Designing for complex ICT-based learning: understanding teacher thinking to help improve educational design

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The work involved in designing good learning tasks is becoming more complex. This is partly because the changing needs of the knowledge society are placing greater demands on the ability of graduates to work with knowledge in more versatile ways. It also arises from the growing complexity of arrangements for learning: involving new and more fluid distributions of learning activity across time and space. Efforts are being made to improve the design resources available to teachers in higher education, yet little is known about how teachers actually engage in design work: what they think about, what experience and expertise they draw upon, what goes on when they create new learning tasks. This paper presents some outcomes of a small scale study of teacher thinking during educational design. It focuses on the teacher design thinking in the context of systems thinking and modelling course. In particular, it explores some ideas about the mental resources that need to be activated and combined in coming to good design decisions – especially when ICT tools are an important part of the educational mix.

Keywords: teaching-as-design; conceptual integration; learning through modelling; epistemic fluency

Designing for complex learning in complex spaces

Recent years have seen a growth in the complexity of higher education, with students being expected to master more complicated forms of knowledge, through novel learning arrangements, distributed over physical and virtual spaces. Expectations about learning outcomes have shifted from a focus on knowledge of a specific discipline to also embrace a broad set of generic competences, and an ability to: integrate knowledge from several disciplines, move smoothly between the theoretical and the practical, and contribute effectively to multidisciplinary teams in rapidly changing organisations (Argyris, 1998; Sennett, 2006). It was once possible to conjure up shared images of tertiary education that focussed on lectures, seminars, lab classes and the library. Each educational space afforded a small set of study activities – listening and taking notes in a lecture hall; reading and taking notes in the library, and so on. Although it is a mistake to underestimate how strongly some established study activities are entrenched, and to wish away the shaping powers of assessment regimes or built space, one must nevertheless acknowledge that students' study practices *are* changing, and that new media devices and other technologies are heavily involved in the rearrangement of what kinds of studies are done where. Sharp divisions between different kinds of spaces and different kinds of activity are softening, as are divisions between various kinds of knowledge and the knowledge practices into which students are inducted. The material and virtual worlds are no longer separate. Multimedia and multitasking blend various forms of knowledge representation, social and study interactions. In short, the knowledge, activities, relationships and resources involved in student learning are becoming more fluid, and are entering into more complex combinations.

We know that what students actually *do* has the strongest influence on what they learn (Shuell, 1986; Biggs & Tang, 2007). Educators concerned about the success of student learning could be more relaxed about this if students were already experts at managing their own learning, skilled at integrating and shifting between different ways of knowing, and had mastered the effective use of technologies for learning. But there is growing evidence that students don't always make good choices with respect to working with others, or using the best tools and resources. There is strong evidence indicating that students are looking to their teachers for guidance on such matters (Ellis & Goodyear, 2009; Ipsos MORI, 2008; Salaway et al., 2008). The shift towards more active, student-centred methods in higher education, slow and uneven though it may be, has been accompanied by a growing acknowledgement of the importance of *facilitation*. ('From the sage on the stage to the guide on the side', as the cliché succinctly puts it.) Less recognition has been given to the need for good *design* of learning tasks, despite the fact that upfront investment of time in design can save a great deal of downstream facilitation work. There are also arguments that the design stages of teachers' work are the most amenable to improvement through incorporation of research-based guidance. In contrast, real-time facilitation draws heavily on personal style: there is little scope for consulting or reflecting on the pedagogical literature. In short, well-designed learning tasks are the foundations for productive learning activity.

Efforts to improve tertiary teachers' design work

Recognition that good design has the potential to make learning more productive *and* make better use of teachers' time has motivated a number of lines of research and development work. This R&D activity has included developing and trialling various kinds of learning design tools and resources (see e.g. Conole & Fill, 2005; Dalziel, 2003; Koper & Tattersall, 2005; Lockyer et al., 2008). It has also touched on some of the social, cultural and professional identity issues involved when tertiary teachers are encouraged to share, test and learn from each other's designs (see e.g. Beetham, 2008; Goodyear et al., 2006; Laurillard, 2008; Margaryan & Littlejohn, 2007).

As Laurillard (2008) and others have observed, there are as yet few signs that tertiary teachers are flocking to become more deeply engaged in design. There are several reasons for this and it is important to recognise that work needs to be done on *all* of them if practical progress is to be made. No single development is likely to make a sufficient change. Firstly, tertiary teachers – especially in research intensive universities – do not perceive strong incentives to improve their teaching, let alone to spend time learning about and engaging in more complex upfront design activities (Elton, 2000; Hannan & Silver, 2000). Institutional cultures need to become more supportive of educational design. Furthermore, teachers' practices need to shift somewhat – which is partly a matter of institutional culture, but also connects with disciplinary and departmental norms (Becher & Trowler, 2001; Roxå & Mårtensson, 2009). In addition, it is important to have good resources to support teachers' design work: resources which are fit for purpose and accessible when needed. Such resources can be of quite different kinds, including such things as guidelines, design principles, pattern languages, templates, computer-aided design tools, intelligent design advisers, learning objects, scripts, case studies and vignettes (Goodyear, 1994; Goodyear & Retalis, in press; van den Akker et al., 1999). The important thing is that they must actually fit within the *credible range* of teachers' working practices, and not depend on improbable changes to such practices. Finally, resources that are intended to support and improve teachers' design work must be compatible with what we know about *design cognition* – there are limits to the amount of information that can be dealt with during design work (as is the case with other kinds of problem solving), and resources need to support teacher-as-designer knowledge practices and forms rather than overload their cognitive capabilities (see e.g. Boot et al., 2007). The complexities of students' cognition, learning and conceptual change are well acknowledged; it is a mistake to underestimate the complexity of teacher thinking involved in design for such learning. All of the above factors are important. None on its own is likely to enhance and extend design practice and we do need to have a good understanding of each factor if progress is to be made. Our focus in this paper is the last factor – design cognition.

Conceptual integration in teachers' thinking and task design

The research reported here arises from the intersection of two lines of inquiry. One is concerned with the use of patterns and pattern languages as resources for educational design. The other is an investigation of how tertiary teachers tackle design tasks and what mental resources are activated in their design work.

We use the term 'mental resources' to denote the various forms of knowledge that someone can potentially bring to bear in order to work upon a task – such as making or explaining an educational design decision. These mental resources originate in a person's experience: whether direct experiences of things or people, or reflections on other people's accounts of the world, including formally learnt knowledge. We like the term 'mental resources' because it carries no assumptions about overarching structures of coherence within which such elements of knowledge are necessarily arranged. In particular, one can think of people typically having quite heterogeneous (and contradictory) mental resources - rather than 'neat' networks of internally consistent knowledge and beliefs. One can explain some important differences between what people are able to do and what they actually do, through reference to the differential activation of mental resources in different contexts. (This turns out to address quite a number of the problems associated with classic accounts of 'transfer'. See, for example, Wagner, 2006). The ease with which different sets of mental resources are activated in different contexts helps explain some aspects of what would otherwise be inexplicable inconsistencies in students' *and teachers'* decisions and behaviour (c.f. Hammer & Elby, 2002; Postareff et al., 2008; Gonzalez, in press).

Various kinds of activity, including those we associate with design, involve the integration of different mental resources (Taura & Nagai, 2005). Following Fauconnier & Turner (1998) and Turner (2008), we use the term 'conceptual integration' to describe the process in which two or more distinct sets of mental resources (referred to as 'mental frames' or 'conceptual spaces') are brought together in the mind, and one new frame/space is created, or 'projected'. Turner (2008) presents four different ways that conceptual integration can occur: simplex network, mirror network, single-scope network and double-scope network. Some of these blends are quite simple, while others are complex and not easy to project. We will summarise each, drawing out some implications for research on educational design, and then will describe some related outcomes from our empirical study.

1. *A simplex network* is a conceptual integration of two conceptual spaces in which one input space has a familiar abstract frame and the other space is a specific situation presenting input values. In educational design, when we take a generic version of a task design (e.g. an activity workflow) and replace the abstract values in the activity sequence with specific content, in essence we create a "simplex network" from the two conceptual spaces. For instance, Laurillard (2008) provides an example of a generic sequence that involves a number of abstract steps, such as "Select *two parameters* to input to the *tool/model* and record your results (*specify which results*)" (p. 151, emphasis in the original). When one applies this sequence for a specific purpose (say, teaching information search), and replaces the generic elements (emphasised in italics above) with specific content, one creates a simplex network from the two conceptual spaces. An example would be: "Select *two words* to input to the *search engine* and record your results (*the first five URLs*)" (p. 150, *our* emphasis).

2. *A mirror network* is a conceptual integration where two input spaces have the same topology, given by an abstract organising frame, and the blend inherits and extends that organizing frame. In educational design such a blend might include taking two existing tasks that have a similar structure and blending them into one task that has the same generic structure. For example, the teacher may want to use two different internet search engines and describe the step above in the following way: "Select *two words* to input to *Google Book* and record your results (*the first five URLs*)" and "Select *two words* to input to *Google Scholar* and record your results (*the first five URLs*)". The teacher could also blend these two steps into a one: "Select *two words* to input to *Google Book and Google Scholar* and record your results (*the first five URLs from each*)". The blend mirrors and extends the same "information search" organising frame, and thus represents a mirror network of the two frames. (The example may seem semantically trivial; the thinking underneath it is not.)

3. *A single-scope network* is a conceptual integration of two input spaces that have different organizing frames and only one of those frames is selected to organize the blended space. For example, a teacher wants to design a task that uses simulation for explaining a relationship between time, speed and distance. Rather than proposing a task such as "Interact with the simulation and figure out how distance is related to speed and time", the teacher could take the task designed for teaching information search from the examples above and integrate it with the simulation. The description of a step in this task could be "Select *speed and time values* to input to the *simulation model* and record your results (*distance travelled*)". Such conceptual integration would involve what Turner calls a single-scope network. The organising structure inherited from the information search task plays the role of the organising frame in a new blend for teaching maths/physics.

4. *A double-scope network* is a conceptual integration of two different input frames into one blended frame that includes some organizing structures from each of the two input frames that were not shared initially. In educational design this may include blending of different pedagogical forms or patterns into one task. For example, a teacher may want to propose an information search task (pattern), but may also want to extend it with a discussion between students working in pairs. The task could be described as follows: "*Discuss with your partner and agree on the two best words* to input to the *search engine*, then *record and discuss* your results (*five URLs that you and your partner think are the best*)". This task is now based on organising structures from both information search and discussion frames and has some new features that were not shared before.

While the first three types of networks described by Turner do not change frames, but rather involve the integration of a familiar frame with different knowledge bases, double-scope networks involve frame blending and are perhaps the most complex to accomplish. While conceptual integration could be a conscious mental operation, Turner (2008) notes that this is not always so:

> …human beings are built to grasp the little packages of consciousness, and to blend the frame for the scientific question with the frames of conscious experience, and so to produce, in the blend, human-scale folk theories of who we are and what we do. (p. 16)

We conjecture that such conscious and unconscious blends of several conceptual spaces and pedagogical frames are common in teachers' design work. Although Fauconnier & Turner (1998) produced many examples of conceptual integration from 'everyday thinking', we are not aware that this line of research has investigated conceptual integration in teachers' design work. There is very little information to shape our understanding of how teachers bring together different pedagogical frames (typically embedded in the descriptions of pedagogical designs) and other (mental) design resources. This has implications for how (physical and/or computer-based) design resources, of various kinds, might help teachers improve their design work – there needs to be a smooth fit with design thinking. To shed more light on this issue, we aimed to explore the following questions in our empirical study:

1. What kinds of conceptual integration of pedagogical frames can we distinguish in the designs of tasks; and what sorts of mental resources does the teacher use for making sense of these pedagogical blends?
2. What other kinds of frames are blended in tasks associated with teaching in ICT-supported learning environments; and what kinds mental resources does the teacher use in her explanations of these blends?

We now turn to reporting some outcomes from a longitudinal study of one teacher's design thinking.

Study context

This study was conducted as a part of a broader project in which we are exploring the ways in which professional workers learn to combine different forms of knowledge and ways of knowing. The current study involved a university teacher (pseudonym 'Sophie') who was teaching a part of one semester course on systems thinking and modelling to postgraduate educational technology students. Sophie was teaching the course for the third time. Most of the interactions between Sophie and the students and between the students themselves took place online. Among other things, students learned to run and construct system dynamics models using the STELLA software package.

We observed all but one of the classes – which were mostly synchronous online sessions - analysed Sophie's teaching resources, papers and notes and conducted a series of interviews asking a range questions about educational design and teaching. We adopted a retrospective method, and asked Sophie to recall and explain to us (i) the educational design decisions that she made prior to each class, and (ii) the actions she took during each class. We met with Sophie the day after each of the synchronous online teaching sessions. We used materials and transcripts recorded during the online observations as prompts. Each interview typically included a set of questions about the overall design of the session that week and a set of questions about the design of one or two specific tasks featured in that session. The interviews were broadly structured around three main design components: design of tasks, design of social groupings (e.g. how the students should work together, divide their labour, etc), and the selection of appropriate tools and resources (Goodyear, 2005). We also asked questions about decisions Sophie made *during* the teaching process and about the students' experiences with these tasks. We adapted an epistemological interviewing approach (Brinkmann, 2007) and aimed to discover how different mental resources are activated and blended in making complex professional judgments about learning design, teaching and inquiry in specific contexts. The interviews took between 45 and 90 minutes each and were audio recorded and transcribed. We adapted and followed an interpretative phenomenological analysis procedure for analysing data (Smith & Osborn, 2003).

The outcomes we want to focus on in this paper come from three of Sophie's classes, and from the associated interviews. We provide three examples that illustrate three different ways of blending two generic forms that are often used in teaching: *explanation* and *visual representation*.

Study outcomes

Blending pedagogical frames

A substantial part of Sophie's course was dedicated to learning about systems structures and system behaviour. As students typically find some aspects of system structure, system behaviour and their relationships hard to understand, Sophie used a range of tasks to help students improve their understanding. Example tasks include:

1. Explore a causal loop diagram and the associated behaviour graph and explain their relationship.
2. Change parameters of a (provided) model and explain the resultant system behaviour.
3. Explain and draw diagrams of different types of feedback in causal loops.

Table 1 shows how Sophie explained these three task designs. Each of the tasks was based on two generic pedagogical forms: explanation and visual representation. Explanation was always achieved by *discussing,* while three different frames were used for visual representation and included: (i) the presentation of static images; (ii) dynamic interaction with models, and (iii) construction of new qualitative representations. That is, in the first task, students *explored*, in the second they *interacted* with and in the third they *created* visual representations. The first task was guided by the organising frame of *discussion*, for which the static models just served as inputs (Figure 1). The second task was guided by a *modelling* frame, with discussion in support. In contrast, the third task was based on the integration of two frames – with *discussion* and *modelling* gradually building on, and intertwining with, each other (Figure 2). In the latter case, students discussed and draw models at the same time. Their modelling draw upon discussion, while the discussion draw on the emerging model.

Table 1: Examples of the tasks used for teaching about model structure and/or behaviour

Task	How it works (extracts from interviews with Sophie)	*Type of blend*
1. Explore causal loop image and behaviour graph and explain the relationship	*Class discusses static visual images of the system. These images provide an input for discussion.* "We go to the background, it [whiteboard] had a bigger view of the graph and the causal loop diagram below it <…>. I'd point out the similarities and the one difference from the graph before. <…> I then asked them if they could think of a real life example where that could be the case. <…> Then we discuss, go through again using that example - that's that bit of it, and that's that bit of it and that's why it's doing that at the end" [4.39]	*Single scope network: organising frame - discussion*
2. Interact with a model (structure) and explain behaviour	*Students individually interact with system models, following detailed instructions, and trying to answer questions. Discussion is used for technical exchanges and checking answers afterwards.* "They had three questions <…> instruction about what to change <…> [5.02.2] They all have access to the model. They change numbers in the model, they run the model, they see how the graph looks at the end. Then they discuss what that might mean in terms of the answer to the question." [5.07]	*Single scope network: organising frame - visual modelling*
3. Explain and visualise different types of feedback in causal loops	Students discuss and create model simultaneously: visual modelling and discussion build on each other. *"The idea is that I put the boxes up on the whiteboard with the variables in them, and I add one arrow each time and I get the class to discuss whether they think that if one variable changes, the other variable would change in the same direction or in a different direction and that determines whether there's a plus or a minus next to that arrow. Then at the end we go through and talk about - be able to describe the entire system following through from each one." [2.25]*	*Double scope network: organising frame is a blend of visual modelling and discussion*

What underlies the task design and frame choices that Sophie made? Sophie explained her sense of the purpose of the discussion frame in terms of the way that it (i) gave her an opportunity to present the information needed by the students and (ii) helped the students remember key points about the nature of the system being discussed:

> The first part is me trying to get them the information that they need. The chat is a good way for good discussions on what a system is, they tend to remember it. [1.18.1]

Sophie described the role of visual representations quite differently. She primarily focussed on the power of visual forms and frames to make abstract concepts and links between them explicit and to help students notice relationships that otherwise might be difficult to observe. She commented:

> You're relating two different ideas and you're having to see why they interact and how they relate to each other and if you don't have some sort of visual aid to do that - it's also the structure of a system and the behaviour in terms of a graph are something quite abstract, it's not something you would normally physically see so you have to notice the behaviour of a system over a period of time and have an idea about how that system was structure in order to relate them unless you've been specifically taught about models and behaviour and structure. So I guess you don't necessarily notice it unless you've been trained to notice it. [5.15]

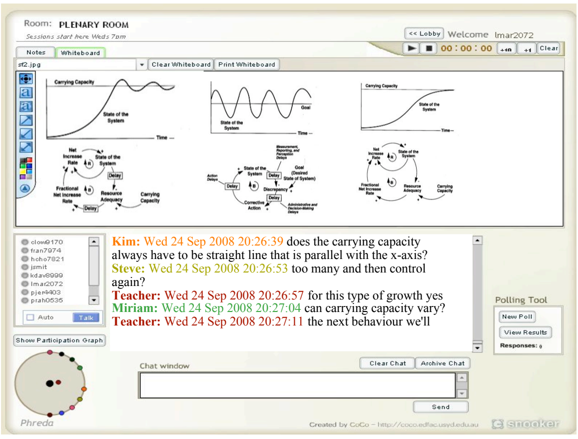

Figure 1: Single-scope blend of modelling and discussion frames (organising frame – discussion)

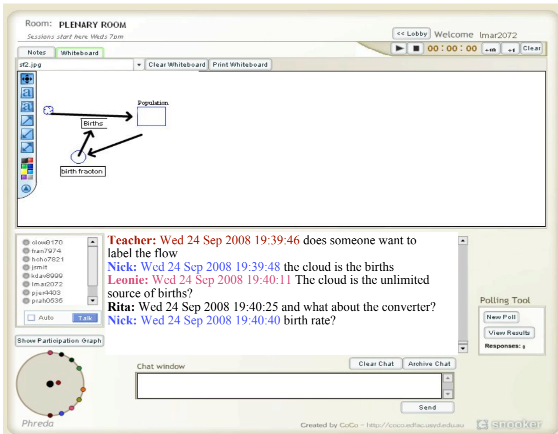

Figure 2: Double-scope blend of modelling and discussion frames

Sophie also readily explained the purpose of each pedagogical frame and the nature of the learning experiences that each frame or their blends could support. While we didn't ask her about this directly, in her explanations Sophie clearly expressed the view that students learn better when they discuss than when they just listen to her, and that they gain a deeper understanding when they construct models rather than just discussing them. She also mentioned that *understanding* a model might not be sufficient for success in *constructing* a model. The following comments are examples that touch on these issues:

> The way of doing causal loop diagrams, it just made sense to me. It's far easier, we have the whiteboard tool there, it's not much good me just showing them example after example. If they get a chance to do it themselves and then discuss, they tend to understand. [2.20]

> I think now that they have the basic knowledge 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. [5.36]

> So I went back to looking at the causal loop diagrams instead [of drawing diagrams] and they were already there with the graphs so just the understanding rather than being able to apply it. [4.26.2]

Sophie, it seems, was mindful of how each pedagogical frame should contribute to student experiences and understood that blends should help them to understand relationships between model structure and behaviour better than would each frame separately. For example, asked a question about the core aspects of the design of Task 1 that helped students to learn the required knowledge, Sophie said:

> Having the causal loop diagram and the graph on one page, applying the narrative that goes with it, having them to think up examples. That relates it all together. [4.56]

Overall, the design work that integrated explanations with various ways of visualising knowledge was not particularly problematic for Sophie. She made the connections between the objectives, pedagogical frames, projected cognitive phenomena (kinds of student understanding) and other aspects of the task design with relative ease. While she rarely used formal pedagogical language, Sophie, it seemed, had the necessary mental resources for understanding and projecting how the blends of different pedagogical frames should function and what kinds of student experience and knowledge they should support. These relationships are summarised in Table 2. In other words, Sophie had *and activated* the mental resources needed to understand and explain those individual pedagogical frames and their blends.

Table 2: Relationship between pedagogical forms and mental resources

	Task 1-3	Task 1	Task 2	Task 3
Pedagogical form	Explanation	Visual representation	Visual representation	Visual representation
Frame	Discussion	Exploring static images of structure and behaviour	Dynamic interaction with a model	Construction
Objective	Make explicit	Show relationship between structure and behaviour	Interact and figure out model structure and behaviour	Visualise model structure
Tools and their functions	Chat for communicating	Whiteboard: showing an image	Modelling software: interacting with a model and behaviour graphs	Whiteboard: drawing a model
Projected student experience and knowledge	Explain relationship	Understand relationship	Experience modelling, see relationship	Apply knowledge

Other mental resources for ICT-based task design

Pedagogical frames were just one type of mental resource activated in Sophie's answers. Her explanations also drew on mental resources related to other elements of the pedagogical design. For example, Sophie built her explanations in parallel on the mental resources needed to understand: the discipline (content and knowledge practices), the physical and social contexts of learning (including the ICT tools used in these contexts) and the students' evolving conceptions. We only have space here to report some findings, illustrating primarily how Sophie linked pedagogical frames with relevant ICT tools - such as chat, whiteboard and modelling software - thereby allowing her to create environments appropriate for the students' learning activity.

> The chat I find really good for communicating information. [1.18.1]

> [t]he whiteboard lets them draw so that everyone in the class can see, lets us all see the same picture at the same time. [4.37]

> They were given a STELLA model that I had already built. <..> So they could change whatever parts they wanted to and they could run the model and see a graph. [5.02]

She explained how ICT supports her different roles as a teacher:

> The chat I use because that's the chat. The whiteboard feature which is the main different feature of that I use because everyone can see it that can actually do an activity as a group. I can put things up there quickly because I can use it more quickly then them and I can scaffold that a bit and put a lot of the detail up. So the first example, then I'll have a bit less for the next one, and they do a little bit more, and then get them to do a bit more each time. It's pretty flexible like that. That's what I usually do. [2.22]

The choice of pedagogical forms, and the conceptual integration of the discussion and visual modelling frames with related ICT tools, looked like effortless commonsense activity rather effortful design work. To our questions "How did you come up with this design?" she often reacted saying: "it just made sense to me" [2.20], "I don't remember why I thought it was a good idea" [3.12]. Other comments were linked to her earlier experience "The chat was probably because I watched Fred [another teacher] in the first year" [1.19.1]. Some explanations were linked to more formally learned pedagogical knowledge and were expressed in comments such as: “the research says that they're going to remember” [5.36]. None of the three types of blending of the two pedagogic frames, or their connection to appropriate ICT tools, was problematic. In other words, Sophie had the mental resources needed to understand how pedagogical frames function and how they could be supported by the available ICT tools. The integration of pedagogical and ICT conceptual spaces resembled a simplex network where ICT tools were just an input to a pedagogical organising frame (which they did not thereby alter).

Nevertheless, Sophie’s explanations showed that the integration of pedagogical frames and ICT tools with other elements of the pedagogical design (such as disciplinary knowledge and students’ understanding) were more complex and difficult to achieve. For example, asked which aspect of Task 2 was most difficult to design, Sophie clearly pointed at the challenges of integrating disciplinary knowledge with an appropriate pedagogical frame:

> I don't know. I think thinking up how to make sure that they would be able to see the differences between the two models and see the differences in behaviour because from the research I knew that was really what fell down last year <….> I had to think about how I would present this information. <…> But I've been thinking about that for the past 6 months or so. [5.21]

Similarly Sophie commented on to the challenge of finding appropriate ICT tools to teach disciplinary knowledge in an online setting. She commented on her teaching experiences in previous years:

> [S]tudents are able to either download the model or interact with an online model simulation, but they can't see the structure of the stock and flow diagram on the online simulation. So, those students couldn't see that there was this extra carrying capacity and were confused about why there were these different behaviours. [5.12]
>
> I wanted to use something that someone else had developed [before], because the idea for doing it in this online setting in groups was new enough. [5.19]

As the above examples show, the integration of disciplinary knowledge with pedagogical and ICT conceptual spaces in task designs was not so straightforward; and disciplinary knowledge was not just mere input in an abstract pedagogical frame. In order to make some of her tasks work, Sophie had to blend the pedagogical, ICT and disciplinary frames. She explained her Task 2 design efforts in the following way:

> This year I made the models myself, I made sure that there was a stock and flow diagram in there that related it back to what they'd done in class so they could see the difference between the two models. <…> I changed the questions slightly. The idea behind the question was still the same, but I changed the wording and I gave them more specific things <…> - much more guidance. [5.12.3]

These examples gives us some initial insights into the complexities of integrating pedagogical frames and ICT tools with the other knowledge frames needed to design productive learning tasks.

Discussion and concluding comments

Discussing these examples we wanted to illustrate the importance of understanding the teacher’s design thinking and demonstrate the possibilities of looking into the complexities of design from the “conceptual integration” perspective. Doing this analysis we acknowledge that, as Belth (1977) argued,

> The problems of the world do not come so well formulated, so consistently structured, that we can learn a tactic of unstructuring the form of that problem, looking into it rapidly, and coming out with proper conclusions. The dreadful fact about thinking that is it takes time, *and it demands action.* (pp. xx-xxi)

Nevertheless we believe that a deeper examination of the frames that guide teacher thinking might reveal some essential gaps between teachers’ cognition and the design resources being created to support them.

Initially we looked at different ways in which two simple pedagogical forms could be integrated. Sophie’s explanations showed that pedagogical forms and frames perhaps were not the most complex and problematic aspect in task design. She integrated pedagogical frames in different ways, but even the most complex pedagogical blends did not pose significant cognitive challenges. Similarly, the choice of ICT tools and how they could support various pedagogical frames was a relatively easy (often quite intuitive) decision.

The focus of some of the current work on design support tools on *descriptions of generic pedagogical forms* may turn out to be based on a rather primitive assumption that the challenge for teachers is to integrate a pedagogic form with an ICT tool. While we do not generalise Sophie's case, nevertheless we have seen that integrating ICT tools with pedagogical frames when both aspects are familiar was not the most complicated aspect of task design.

Sophie, nevertheless, needed (and had) a set of mental resources that allowed her to understand pedagogical frames and ICT tools and project their blends. Sophie's mental resources were more experiential than formally learned. It seemed it was particularly her experience with ICT tools and group learning that helped her to project and blend those components into existing tasks – i.e. it provided robust mental resources for making these teaching decisions. The nature of mental resources concerning the (ICT) tools, and more generally about everything that goes into the learning environment and social organisation are "experiential" and contextualised in nature. Sophie's case suggests that experience with tools could be critical for making projections and becoming good at task design. In other words, educational design, like other thinking processes, does not lie outside the experienced world, but rather arises from within that world (e.g. see Belth, 1977).

In contrast the most complex part of the task design was the integration of the pedagogical frames and ICT tools with other task components that contributed to the task design for teaching specific disciplinary knowledge. Sophie, it seems, was particularly challenged when she had to create new tasks and blend disciplinary knowledge (and disciplinary frames) with pedagogical frames (i.e. to find effective ways to explain/teach "troublesome" disciplinary knowledge).

General pedagogical frames are often seen as dominant structures that should guide teacher design decisions and practice, while discipline, teaching context and students' characteristics are perceived as static inputs to these organising pedagogical frames. This view looked reasonably acceptable when Sophie explained very basic principles that she used for teaching static "know that" type knowledge, such as definitions, as when she commented "[this] is me trying to get them the information that they need". Sophie here " taught" with a purposefully chosen pedagogical organising frame.

This dominant pedagogical frame became problematic when Sophie designed and used tasks for teaching students to explore and construct their own knowledge. For learning "know how" type knowledge, the tasks had to integrate ways of inquiry (and frames) from the disciplinary domain. Thus, these tasks could not be based solely on the pedagogical organising frames. While we cannot generalise our findings, our examples suggest that more authentic tasks - such as those which support deep engagement with knowledge and knowledge building - were based on disciplinary inquiry practices that were scaffolded and carefully blended with the pedagogical frame. Generic pedagogical frames (and resources that support such design) might miss one essential point: that they are suited to teaching either static (or indeed generic) types of knowledge, and might well fail when one wants to use them for teaching (multi) disciplinary ways of building knowledge.

References

Argyris, C. (1998). *Teaching smart people how to learn.* Harvard Business Review on Knowledge Management. Cambridge, MA: Harvard Business School Press.

Becher, T. & Trowler, P. (2001). *Academic tribes and territories*. Buckingham, SRHE/Open University Press.

Beetham, H. (2008) *Review: design for learning programme.* Phase 2. Bristol, JISC.

Belth, M. (1977). *The process of thinking.* New York, David McKay Company Inc.

Biggs, J. & Tang, C. (2007). *Teaching for quality learning at university: What the student does.* Buckingham, Open University Press.

Boot, E., Nelson, J., van Merrienboer, J. & Gibbons, A. (2007). Stratification, elaboration and formalisation of design documents: effects on the production of instructional materials. *British Journal of Educational Technology,* 38**,** 917-933.

Brinkmann, S. (2007). Could interviews be epistemic?: An alternative to qualitative opinion polling. *Qualitative Inquiry*, 13(8), 1116-1138.

Conole, G. & Fill, K. (2005). A learning design toolkit to create pedagogically effective learning activities. *Journal of Interactive Media in Education*, 2005/8, 1-16.

Dalziel, J. (2003). Implementing learning design: The Learning Activity Management System (LAMS). In *Interact, integrate, impact: Proceedings ASCILITE Adelaide 2003*. http://www.ascilite.org.au/conferences/adelaide03/docs/pdf/593.pdf

Ellis R., & Goodyear, P. (2009). *Students' Experiences Of E-learning In Higher Education: The Ecology Of Sustainable Innovation.* New York, NY: Routledge

Elton, L. (2000) The UK research assessment exercise: unintended consequences. *Higher Education Quarterly,* 54**,** 274-283.

Fauconnier, G. & Turner, M. (1998). Conceptual integration networks. *Cognitive Science,* 22**,** 133-187.

Goodyear, P. (1994). Infrastructure for courseware engineering. In Tennyson, R. & Barron, A. (Eds.), *Automating instructional design: computer-based development and delivery tools* (pp. 11-31). Berlin, Springer Verlag.

Goodyear, P. (2005). Educational design and networked learning: Patterns, pattern languages and design practice. *Australasian Journal of Educational Technology*, 21(1), 82-101. http://www.ascilite.org.au/ajet/ajet21/goodyear.html

Goodyear, P., de Laat, M. & Lally, V. (2006). Using pattern languages to mediate theory-praxis conversations in design for networked learning. *ALT-J*, 14(3), 211–223.

Goodyear, P. & Retalis, S. (forthcoming). Learning, technology and design. In Goodyear, P. & Retalis, S. (Eds.) *Technology-enhanced learning: design patterns and pattern languages.* Rotterdam, Sense Publishers.

Gonzalez, C. (in press). What do university teachers think eLearning is good for in their teaching? *Studies in Higher Education*.

Hammer, D. & Elby, A. (2002). On the form of a personal epistemology. In Hofer, B. & Pintrich, P. (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 169-190). Mahwah, NJ, Earlbaum.

Hannan, A. & Silver, H. (2000). *Innovating in higher education: Teaching, learning and institutional cultures.* Buckingham, SRHE/Open University Press.

Ipsos MORI (2008). *Great expectations of ICT: How higher education institutions are measuring up*. JISC.

Koper, R. & Tattersall, C. (Eds.) (2005). *Learning design: A handbook on modelling and delivering networked education and training.* Berlin, Springer.

Laurillard, D. (2008). The teacher as action researcher: Using technology to capture pedagogic form. *Studies in Higher Education,* 33**,** 139-154.

Lockyer, L., Bennett, S, Agostinho, S. & Harper, B. (2008). *Handbook of research on learning design and learning objects: Issues, applications and technologies*. Information Science Reference

Margaryan, A. & Littlejohn, A. (2007). Repositories and communities at cross-purposes: issues in sharing and reuse of digital learning resources. *Journal of Computer Assisted Learning,* 24**,** 333-347.

Postareff, L., Katajavuori, N., Lindblom-Ylanne, S. & Trigwell, K. (2008). Consonance and dissonance in descriptions of teaching of university teachers. *Studies in Higher Education,* 33**,** 49-61.

Roxå, T. & Mårtensson, K. (2009). Significant conversations and significant networks - exploring the backstage of the teaching arena. *Studies in Higher Education,* 34**,** 547-559.

Shuell, T. (1986). Cognitive conceptions of learning. *Review of Educational Research,* 56**,** 411-436.

Salaway, G., Caruso, J. B. & Nelson, M. (2008). The ECAR Study of Undergraduate Students and Information Technology, 2008. Boulder CO, EDUCAUSE Center for Applied Research.

Sennett, R. (2006). *The culture of the new capitalism*. New Haven, Yale University Press.

Smith, J. A., & Osborn, M. (2003). Interpretative phenomenological analysis. In J. A. Smith (Ed.), *Qualitative psychology: A practical guide to research methods* (pp. 51-80). London, Sage publications.

Taura, T. & Nagai, Y. (2005). Primitives and principles of synthetic process for creative design. In Gero, J. & Maher, M. L. (Eds.) *Computational and cognitive models of creative design* (pp. 177–194). Sydney, Key Centre of Design Computing and Cognition.

Turner, M. (2008). Frame blending. In Favretti, R. (Ed.) *Frames, corpora, and knowledge representation.* Bologna, Bononia University Press.

van den Akker, J., Branch, R., Gustafson, K., Nieven, N. & Plomp, T. (Eds.) (1999). *Design approaches and tools in education and training,* Dordrecht, Kluwer.

Wagner, J. F. (2006). Transfer in pieces. *Cognition and Instruction, 24*(1), 1-71.

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