Multimedia Learning – Identifying Research Directions

Hanna Olsson

Mid Sweden University, Department of Information, Technology and Media
hanna.olsson@miun.se

Abstract. An infinite amount of information is within reach for anyone with access to the Internet. This appears to create a demand for efficient and accessible sources for learning. Multimedia Learning could potentially take part in meeting this demand. However, there are indications that technology is not fully taken advantage of for learning purposes (Greitzer 2002; Kahiigi, Ekenberg, Hansson, Tusubira and Danielson 2008). Hence, the problem at hand, motivating this paper, is that the demand for efficient and effective sources for learning is not necessarily met at its fullest potential. The conclusion is that research is needed in the areas of learner-learner interaction in multimedia, personalization through feedback, identification of stakeholders, minimalistic design of multimedia learning, flexibility and control in multimedia learning and cognitivity aspects in combination.

Key words: multimedia learning, e-learning, learner-centred approach, knowledge needs

1 Introduction

> *Fiction: The learner wants to obtain knowledge efficiently and effectively. Therefore he turns to multimedia. The colourful images mixed with video and sound appear accessible. Since he watches TV and surfs the Internet more frequently than he reads books, multimedia feels like familiar grounds. He is used to applying his senses interchangeably, as he watches TV, while he has a conversation and plays the guitar at the same time. Yet, the multimedia application that is supposed to promote and enable knowledge construction is not fulfilling his expectation. It is neither as efficient nor effective as he expected it to be.*

The evolution of information and communication technology during the last decades has led to many changes in everyday life. How people learn is one of those changes, enabled by the infinite amount of information within reach for anyone with access to the Internet. The introductory fiction wishes to establish the context, as a portrait of a young person of today. Why does one need to know the name of the capital of Chad by heart, when it is only a few clicks away? Likewise, sources for learning appear to be expected to be efficient and accessible. Multimedia Learning could potentially be a way to meet such expectations. But how should this technology be approached in order to be benificial?

Multimedia offers a great number of possibilities and can be used for diverse purposes such as entertainment or learning. This paper has, as is obvious from the title, its focus on multimedia for learning. The technology offers the possibility of mixing modes (e.g. images, video, sound etc.) in creative ways. However, caution is advised. Nielsen (2000) has pointed out that design of multimedia products needs to be disciplined in order to be profitable. Refraining from charging all possible modes with material is strongly advised. Cognitive Load Theory (Sweller 1988) and Cognitive Theory of Multimedia Learning (Mayer 2005) also guide towards a moderate design.

1.1 Purpose and contribution

There are indications that technology is not fully taken advantage of for learning purposes (Greitzer 2002; Kahiigi, Ekenberg, Hansson, Tusubira and Danielson 2008). Hence, the problem at hand, motivating this paper is that the possibility for efficient and effective sources for learning is not necessarily taken advantage of at its fullest potential. The purpose of this paper is, thus, to explore the state of the art of multimedia for learning, in order to identify knowledge needs and motivated directions for future research.

Many studies on Multimedia Learning involve experiments isolating a specific part of the matter (e.g. Mayer, Hegarty, Mayer and Campbell 2005; Hasler, Kersten and Sweller 2007; Ozcelik, Karakus, Kursun and Cagiltay 2009). However, no research has so far offered a satisfactory holistic approach to the design of Multimedia Learning-situations. This paper presents a holistic approach, with the interest in the combination of factors such as structures, modes and user experience. Through a literature study, conclusions are made about motivated scopes for future research. Hence, the contributions of this paper are directions for future research within a holistic view of Multimedia Learning. Multimedia professionals could benifit from this roadmap.

1.2 Key concepts

In his efforts of "disciplining multimedia", Gonzalez (2000, p. 74) offers a useful description of **multimedia**: "…multimedia is an interactive, multimodal information space in an artificial environment conceived by fusing the medium and the message." This description stays within a digital environment, thus excluding printed media. It underlines that information is in a space, not on a flat surface. This together with interactivity could be reason enough to exclude broadcast television. Also important is that the medium is dependent on the message, and vice versa, in order to qualify as multimedia. This definition is valid for the present paper.

Knowledge is acquired by organizing information (Marakas 2003). Bhatt (2002) describes this in a poetic way, as information gaining life through organization, in the form of knowledge. In addition, knowledge is justified by personal belief (Nonaka 1994). Knowledge, thus, cannot be transferred, but has to be constructed through organization within the mind of the learner.

Learner in this paper refers to an adult person with a purpose to acquire a specific knowledge. Learner and user could in this case be used interchangeably.

Learning is described by Kirschner, Sweller and Clark (2006) as a change in long-term memory. Given that learning occurs, it can result in two types of learning, namely rote or meaningful (Mayer 2005, p. 13). Rote learning is when information is remembered, while meaningful learning is when information is remembered and understood (ibid). Complex learning is defined by van Marriënboer (2002) as achieving integrated sets of learning goals, hence, coordination and integration of separate skills, where the whole is more than the sum of the parts. In this paper focus is on meaningful, complex learning.

Multimedia Learning refers to learning enabled through the use of multimedia products. Mayer (2005, p. 2-3) describes the difference between Multimedia Learning and Multimedia Instruction. According to his description, a Multimedia Instruction (what he also refers to as Multimedia Learning Environment) is the learning material presented in the form of multimedia, whereas Multimedia Learning refers to the learner-constructed knowledge that results from a Multimedia Instruction. In this paper, on the contrary, Multimedia Learning has been chosen to represent the learning situation. Where clarification is needed between the action of the learner and the designed multimedia product, the addition of "situation" is added; hence, Multimedia Learning-situation. The main reason for the choice is that "learning", rather than "instruction", corresponds to the view of student-centred learning where the word "instruction" seems misplaced.

e-Learning can take various forms, for example tutorials, simulations, distance learning through Learning Management Systems (LMS) or Computer Based Training (CBT). Any e-Learning, supplying more than one mode simultaneously together with interactivity, thus fits within the above description of Multimedia Learning. In this paper e-Learning and Multimedia Learning are considered to be closely related.

1.3 The framed scope

This paper treats the use and design of Multimedia Learning-situations. However, no technical aspects such as algorithms, indexing or hardware components fall within the scope of this paper. In accordance with Ulrich's Boundary Critique (2000), the area of interest for the present paper is expressively mapped. The area of interest for a holistic view of Multimedia Learning is examined from three perspectives, namely Learner (agent), Multimedia (technology), and Learning (activity) (see figure 1). The Learner is the centre of attention and the owner of the problem. The Learner wishes to obtain Knowledge, through the channel of Multimedia supported by Learning approaches.

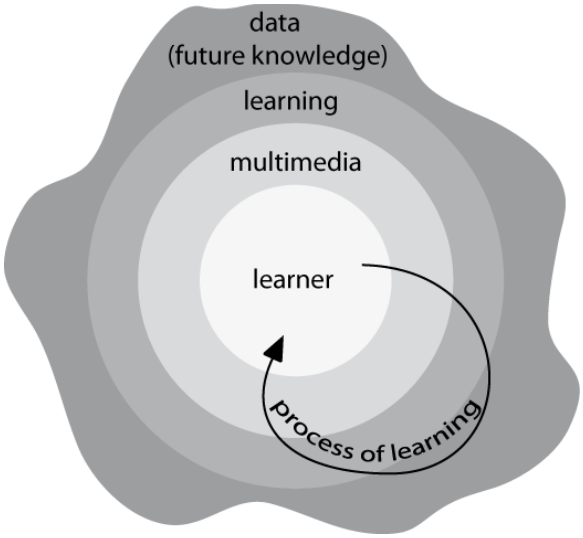

Figure 1: Areas of interest

Within the perspectives, subjects can be organized, and seen as sub-areas (see figure 2). Learner is concerned by the sub-areas Human-Computer Interaction (HCI), Usability, User Experience, Personalization and Learning Styles. Multimedia is treated through the sub-areas Information Systems, Structure/Organization and Modes/Modalities. Learning, while also covered by Structure/Organization, is mainly concerned by Educational Approaches and Cognitivity. To assimilate the Data in order to construct Knowledge is the ultimate goal.

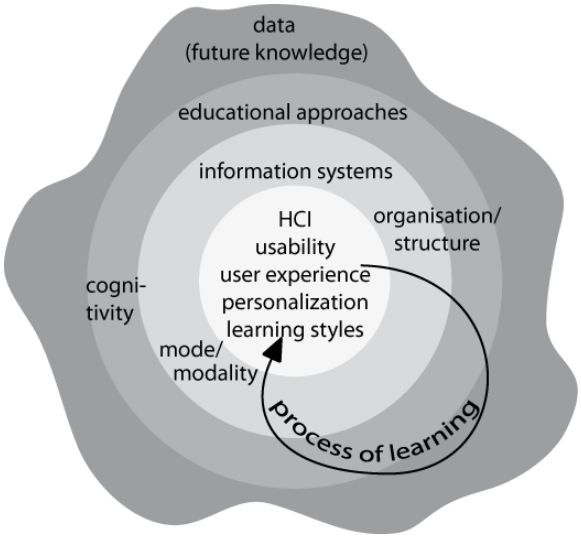

Figure 2: Subject areas of interest

2 Method

A vast amount of literature was scanned and the boundaries for the area of interest were set, as described in section 1.3. The primarily used database was Scopus. The reason for the choice was that Scopus is a citation database, with a scope wider than other citation databases, such as ISI Web of Science. The wider scope is relevant since the area of interest is inter-disciplinary, with interest within Systems Science, Informatics/Information Systems, Computer Science, Psychology and Pedagogy.

Search terms were identified by comparing the numbers of resulting hits, in addition to the relevance of resulting hits. The primary search terms used were "Multimedia Learning", "Multimedia Instructions" and "Educational Multimedia". Searches were also made with the terms "e-Learning", "Computer Based Training" and "Advanced Distributer Learning", where a delimiting search within the respective search results was done with the term "Multimedia". For the number of resulting hits, see Table 1. Interesting to observe in the table are trends, such as the elevated number of hits on "e-Learning" during recent years. Important to note is that the number of hits for the years of 2009/2010 is not complete, since the year 2010 had only just started when the search was performed. Some results from year 2009 can also be expected to be registered late.

	1995/ 1996	1997/ 1998	1999/ 2000	2001/ 2002	2003/ 2004	2005/ 2006	2007/ 2008	2009/ 2010	1995- 2010	total*
Multimedia Instructions	17	20	25	21	22	25	34	10	174	185
Multimedia Learning	20	24	24	29	62	88	114	68	429	447
Educational Multimedia	11	16	25	16	22	12	34	12	148	151
E-learning	9	16	35	245	926	2110	3828	1985	9154	9195
E-learning + Multimedia	0	2	4	46	297	631	1987	960	3927	3927
Computer Based Training	60	94	98	77	89	90	99	38	645	839
Computer Based Training + Multimedia	20	33	35	18	28	24	18	9	185	198
Advanced Distributed Learning	0	0	2	4	6	7	4	2	25	25
Advanced Distributed Learning + Multimedia	0	0	1	1	3	1	0	2	8	8

* The total includes years preceding the year of 1995.

Table 1: Number of hits per search term, in the Scopus database.

The term with the highest number of hits and with the perceived highest relevance, in relation to the scope of this present paper, was “Multimedia Learning”, followed by “Multimedia Instruction” and “Educational Multimedia”. “e-Learning”, was judged returning with too wide of a range, and thus, high irrelevance rate. “Computer Based Training” also returned high irrelevance rate. “Advanced Distributed Learning” returned few results in total, and they were also of high irrelevance rate.
The resulting hits were then sorted by citation rate. Articles ending up high in the sorted list and with relevant scope were studied. Articles cited within those articles and with perceived relevant content, were then studied, and so on. Interesting links were in this way traced backwards.
In a similar manner, articles citing the original articles were studied, and so on. In this way, links were traced forward.

Through this process relevant authors were framed, and their contributions were studied cautiously. The process of tracing citation links forward and backwards would here start over from a relevant article as starting point. When several circles had returned to the same sources, the scanning of literature was considered substantial enough, and hence, saturated. In the next section, findings and trends are described.

3 Directions in research

Below follows a summary of relevant findings presented in existing literature.

3.1 Learner

The advantages of a moderate design approach are well established in the Human-Computer Interaction (HCI) community, especially by Carroll (1990, 1998) and Nielsen (1993). Carroll’s minimalist approach builds on “learning-by-doing”, thus engaging the learner through meaningful activities. Two other main principles of Carroll’s minimalist design approach are context of use and support for error (recognition, diagnosis, recovery and undo-functions) (Carroll 1998, p. 28). Nielsen (1993) promotes simplicity, which usability relies heavily upon. Usability is of great importance in Multimedia Learning, since the learner needs most possible cognitive resources available for learning. Hence, the learner should not need to waste resources due to usability problems, for example navigation.

The importance of usability in information systems for learning has been underlined in recent research founded on best practice principles (Payne, Stephenson, Morris, Tempest, Mileham and Griffin 2009). The study reports successful results from implementation of Multimedia Learning in workplace learning, based on an active learning approach.

Personalization could look different, as it could appear on different levels. Chang and Chu (2010) propos the use of learning behavioural Petri nets (LBPN) to monitor learners’ behaviours in web-based learning environments. One of the findings from their research is that LBPN could enable personalized learning by recommending appropriate learning content. This approach, or other approaches building on cybernetic ideas of feed-back, communication and control, could be of interest for personalization of Multimedia Learning. Commonly, personalization focuses on learner preferences and behaviours, but neglects learners abilities (Chen, Lee and Chen 2005). A rich approach to personalization, including learner abilities could be beneficial in Multimedia for learning.

3.2 Multimedia

Many design guidelines for multimedia have been proposed. As seen below, researchers have taken different approaches towards the design of multimedia.

Nielsen's heuristics was proposed for general purposes (1993) and was later developed into a specific multimedia version (2000). Those fundamental usability guidelines rest on results from cognitive research. However, they expand the view by incorporating aspects of function and user satisfaction.

Narayanan and Hegarthy (2002) propose a framework for design of multimedia, emphasizing the importance of structure and content. Their work is also heavily founded in cognitive psychology, and they find that a proper cognitively informed design is superior, regardless of delivery media, thus reminding that the cognitive aspects are not to be ignored in the holistic view.

Ainsworth (2006) offers DeFT, a conceptual framework for Multimedia Learning. DeFT stands for Design (principles for learning with multiple representations), Function (pedagogic function) and Task (cognitive task undertaken by learner). While widening the view, the scope is still narrow and with a heavy focus on cognitivity.

Sutcliffe et al. (Sutcliffe, Kurniawan and Shin 2006) proposed a method for design of multimedia, concretized through a software tool. The method takes influences from existing theories and previous experiments, offering a somewhat wider scope than most other studies. Their method includes selection of form, as well as advice on visual and aesthetic design. Though this widens the view, compared to those guidelines only concerned with selection of form, it is still not a holistic view. There is for example no attention given to the structure of the system. The area of concern has been framed to what is seen on screen.

Heller and Martin (1995) proposed a taxonomy, where every mode is related to an "expression". There are three expressions, namely Elaboration, Representation and Abstraction. Elaboration is material where no information has been edited out (but information may be added), for example an unedited photo or a narrative of an event. Representation is more stylized, controlled material, for example a map or an edited video. Abstraction represents metaphors, for example a logo or an icon. The taxonomy is used to support evaluation or design.

3.3 Learning

A common understanding is that multimedia is highly engaging. That this would have a possitive impact on learning has, however, not shown any evidence in cognitive experiments (Clark 2005). Warnings are raised about students being highly motivated due to their expectations that Multimedia Learning demands less effort. Hence, the lack of effort, considered related to high motivation, obviously would lead to weak learning. In addition, the minimalist approach to learning, often set in relation to constructivist learning, has received heavy criticism from the same direction (i.e. cognitive research). Respected cognitive psychologists (i.e. Kirschner, Sweller and Clark 2006), declare the reasons for the perceived failure of constructivist approaches. A fear of getting lost in a myriad of information is expressed, as well as of learning faulty information, thus losing time and quality of the learning results.

In reference to Cognitive Load Theory (CLT) (Sweller 1988), the constructivist approach is criticized for heavy strain on the working memory, thus prohibiting learning. This would be much due to the condition that the resources of working memory needed for learning are overlapped by those resources needed for problem-solving. Furthermore, extensive research on Multimedia Learning from a cognitivity perspective has been conducted by Mayer et al. (e.g. Mayer 1997; Moreno and Mayer 1999; Mayer 2005; Mayer, Hegarty, Mayer and Campbell 2005). Mayer's

(2005) Cognitive Theory of Multimedia Learning is the result of many experiments on cognitive learning effects of Multimedia Learning. Mayer's (2005, p. 2) view of multimedia is, however, much broader than that of this paper, covering every representation including more than one mode. Hence, a book with images fits within Mayer's view of multimedia. Although from a different viewpoint, Mayer's findings are of great value, setting the foundations for design of Multimedia Learning-situations.

The extensive amount of existing literature regarding cognitivity in relation to Multimedia Learning makes a solid theoretical foundation. Those theories are to be respected, and taken into consideration. However, applying those cognitive theories in the greater perspective also calls for considering other, sometimes contradictory, ideas.

The choice of pedagogical approach for the design of Multimedia Learning-situations is essential. Since the paradigm shift from "teaching" to "learning" (Barr and Tagg 1995), many have adopted the student-centred approach. This is also the view taken in this paper. Furthermore, the perspectives of learning through behaviorism, cognitivism and constructivism can be debated (Ertmer and Newby 1993). Without going into detail, the constructivist perspective seems to be well applicable to Multimedia Learning, due to the active and exploring character. Hoffmann and Ritchie (1997) contribute an appealing solution to the problems of constructivist learning (in this case PBL) by the use of multimedia. A constructivist approach can also be suitable for workplace learning, as it resembles the way people normally learn at work (Payne, Stephenson, Morris, Tempest, Mileham and Griffin 2009). A Guided-Discovery approach has shown to be suitable for Multimedia Learning (Greitzer, Merrill, Rice and Curtis 2004; Jong 2005). The 4C/ID-model, provided by van Merriënboer and colleagues (van Merriënboer, Clark and de Croock 2002), represents a design theory for complex learning, applicable for design of Multimedia Learning-situations. The four parts of the 4C/ID-model are (a) learning tasks, (b) supportive information, (c) just-in-time information, and (d) part-task practice (ibid). The strength of the model is most of all in its holistic approach.

4 Holes in the holistic image

Here follows motivated future research directions (see figure 3). However, the ambition is not to offer a total image; certainly, there are more holes in the image which are not listed here.

The learner is central; this is commonly accepted. However, other stakeholders, such as teachers and future employers, should be evaluated for the holistic image. In this search, no satisfactory work that identifies who those stakeholders might be, has been found. Furthermore, personalization has been examined to a certain extent. However, the personalization of multimedia needs further work. How to use feedback loops to make the system adjust to the learner's preferences, learning style, prior knowledge, and achieved learning is an interesting direction for future research.

Minimalistic design of multimedia has gained mainly positive reactions, as shown in section 3.1. However, minimalistic design of instruction has been more controversial. The combination of the two – minimalistic design of Multimedia Learning-situations – could potentially show interesting results. Hence, research is motivated. In relation to this, multimedia could possibly be the platform for control and flexibility to co-exist. This should be evaluated as a direction of research where, in addition, the levels of the individual and the organization should be considered.

The importance of interaction is known. However, could the interaction be extended from the learner-system, to a learner-learner interaction? Research on the implications, benefits and drawbacks of incorporating this dimension in Multimedia Learning is needed. Furthermore, testing

of cognitivity aspects in combination, rather than in isolation as has earlier been the case, would greatly contribute to the holistic view. Could the total possibly be greater than the sum of its parts?

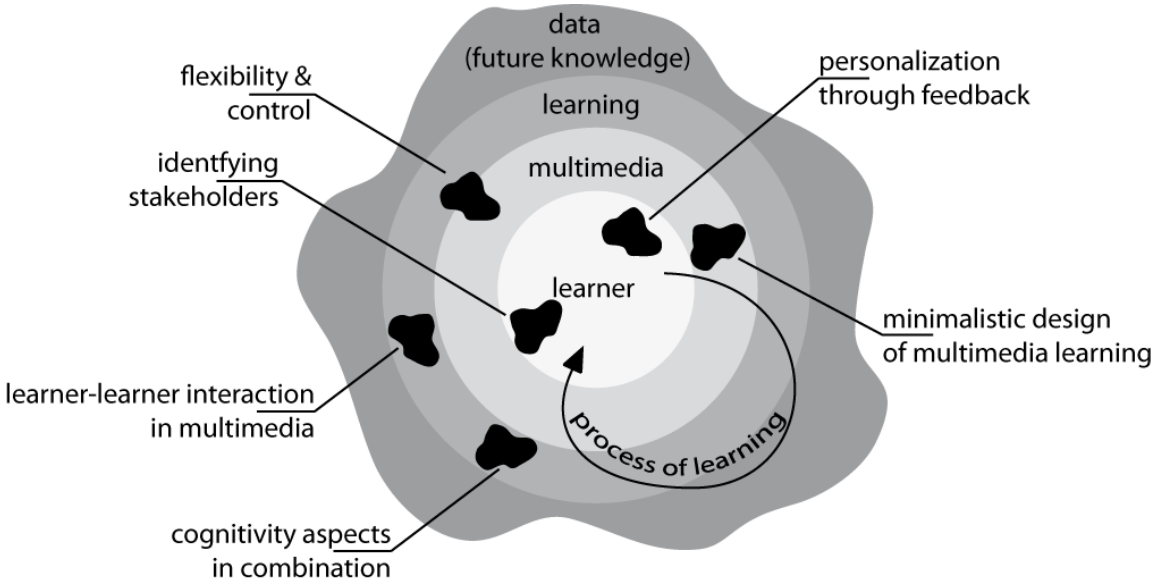

Figure 3: A holistic view of motivated directions for research on Multimedia Learning

5 Concluding remarks and future directions

In order to take full advantage of multimedia for learning, future research covering the knowledge gaps is needed. There are parts well covered by research, but connecting bridges of knowledge, setting the known parts in relation are needed. The identified areas needing attention are learner-learner interaction in multimedia, personalization through feedback, identification of stakeholders, minimalistic design of multimedia learning, flexibility and control in multimedia learning and cognitivity aspects in combination. With more knowledge, potentially, Multimedia Learning could allow for learning to be flexible, active and exploring, within a safe, controlled and supporting environment. A minimalistic design of Multimedia Learning-situations could tentatively be effective, efficient and beneficial for the learner.

Hence, the direction for future research will be to evaluate the potential of a minimalist design approach of multimedia for learning. Feedback systems to allow for personalization fall within the scope, as a condition for efficient minimalist design. Cognitivity aspects in combination, and stakeholders, needs to be evaluated. Further, the co-existence of flexibility and control on multiple levels, through the use of Multimedia Learning will be evaluated. Other interesting areas of research concern learner-learner interaction through multimedia applications.

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