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USING CONCEPT MAPS TO BRIDGE EMPIRICAL AND EXPERT KNOWLEDGE

Christian Barrette
Association pour la Recherche au Collégial (ARC), Québec, Canada

Abstract. In their daily complex environment, professional practitioners reason out their actions on the basis of both theoretical models derived from formal research and the model of reality they shape through their own reflective practice. Such is the case in education where the links between theoretical knowledge and reflective practice are not always obvious. An exploratory study seeks to shed light on the relation between the findings of a metasynthesis of results from experiments in the field of IT in pedagogy and the models by professional experts regarding the determinants and conditions of successful IT pedagogical integration. The use of concept maps to convey the complex and dynamic knowledge involved, especially through a refined vocabulary of verbs to help formulate the propositions, facilitates the comparison of the theoretical and experts' models. The qualitative data (concepts and propositions) is submitted to an analysis loosely inspired by the grounded theory in ethnography. The analysis shows an important overlap and convergence in both theoretical and expert knowledge. It also highlights certain original concerns of the experts, suggesting new avenues for research. Action-research seeks to disseminate and validate the heuristics contained in the metasynthesis and the experts' models among the community of professional practitioners engaged in pedagogical integration. Here too, the use of concept maps proves instrumental in supporting effective discussions.

1 Introduction

The daily life of professionals is not best described as routine work, but rather as challenging decision-making in complex situations. Given these conditions, a professional's action is usually based on heuristic reasoning rather than the explicit application of rules in an algorithmic mode. What references orient the reasoning of professionals in a context of highly unpredictable conditions? Through their initial and ongoing education, professional practitioners have access to formalized or theoretical knowledge generated by research that is basically conducted under quasi-experimental conditions. But professionals also call upon their own model of reality, which they shape more or less consciously in their reflective practice. Such is the case in the teaching profession (Schön, 1983) where, at times, these two sources of knowledge, empirical research and reflective practice, are thought of as discrete, or even conflicting. Boutet (2004) argues that theory, which arises out of empirical research, is not opposed to practice, which produces driving constructs, especially in education: "… there is no precise boundary between experience (Aristotle's world of the senses) and thought (Plato's world of reason), but rather a complex interplay that we must dwell on in order to gain a better understanding of human development"[1] (p. 5).

In the application of information technologies (IT) to teaching and learning, it is necessary to establish a dialogue between theory and practice, one of only many such examples. Many principles can be derived from experiments on learning carried out using rigorous protocols and best practices for integrating IT into the classroom. At the same time, in this completely new, rapidly-changing field, expert practitioners are accumulating experiential knowledge which provides them and their colleagues with more and more specific prescriptions for action. The purpose of this paper is to present the first steps of action-research that seeks to create a bridge between empirical and expert knowledge in the field of pedagogical integration of IT.

2 Relevance in view of previous work

Barrette, commissioned by the Association pour la recherche au collégial (ARC), recently conducted a metasynthesis (2004a; 2004b; 2005; 2007) of the results of 32 empirical studies on IT integration into teaching/learning that took place in the college network in Québec, Canada between 1985 and 2005. The reports were assembled, analyzed and synthesized following Miles and Huberman guidelines for cross-case analysis (1994) in order to establish a causal model of the effectiveness of IT integration into teaching/learning. The partial conclusions derived from the small corpus of 32 reports were compared and validated with those proposed by the Center for Applied Research in Educational Technologies (2005). The results help identify theoretical principles that should be considered, if not followed, in any project designed to introduce IT into the teaching/learning process (Barrette, 2007).

Of course, as Cathy Ringstaff and Loretta Kelley (2002) assert: "… measuring the impact of technology use on student achievement is fraught with difficulties. Classrooms are not experimental laboratories where scientists can compare the effectiveness of technology to traditional instructional methods while holding all

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other variables constant." Joy II and Garcia (2000) meticulously examined all the conditions that must be established in order to conduct conclusive experiments on the impact of IT on education. They maintain that it seems practically impossible to ensure that all these conditions are present at once, and even if they could be, this would result in a situation so far removed from students' and teachers' current practices that the conclusions one might draw might not apply.

These methodological, almost epistemological, limitations bring to the fore the importance of confronting theories derived from empirical research with knowledge formalized by experienced practitioners, so that both theoretical models and experts' constructs can generate greater effectiveness in solving complex problems. In the words of Boutet (2004): "In every profession (and, we might add, *especially* in professions in which science still imposes few prescriptions), the practitioner's actions cannot be reduced to applying the results of research that was carried out in experimental conditions to real-life situations. On the contrary, the teaching professional very often grapples with singular, unstable problems and must construct their meaning before even attempting to solve them; the solutions to these problems are multi-pronged and normative rather than unique and objective. That is why Schön (1987) stresses the need for examining the practitioner's actions to discover the knowledge hidden in them"[2] (p. 4-5). It is reassuring that the hidden knowledge of practitioners can be brought to light. Boutet (2004) says that expert experience "manifests itself publicly in the individual's words and behaviour."[3] (p. 5). Concept maps can be seen as valuable tools in the process of eliciting and making explicit the *hidden knowledge* of the expert practitioner.

In 2007, in response to the need to create a bridge between empirical and expert knowledge, Barrette undertook to compile experts' knowledge in the field of IT integration into teaching, and to help formalize representations of the determinants of the effects of this integration on student success. The goal of this exploratory research is to answer the question "How does the model set out in the metasynthesis of empirical research relate to the constructs resulting from the reflective practice of experts on the integration of IT into teaching?" Do these two sources of guidelines for professional heuristics converge? Do they complement one another? Do they contradict one another"?

Initially, four experts were retained: two women and two men who had at least ten years of experience in the Québec college network, either as teachers or as educational advisers, who had participated in projects concerned with the integration of IT into teaching/learning, who had carried out research actions or experimental research, and who had published on the subject.

3 Concept maps used to connect empirical knowledge with expert knowledge

To facilitate the comparison of empirical models with expert models, concept maps have been constructed with the software CmapTools (Cañas et al., 2004) and used according to both the recommendations of researchers at the Institute for Human Machine Cognition and the rules of the Copilot method (Barrette & Regnault, 1992). Concept maps are diagrams that simplify the expression of complex relationships within a field; they therefore serve as knowledge maps. Béatrice Pudelko and Josianne Basque (2005) provide the following generic definition: "A knowledge map is a sphere of knowledge represented in the form of a network of graphic objects, developed according to a pre-established representation convention"[4] (p. 1). Novak and Cañas (2006) specify some of these graphic conventions: "Concept maps … include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts indicated by a connecting line linking two concepts.… Propositions are statements about some object or event in the universe, either naturally occurring or constructed. Propositions contain two or more concepts connected using linking words or phrases to form a meaningful statement." (p. 1).

Many studies and experiments have already demonstrated that the use of concept maps facilitates the expression of expert knowledge (Coffey *et al.*, 2002), as evidenced by their use in management (Cossette, 2003). The expression of empirical and expert knowledge in the form of concept maps makes it easier to achieve the research objective, which is to connect these two fields of knowledge from different sources, provided that this expression is sufficiently formalized that maps can be compared with each other. With the method used, these requirements are met.

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3.1 Method

The conclusions of the metasynthesis of 32 reports on experiments on integrating IT into teaching identify relationships among some of the factors that characterize the integration experiments that were successful in helping students achieve better learning. It is relatively easy to translate these relationships into a concept map, with nodes consisting of factors and effects, and links showing their relationships. This map is constructed in accordance with formalistic principles advanced by Joseph D. Novak and Alberto J. Cañas, and by the Copilot method. The same principles apply to experts' maps, thereby facilitating their comparison.

3.1.1 Formalistic principles followed in the construction of concept maps

3.1.1.1 Constructing a focus question.

Novak and Cañas (2006) maintain that the most useful concept maps are those that express dynamic, complex and contextualized knowledge. For this, they recommend that the map answer a focus question: "A good way to define the context for a concept map is to construct a *Focus Question*, that is, a question that clearly specifies the problem or issue the concept map should have to resolve. Every concept map responds to a focus question, and a good focus question can lead to a much richer concept map." (p. 7). This strategy, one of several avenues for creating rich, complex maps, was tested and validated by Derbentseva, Safayeni and Cañas (2006).

It is rather easy to construct the focus question answered by the metasynthesis conclusions expressed in a concept map: "What are the main determinants (causes and conditions) that must be taken into account in order to ensure that the use of IT in the classroom has a positive impact on student outcomes?"

3.1.1.2 Expressing links in the form of phrases

As specified by the above definition by Novak and Cañas, a concept map contains both concepts and links; the combination of two concepts and the link relating them constitute a proposition. This often gives rise to the suggestion that verbs be used as labels for links, and that arrows be used to indicate reading direction: "Concept Maps are a graphical two-dimensional display of knowledge that is comprised of concepts (usually represented within boxes or circles), connected by directed arcs encoding brief relationships (linking phrases) between pairs of concepts." (Cañas et al., 2005. p. 2-3). Here, the proposition takes the form of a simple phrase consisting of a subject, a verb and an object.

It appears this suggestion has been taken up, especially in cases where maps are analyzed and evaluated: "Much of the research on concept maps has scored them by analyzing propositions, that is, by extracting node-link-node combinations. In directed graphs, which are networks in which the link is directional (arrows), the propositions are clearly analogous to the subject-verb-object structure of sentences. Propositions are then typically scored against a template of propositions considered correct. In open-ended domains such as design process, there is no one right answer. In such circumstances, novices' propositions are compared to propositions on which experts agree" (Knight et al. 2004, p. 1). Our study, which is designed specifically to compare concept maps, adopts this recommendation of constructing concept maps that use phrases expressing interrelated ideas.

The Copilot method of constructing concept maps, and its now obsolete software *Copilot* (CCDMD, 1998), is based on the systematic use of verbs to name the links that describe 13 types of relationships, which are grouped into three major classes:

1. Description
   a. Characterization with verbs like "characterizes" or "is typical of"
   b. Example with verbs like "is an example of" or "illustrates"
2. Ordering
   a. Classification with verbs like "comprises" or "groups together"
   b. Composition with verbs like "is composed of" or "consists of"
   c. Sequence with verbs like "precedes" or "is prior to"
   d. Size with verbs like "is smaller than" or "is less than"
3. Explanation
   a. Primary Subject with verbs like "makes" or "performs"
   b. Assisting Subject with verbs like "assists" or "contributes to"
   c. Object with verbs like "focuses on" or "transforms"
   d. Result with verbs like "produces" or "generates"
   e. Instrument with verbs like "uses" or "resorts to"
   f. Goal with verbs like "targets" or "aims to"
   g. Conditions with verbs like "depends on" or "is subject to"

3.1.2 Metasynthesis conclusions in the form of a concept map

When the above formalistic principles are applied, the conclusions of the metasynthesis are translated into a concept map that will serve as a reference point during the analysis of the interviewed experts' maps (figure 1).

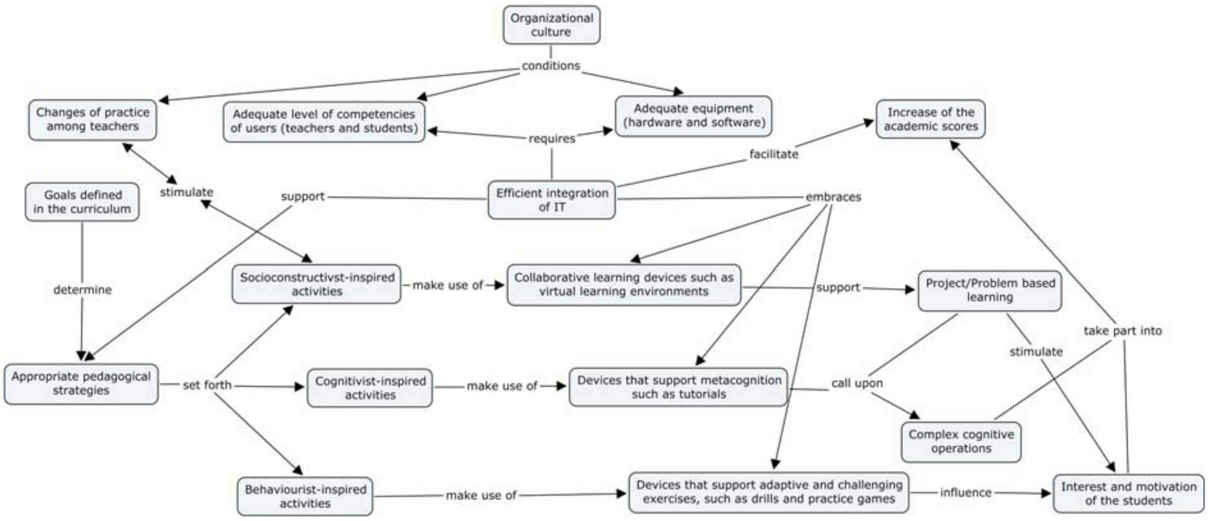

Figure 1. Concept map containing the expression of conclusions of the metasynthesis of the results of experiments on the integration of IT into teaching in Québec colleges.

3.1.3 Compiling expert knowledge

The map based on the conclusions of the metasynthesis contains the knowledge derived from empirical research. Our study is designed to connect this knowledge to the knowledge expressed by experts in a process of reflecting about their practice. Using a knowledge management method designed by Pierre Cossette (2003) that is largely based on the use of dynamic concept maps, this can be achieved in four phases:

1. The material is compiled by means of a semi-open interview of an informant
2. The recorded material is processed so that concepts and links can be extracted
3. The processed material is represented in the form of a concept map, validated by the informant
4. The material represented is analyzed to identify:
    a. The number of concepts and propositions
    b. The concepts considered important because of the number of links with other concepts
    c. The propositions counted and sorted according to the 13 types of relationships
    d. The emphasis on propositions described as strong because they use explanatory verbs that involve primary or assisting subjects, or results, as well as concepts considered important

The semi-open interview starts with the same question as that answered by the concept map from the metasynthesis: "What are the main determinants (causes and conditions) that must be taken into account to ensure that the use of IT in the classroom has a positive impact on student outcomes?" The interview is taped and lasts about two hours. The main researcher listens to the recorded interview and produces a first version of the concept map. The map is drawn with CmapTools; it is then saved on a server so that its author can access it with administrator rights. The main researcher meets with the expert again and together they validate each and every proposition on the first version of the map. After about two hours, they agree on a satisfactory version, which is saved again on the server. The main researcher then analyzes the map produced (phase 4 of the process) and returns the result to its author so that he or she can react and, if necessary, make further changes to the map.

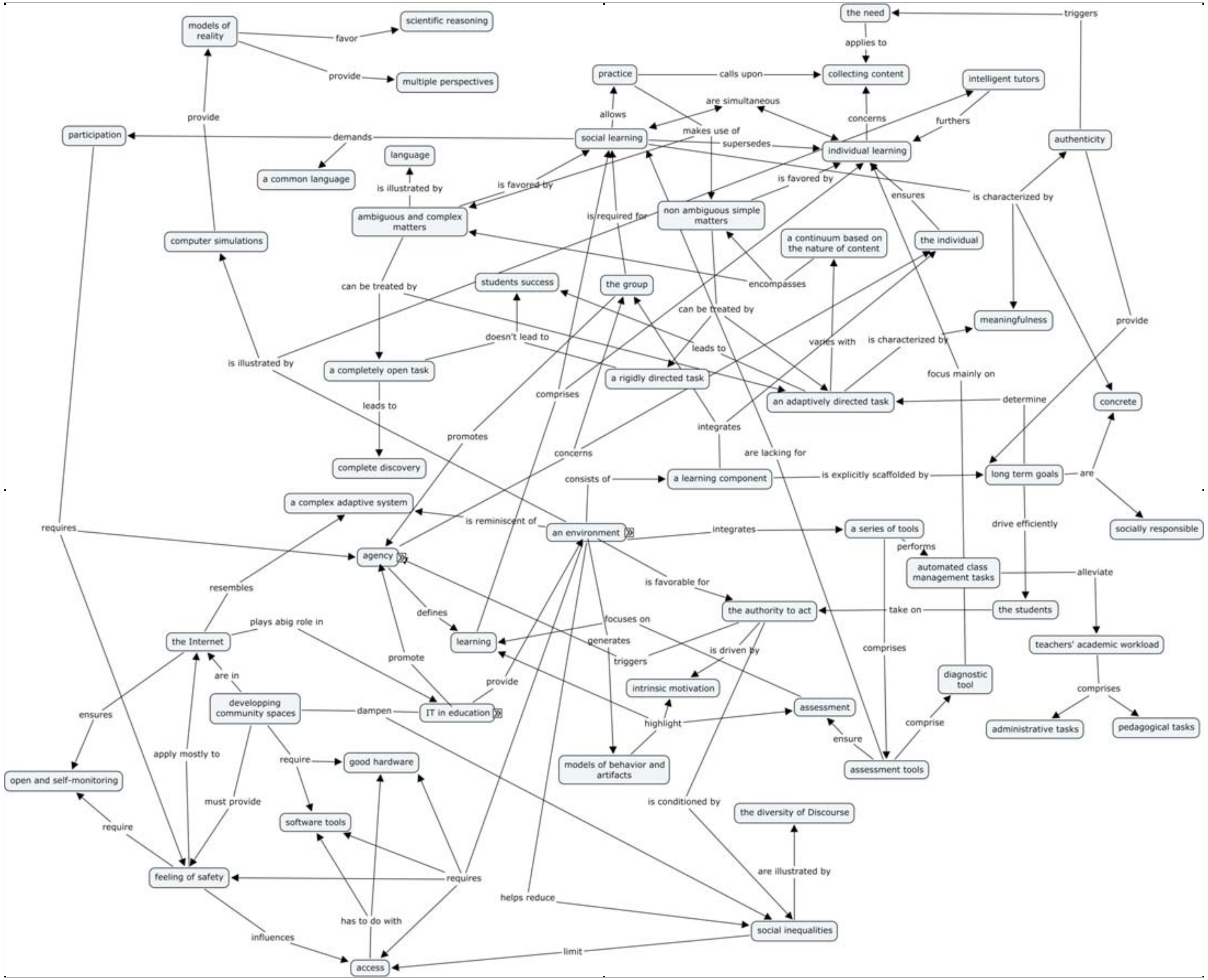

Figure 2. Concept map expressing expert knowledge on IT integration into teaching.

The map in Figure 2 shows a concept map produced on the basis of an interview with an expert and validated by her. The map is constructed according to the formalistic rules established for research. It contains 76 concepts connected by 119 propositions. Based on the number of links transiting them, the most important concepts are:

- Environment (15 links)
- Agency (12 links)
- Social Learning (12 links)
- IT in Education (10 links)

In this expert's discourse, strong propositions can be identified by their use of both explanatory verbs involving causes (primary or assisting subjects) and effects (results), and concepts engaged in several other relationships. The following sequence of ideas, taken from the example, illustrates the richness of this expert's vision: "IT in education provide an environment that is favorable to the authority to act which triggers students' agency and is driven by intrinsic motivation."

Content of the maps provided by each of the four experts ranges from 45 to 76 concepts and from 68 to 136 propositions —many more than the metasynthesis map, which contains 17 concepts and 25 propositions. As evidenced by the example (Figure 2), each expert's map is highly complex and is of little practical use besides serving as a vault storing his or her representation of the knowledge domain. Obviously, the qualitative data these maps contain has to be further analyzed in order to answer our research question.

3.1.4 Analyzing the experts' knowledge

A method of qualitative data analysis, proposed by Pierre Paillé (1994) and adapted from the ethnographic grounded theory approach, is applied to the experts' maps, in order to progressively analyze them against the metasynthesis.

1) Initial codification	Propositions (concept—verb—concept) are considered as units of analysis. The set of propositions formulated by each expert is fashioned into a concept map (as in the example shown in Figure 2) validated by the expert.
2) Categorization	Linking of the ideas expressed in the form of propositions by the experts with each and every proposition (considered a category) of the metasynthesis or with an original category emerging from the expert's material.
3) Ordering	Aggregation of the expert's ideas related to each of the categories. Provides small, manageable concept maps that deal with a circumscribed subject that can be deliberated among practitioners.
4) Integration	Integration of the expert's ideas within a thread of arguments. Provides large and complex concept maps that can be translated into an article or an essay intended for practitioners to discuss.
5) Modelization	Validation by practitioners of the heuristic value of the arguments in the course of long-term consultation and counseling, or congresses, seminars and courses. Serves as theoretical sampling and allows for refinement of the arguments and emergence of new ones.
6) Theorization	Taking hold of the arguments among the community of reflective practitioners. New research projects resulting form this process feeding back new evidence and consolidating the framework of professional decision-making.

3.2 Initial findings and conclusion

At this time, phases 1), 2) and 3) of the analysis have been completed. The initial coding of the experts' material has been easily and successfully conducted, indicating the instrumental value of concept maps, especially when using a formalized scheme for designating the relationships between concepts. Validating a proposition implies that the researcher accompanies the expert in this evaluation procedure:

1. I link these two concepts.
2. The link I establish serves to describe, order or explain the concepts involved.
3. The specific verb and verbal form (negative or antonym) used in the proposition appropriately translates the relationship sub-type I want to express.
4. The specific verb I choose among synonyms refines what I want to convey about the relationship.

Findings: First, the categorization phase showed that 60% to 86% of the propositions expressed by the experts can be linked to categories (propositions) taken from the metasynthesis, indicating that the experts are essentially dealing with the same field as the field covered by the empirical research. Second, none of the 397 propositions from the experts contradicts the metasynthesis conclusions. Third, only rarely are certain propositions derived from metasynthesis conclusions not evoked in expert discourses. Fourth, experts addressed determinants that were not taken into account in the research corpus used for the metasynthesis. Two dimensions of the experts' original contributions thus become evident. The first is related to the role and tasks of teachers. The second involves the social, cultural, ethical and political issues related to IT integration into teaching. Propositions about these topics provide new categories of analysis.

To date, the data-ordering phase has produced all of the concept maps around the categories borrowed from the metasynthsesis (figure 3) and a few around the original categories emerging from the experts' material. The integration phase is still pending. Modelization is well under way: teachers and pedagogical advisors have already participated in workshops held in their own schools or at their professional association's annual congress, where they discussed the appropriateness of some of the aggregations of ideas set forth. Some of the experts participated in these workshops, when their schedules permitted. The quality and intensity of the discussions reveal the efficiency of concept maps in the modeling process, which feeds back into the coding, categorization and relation phases.

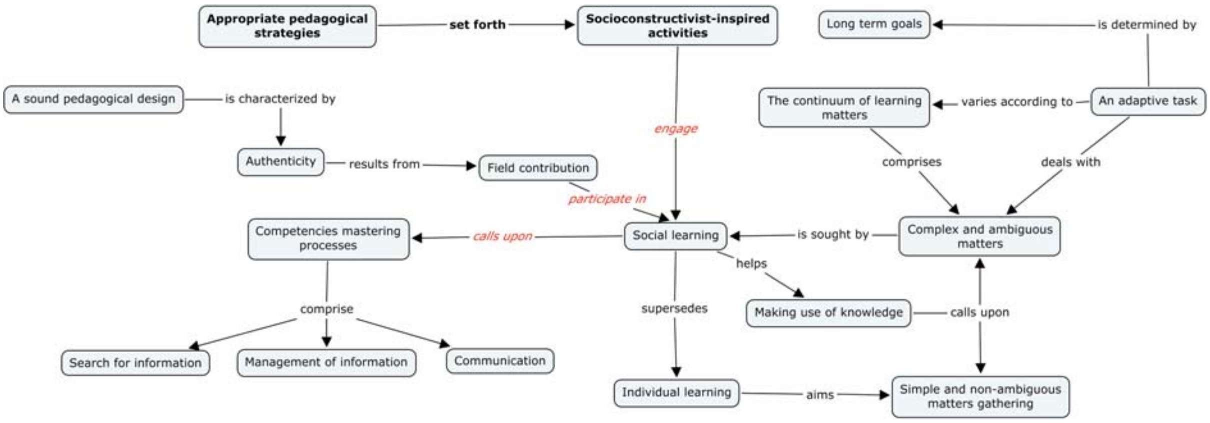

Figure 3. A typical concept map created in the data-ordering phase of the analysis that can be debated by practitioners in a 60 to 90 minute session. Concepts and links are from the interviewed experts, and in bold, from the metasynthesis. Links suggested by the researcher are in italics.

In the next steps, work will focus on the integration phase so it can start to feed the ongoing modeling process. With the help of ARC and its partners, the goal is to mobilize professional associations and networks over the longer term, in order to develop theories among the community of practitioners in the field of IT pedagogical integration. One of the research projects that could arise from this theorizing process relates to the observation and analysis of decision-making by professionals in the field.

In all its stages, our research shows the benefits of using concept maps. It has helped show that the contributions of theoretical and expert models can be distinct yet compatible. It also has been effective in supporting discussion, validation and hopefully theorizing among a community of professional practitioners, simultaneously nurturing empirical knowledge and effective professional practices.

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