognition is required if we want to develop tools that teachers are likely to find useful while designing technology-enhanced learning activities.

In the next part of this article, we introduce a line of research which extends the lessons learned from the foregoing design research literature and which we believe is critical to the issue of how to support teachers' design processes. This line of research explores the nature of personal pedagogical knowledge and the complexities in making task design decisions in (and for) specific teaching and learning contexts.

Insights into the nature of personal pedagogical knowledge

A major issue that needs better resolution if we are to understand the relationships between teachers' pedagogical commitments, use of technology and engagement in design is the question of whether their pedagogical beliefs are stable and coherent, or contextually-sensitive and fluid. This matters for a number of reasons. For example, talking more generally about university teachers' use of technology, Bates and Poole assert:

The choice and use of technology are *absolutely dependent* on beliefs and assumptions we have about the nature of knowledge, how our subject discipline should be taught, and how students learn. (2003, 25, our emphasis)

Similarly, Bain and McNaught (2006) report on a number of 'complex, yet interpretable' relationships between university teachers' beliefs about teaching, learning and knowledge (on the one hand) and their uses of educational technology (on the other). While urging against oversimplification of the relationships between beliefs and practices, they nevertheless imply that beliefs are relatively stable and coherent (at the intra-individual level) and are causal – i.e., that practices flow from beliefs, rather than vice versa.

More recently, Donald and colleagues have described their HEART (HEaring And Realising Teaching-voice) methodology – an approach to design which is intended:

to help teachers and designers select and work with existing learning designs, by helping them reflect on and articulate the educational beliefs *underlying* their own and others' teaching and learning design practice. (2009, 180, our emphasis)

In short, while a more fragmented, intuitive and context-sensitive picture of teachers' knowledge, thinking and action has been painted in some of the more general literature on the teaching profession (cf. Atkinson and Claxton 2000; Torff and Sternberg 2001), one can still find quite strong views in the learning design literature that conceive of teachers' pedagogical beliefs as coherent and foundational. They appear to constitute a kind of personal

pedagogical theory, used to make decisions which result in pedagogical actions (including design actions). Our research, as we describe below, is leading us to challenge this view and to see it as an obstacle to the improvement of design practice (because it suggests teachers' beliefs are inflexible and that they guide their design decisions regardless of context).

In addition to drawing on our empirical observations, our argument against a coherent, stable and foundational view of personal pedagogical theory is informed by some developments in theorising about personal epistemologies (e.g., Hammer and Elby 2002) and on research revealing discrepancies between teachers' conceptions of teaching and aspects of their educational activities (e.g., Eley 2006; Foley and Ojeda 2008; Henderson and Bradey 2008; Postareff et al. 2008).

Hammer and Elby (2002) argue persuasively against what they call a 'unitary theory' view of personal epistemology. They draw on diSessa's work on conceptual change in physics (e.g., diSessa 1993, 2006; also Wagner 2006), which introduced the notion of 'knowledge in pieces' to account for commonly observed (mis)conceptions in students' physics knowledge. According to diSessa, people's direct experiences of the physical world lead to the creation of mental resources that he calls 'phenomenological primitives' or 'p-prims'. p-prims form a layer of knowledge between 'hard-wired' direct experience and conscious concepts. They may be an individual's interpretation of an observable phenomenon, which they then use to explain that and other similar phenomena encountered in the world. p-prims are readily activated when the context feels right. While sometimes p-prims might be activated incorrectly and, thus, might lead to a (mis)interpretation of a physical phenomenon, overall, p-prims provide a powerful generative mechanism for building one's conceptual understanding about the physical world. By extension, 'epistemological p-prims' are created through experiences with different forms of knowledge and ways of knowing (Hammer and Elby 2002) – they are part of how people make sense of what knowledge, knowing and learning are. An important explanatory advantage of this 'knowledge-in-pieces' view of human mental resources is that it can deal with observed inconsistencies in people's physical and epistemological understandings. Different sets of p-prims are activated in different contexts. People are generally good at making sense of things in specific contexts. They are not famously good at maintaining coherence among large sets of beliefs and across diverse contexts.

We now want to provide initial evidence and claim a place for *pedagogical p-prims* – which are implicated in pedagogical sense-making. Just as p-prims arising from experience with the physical world can be implicated in 'naïve physics', so p-prims arising from experiences of being taught, or of teaching, may be the building blocks of 'folk pedagogy'. They typically are implicated in what might be called 'traditional teaching', formed through a process in which an individual teacher's ways of teaching are strongly shaped by his/her personal experience of being taught. These p-prims encode direct experiences

of learning and teaching and provide important generative mental resources for pedagogical sense-making in learning design.

In the next part of this article, we offer summaries of two related lines of empirical research through which we have been examining some important aspects of the situated nature of teachers' design cognition. The first line of work, by Kali and colleagues, focuses on some difficulties that teachers, who are novice designers, experience when designing an artefact as part of an educational technology design course. The second line of work, by Goodyear and Markauskaite (2009), looks quite closely at the mental resources and the complexities of their activation and integration when a teacher is thinking about appropriate combinations of technology and pedagogy for her students in specific contexts. We describe how outcomes from each of these studies can be understood from the pedagogical knowledge-in-pieces perspective, and conclude the article by drawing out some implications for future R&D in the learning design field.

Interpreting our studies through the lens of pedagogical knowledge-in-pieces

Pedagogical knowledge-in-pieces in the design course study

The study reported in this section of the article draws its data from a course for graduate students in education who were school teachers (we refer to them as 'teachers'). The goal of the course was to provide these teachers with knowledge and tools required to design technology-enhanced curriculum modules. The study has the twin objectives of (1) developing, testing and improving an appropriate teaching model for these teachers – novice designers; and (2) clarifying the nature of design cognition by examining the learning processes and achievements of the teachers involved in the course.

The course used for this study was a semester-long face-to-face course in which a total of 33 teachers participated. The teachers worked in 14 small groups of two or three teachers each. All of the participants had some experience as school teachers (elementary school or high school). While they typically had some experience of designing learning materials, they had no experience of designing technology-enhanced learning. Figure 1 captures the three main elements of the teaching model.

The teachers were introduced to the ADDIE model. In this particular teaching model, the *Design* stage was expanded to include three additional non-linear iterative stages: *Brainstorm Activities*, *Build Flow* and *Design Features*. Teachers brainstormed ideas for activities that can help potential learners gain skills and knowledge required for understanding the topic of the module they designed. Then, they built a flow of activities or several possible scenarios for learners to follow in their module. Finally, they designed features for each activity, showing in detail how each activity would be viewed by a learner,

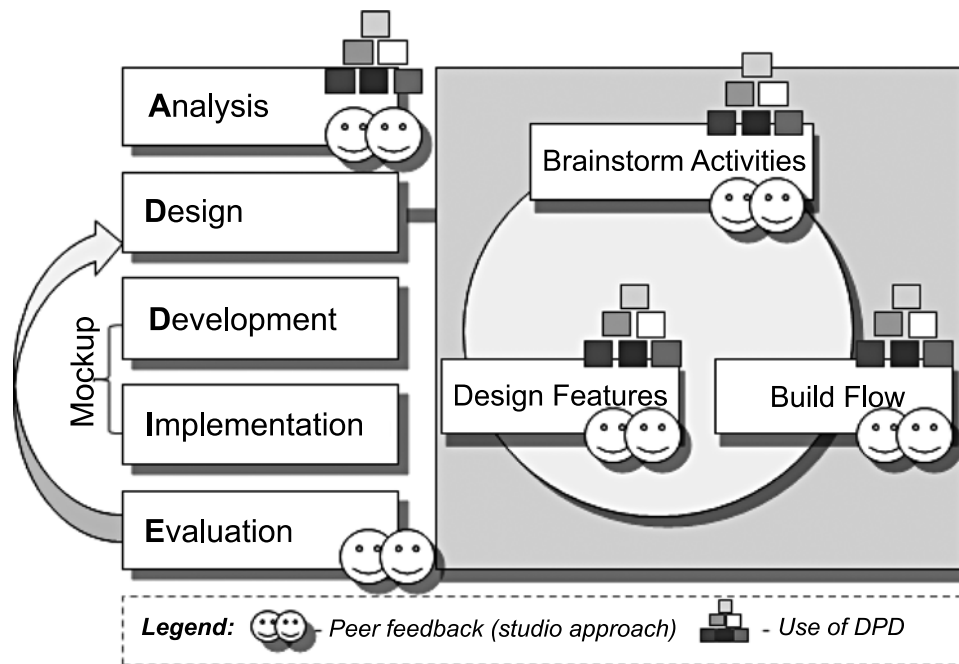


Figure 1. Three main elements of the teaching model: use of ADDIE, the studio-based approach and the Design Principles Database (DPD).

including a screen layout, interactive elements and instructions. All course meetings took place as ‘design studio’ sessions. At key stages, each group would present the latest version of the artefact it was designing and received peer feedback from other teachers. The use of a resource called the Design Principles Database (DPD) was structured into the students’ work process. The DPD is an online tool depicting design principles, linked to example features from multiple contexts (Kali 2006, 2008). The teachers were required to use the DPD at four points in the process: analysis, brainstorming, designing the flow of activities and creating design features.

A rubric was constructed, based on inductive analysis of the data, to assess the epistemological sophistication of the design artefact created by each group. This had three dimensions: learner activity, collaboration and content accessibility (see Table 1).

This rubric allowed an assessment to be made of each group’s *enacted* beliefs about how students (should be helped to) learn – enacted through their crystallisation in the group’s designed artefact.

Outcomes indicated that in *discussion-based* activities, at the beginning of the course, students evinced pedagogical beliefs that were broadly consistent with socio-constructivism. However, their *designed artefacts* embodied very different positions on this matter, with fewer than half of the groups showing an ability to design artefacts consistent with a socio-constructivist position.

Table 1. Rubric for assessing epistemological position (Ronen-Fuhrmann and Kali 2010).

Dimension	Low	Medium	High
Learner activity The degree to which students expressed ideas that support active engagement of learners within a technology-based learning environment.	Passive: e.g., learner reads or views information	Example: learner clicks on links	Active: e.g., learner manipulates variables
Collaboration The degree to which the students supported using technology in ways that enable learners to learn from each other.	Individual learning	Group work is not supported by technology	Technology-mediated collaboration is intrinsic to the activity
Content accessibility The degree to which students expressed views that support makes the contents of a learning environment accessible to learners.	No effort to connect content to learners' world	Motivational aspects are extrinsic to activities	Motivational aspects are intrinsic to activities

For example, one group of teachers designed a technology-based module designated for high school computer science learners. Their module focused on recursive algorithms for scanning data structure trees. One of the features they designed, from a very early stage in the design process, was an animation that demonstrates a certain algorithm for scanning a tree. Their (potential) students were required to solve problems that utilise the demonstrated algorithm.

Analysis of this group's learning process using the rubric (Table 1) revealed that at the beginning of the semester, in general discussions about educational technologies, each of these teachers expressed ideas that were classified as high level of sophistication with regard to each of the dimensions of the rubric (e.g., expressions in the discussion such as 'one of the most important things when designing educational technologies, is to use the capability of the computer to support interactivity and provide feedback on students' actions' – were classified as *high* in the *learner activity* dimension). However, when this group began to design its animation feature, it required learners only to passively watch the animation. There was no attempt to make the content more accessible to students (the animation was an abstract schematic representation), and collaborative aspects were minimal (a forum was designed for questions and answers). Gradually, this feature was revised following discussions with peers and instructors and the use of the DPD. Finally, it was changed into a manipulable tool which enabled learners to solve real-world problems by exploring various ways to scan given trees, as well as their own trees.

A number of implications can be drawn from this study, but we will focus here on just one: that even experienced teachers can evince discrepancies between how they talk about their pedagogical beliefs and how they design technology-based learning resources. Such dissonance is usually assumed to be odd (needing explanation) and problematic (causing difficulties for teachers and/or their students). It is *odd* if one subscribes to the view that a coherent personal theory of teaching is normal. It is *problematic* if the enactment of apparently conflicting pedagogical positions in different contexts (in this case – discussions vs. actual design) causes problems for either students or teachers. Both of these assumptions require careful examination. For example, recent research on *study orchestrations* and *teaching orchestrations* is beginning to show that both students and teachers are capable of holding apparently contradictory beliefs and engaging in apparently dissonant educational practices, depending on *context* (Lindblom-Ylänne 2003; Postareff et al. 2008).

In terms of pedagogical knowledge-in-pieces, it seems that these teachers were able to activate sophisticated ideas of instruction in the context of *discussing* educational technology design. However, when they were in the novel space of *actual design*, they activated more traditional ideas of instruction (in which students are passive). The latter ideas might have been influenced by technology tools and activity contexts they were familiar with. In other words, specific design situations activated experiential knowledge in the form of pedagogical p-prims.

Pedagogical knowledge-in-pieces in online learning design and teaching study

The second strand of empirical research on which we wish to draw is concerned with the detailed nature of the mental resources implicated in a teacher's design thinking and decision-making during teaching time (Goodyear and Markauskaite 2009; Markauskaite and Goodyear, under review). Our data come from an in-depth study of one university teacher's learning design and teaching experiences (whom we call 'Sophie') who taught a part of a postgraduate course on system modelling for educational technology students. This course introduces students to ideas and techniques from the area of systems thinking, including the use of systems dynamics models and modelling tools, such as STELLA. The subject is mostly taught online and makes extensive use of real-time collaboration tools, such as synchronous online chats and a shared whiteboard. In addition to observing Sophie's online teaching, we also examined all the material Sophie used, activities that she designed and the protocols of the synchronous sessions. (The online environment that Sophie used kept a trace of most of class activities.) We also held eight in-depth interviews with Sophie, each after one of her teaching sessions, in which we asked Sophie to explain her lesson and activity designs and decisions made during class time. The interviews were based on the

principles of critical decision-making (Hoffman, Crandall, and Shadbolt 1998) and epistemic interviewing (Brinkmann 2007). The questions about learning design were broadly structured around three main design components: task, social organisation and tools (Goodyear 2005). For analysing the interview data, we adapted and followed a procedure of interpretative phenomenological analysis (Smith and Osborn 2003). We initially re-read the transcripts several times, specifically exploring the epistemic meanings of Sophie's accounts. Then, we identified and labelled themes, reflecting frames of reference in which knowledge and meanings were situated and sources of knowledge. Finally, we clustered these themes into a smaller number of broader-based categories. For this article, we chose to focus on two aspects of our findings: (1) the nature and integration of different mental resources; and (2) Sophie's use of contrasting pedagogical approaches in making learning design decisions in different situations. Since our goal is not to provide a detailed account of all possible mental resources and ways of blending them but to summarise the thinking that led us to reject a traditional 'theory-like' understanding of teachers' pedagogical knowledge – and suggest a knowledge-in-pieces framing for interpreting teacher design cognition – we will describe and illustrate only the most relevant key findings.

First, we explored the kinds of mental resources that Sophie activated in her accounts of learning design decisions. We identified seven main frames of reference, summarised and illustrated in Table 2 (Markauskaite and Goodyear, under review).

In her typical accounts of design decisions, Sophie often integrated several frames of reference that referred to the general epistemological and pedagogical aspects (such as the nature of disciplinary knowledge, how people learn and how to teach) and more specific context-related frames (such as the context of the course, educational environment, students' and Sophie's own experiences). For example, asked to explain the content and design of one lesson, Sophie responded with a short account that integrated four frames:

The topics are the building blocks [1. Disciplinary content]. They are what's fairly consistent between all the different schools of thought on how you should be teaching it [3. How to teach], that you need to understand those concepts [2. How people learn]. The way of doing causal loop diagrams [1. Disciplinary content], it just made sense to me [3. How to teach]. It's far easier, we have the whiteboard tool there [5. Educational environment], it's not much good me just showing them example after example [3. How to teach]. If they get a chance to do it themselves and then discuss, they tend to understand [2. How people learn]. (0828Q20)

Second, Sophie's decisions in different situations have been based on rather contrasting pedagogical views. For example, Sophie often aimed to provide students with open tasks that required students to collaborate, discuss and construct their own knowledge. She explained her design decisions:

Table 2. Frames of reference and examples (adapted from Markauskaite and Goodyear, under review).

Frame of reference	Example
1. Disciplinary content and subject nature (subject knowledge, skills, etc.)	‘The topics are the building blocks’ (0828Q18) ^a ‘It explains the concepts that you need to know’ (0828Q28)
2. How people learn (cognitive and social processes, etc.)	‘You need to understand those concepts’ (0828Q28) ‘If they get a chance to do it themselves and then discuss, they tend to understand’ (0828Q20)
3. How to teach (pedagogical ideas, instructional strategies, etc)	‘It’s not good me just showing example after example’ (0828Q20)
4. Course (aims, context, etc.)	‘The rest of the subject is about organisational change and about learning to change, so it’s a good tool that fits’ (0828Q1)
5. Educational environment (affordances, constrains, time, teaching mode, tools, etc.)	‘It’s much easier, we have the whiteboard tool there’ (0828Q20)
6. Students (needs, interests, motivation, experiences, knowledge, etc.)	‘I want every single student to specifically experience this’ (0904Q19)
7. Teacher (aims, experience, knowledge, etc.)	‘It’s too big of a task and it doesn’t give me the opportunity to see how they’re going, to check where they’re up to’ (0904Q31)

Note: ^aThese codes refer to segments of the interview transcripts.

It’s a lot more powerful if they come up with these ideas themselves. Most of the research says that they’re going to remember them because they had to construct them, they had to figure them out. They get experience working in groups, they don’t have to listen to me. So it’s different, it’s more fun, plus they get to interact with model so they get value added and they get experience in the software as well as learning what they need to learn. (1009Q36)

However, when students needed to learn basic system dynamics concepts or to use new software (STELLA), Sophie typically created activities for whole-class teacher-led discussions or gave students very structured individual tasks (such as step-by-step instructions on how to construct a model). For example, when students learnt new system modelling concepts, Sophie opted to discuss them in a large class. Sophie explained her decision:

This time I just wanted to make sure that they understood it [concepts]. I didn't trust that they'd read it and understand it to that level. So it was a good opportunity for us all to discuss it, for them to ask questions and for me to make sure that they're getting it along the way. (0926Q33)

However, she understood that she could organise this lesson differently. When asked the question, 'If you wanted to achieve the same aims of this lesson using a different type of task or activity would you be able to do that', Sophie responded:

If I was doing this differently I could split them into groups if it was a big class, six groups probably, and give them instructions on making model that would fit each of those types of behaviour. So they'd make the model, they'd be able to see this behaviour and then they'd come back and show the rest of the group what they made and the type of behaviour and see that they all had different models with different types of behaviour that went with them. (0926Q30)

While this chosen pedagogical approach was dissonant with other approaches found in Sophie's accounts, and with her espoused 'teaching philosophy', this choice was 'optimal' for Sophie for teaching that type of knowledge in this specific context (under existing constraints of time). Sophie explained this choice on several occasions in the following ways:

It's not a big enough class to do that [group work] and I would want more lead up time, more practice modelling before they did that, and it's not the case in this class. (0926Q30)

I don't need [students] to come up with these ideas [definitions] themselves, I just need them to know them, and then we can move on to the more exciting things where we do break into groups and all that. (0904Q14)

In short, Sophie employed, and was able to account for, strongly contrasting pedagogical approaches in different teaching contexts – switching between exploration and knowledge-building (when the students need to understand complex relationships) and direct teaching and step-by-step instructions (when they need to learn basic concepts or how to drive a piece of software) (for more examples, see Markauskaite and Goodyear, under review).

Further, many of Sophie's accounts of her pedagogical choices turn out to be deeply rooted in her previous learning and teaching experiences. These experiences provided her with a mental resource for predicting which pedagogical strategies should work in this specific new context. For example, to the typical epistemic question, 'How did you come up with this decision', Sophie responded in a very experiential way: 'Because that's how I learned it' (0828Q10); 'This is just what I've always done. I tutored maths ...' (0828Q36); 'That's how he [a senior colleague] managed teams and I continued to do it the same because it worked quite well. But I haven't thought about it enough to know where that comes from ...' (1016Q22). Nevertheless, many

of Sophie's decisions also can't be accounted for by a simple 'folk pedagogy' and replication of her previous experiences. The consideration of details of her teaching context and differences between the context of her knowledge and the situation were evident in many of her accounts. For example, in making her choices about the course readings and class tasks, Sophie often reflected on the time constraints of 'half a course in education' (0821Q13), differences between professional system modellers and her education technology students, and specific student interests in this course:

I found making the [modelling] task relevant [for education students] very difficult ... This year I feel like it's a very relevant task to give them so I'm waiting to see the final assignment to see if that's added another layer to the learning in this class. (1016Q15)

Discussion and implications for the future of learning design

In both studies, described above, teachers' design knowledge and thinking cannot be accounted for by a single pedagogical theory or even pedagogical orientation. These studies suggest that educational design need conceptual frameworks that could explain those numerous inconsistencies in teacher cognition and take into account the experiential mental resources that are so often activated in teachers' accounts of their decisions. Traditional conceptual frameworks of teachers' cognition have been rather unproductive in their attempts to explain such inconsistencies. They often view teachers' mental resources (that are rooted in their direct encounters with pedagogical phenomena) as 'epistemological obstacles' for the acquisition of 'correct' pedagogical theory. 'Pedagogical p-prims' offer a different framework. While p-prims are based in direct experiences, in principle, pedagogical p-prims provide useful, generative, mental resources for sense-making and for building and applying more abstract pedagogical knowledge in new design situations. An important explanatory advantage of this 'knowledge-in-pieces' view is that it can deal with observed inconsistencies in pedagogical beliefs and decisions. Different sets of conceptual, epistemological and pedagogical p-prims are activated in different contexts. p-prims help explain how it is that teachers can appear to espouse contradictory pedagogical views when asked to think about different specific teaching contexts (see Kane, Sandretto, and Heath 2002; Eley 2006; Postareff et al. 2008).

We think that this perspective on personal pedagogical knowledge has a number of significant implications for thinking about how teachers (will) engage in design, and for the tools that can support their design activity. We specifically want to point to the complexity of knowledge integration and the role of context in design.

Instructional design models do not often draw attention to the fact that design for learning involves *balancing* competing forces and *integrating*

diverse knowledge systems. For example, any one learning activity may have multiple intended learning outcomes: some may be near-term and concrete ('learn this equation'), while others may be longer-range and more abstract ('learn to be a good team-player'). Then again, teachers' designs have to negotiate an acceptable compromise between students' wants and students' needs, and between the pedagogically ideal and the affordable. Design is intimately concerned with finding workable compromises, with resolving tensions (Collins 1996). There is no calculus for making these choices – the forces concerned cannot all be reduced to a common currency. Rather, design cognition *has to* deal with different forms of knowledge and ways of knowing; it necessarily involves the activation of mental resources that are hard to integrate. Context both helps and complicates matters. Having a specific context in mind – i.e., working on a delimitable part of a larger design problem – should make it easier for relevant mental resources to be activated (cf. Wagner 2006), but local solutions have to be articulated with one another, to some acceptable degree. Expertise in design can be seen, in part, as the capacity to activate the mental resources that are needed by the current problem context.

One practical implication that we are now exploring is that some kinds of design aids – for example, design patterns assembled in pattern languages – take a form that would appear to be particularly handy for managing contexts. Voigt (2010) has drawn attention to the way in which the hierarchical structure of a pattern language permits pedagogical design guidance to be restricted to particular contexts – an advance on trying to apply universalistic pedagogical guidelines. Similarly, sets of design principles, exemplified in various contexts, and linked to each other, such as those described in Kali, Levin-Peled and Dori (2009), seem like a promising direction to guide teachers in their design process. What is now ripe for further empirical exploration is the way in which specific sets of mental resources come to be activated as a teacher-designer reads and works with carefully constructed design guidelines in a sequence of contexts.

Concluding comment

In this article, we have tried to sketch some issues for the future of learning design that emerge from recent empirical work and theorising about the nature of design practices and design cognition. In particular, we have drawn attention to the significance of contexts in the design process and to some of the difficulties entailed in treating a teacher-designer's personal pedagogical knowledge as coherent, theory-like and a foundation for action. We also wanted to point to some of the explanatory and practical benefits that can flow from seeing personal pedagogical knowledge as 'knowledge-in-pieces' and from seeing teacher's design knowledge as a knowledge that requires careful 'blending' of diverse frames of reference and diverse mental resources. Further consideration of these aspects can inform practical developments in

the technology of learning design as well as more fruitful empirical research into the design process.

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