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ORIGINAL ARTICLE

Learner Control in Hypermedia Environments

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Abstract Contrary to system-controlled multimedia learning environments, hypermedia systems are characterized by a high level of interactivity. This interactivity is referred to as learner control in the respective literature. For several reasons this learner control is seen as a major advantage of hypermedia for learning and instruction. For instance, learner control might increase students' interest and motivation, facilitate adaptive instruction, or provide affordances for active and constructive information processing. In this paper we analyze the instructional potentials of learner-controlled hypermedia environments as well as possible reasons for the ambiguous results of studies that have aimed at determining the effectiveness of hypermedia learning. According to our analysis, the potential effectiveness of self-controlled learning with hypermedia might be difficult to demonstrate due to (1) usability problems (i.e., disorientation, distraction, cognitive overload), (2) moderating learner characteristics (i.e., prior knowledge, self-regulatory skills, cognitive styles, and attitudes towards learning), (3) a lack of conceptual foundations, and (4) methodological shortcomings of many hypermedia studies. The findings reviewed in this paper and the corresponding claim that hypermedia may be effective only if used in a sensible way are used to derive a couple of guidelines for further research on hypermedia learning.

Keywords Learner control · Hypermedia learning · Learner characteristics · Instructional approaches · Navigation strategies · Usability problems

This paper on hypermedia learning is part of a special issue on interactive learning environments. Broadly speaking, interactive learning environments allow learners manipulating the presentation of information that they contain. In the literature on computer-based instruction, the term interactivity is most often used for describing the malleability of single

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representations (e.g., pacing an animation or setting parameters in a simulation). On the other hand, if learners can alter multiple representations and if they have multiple ways of interacting with these representations (i.e., sequencing, selection of content, representation control, pacing; see below), the term learner control is used. Despite these connotative differences, the two terms—interactivity and learner control—can be used interchangeable, as interactivity by definition implies that the learner has control over the display of information. In the remainder of the paper, we will, however, continue the aforementioned terminological tradition by using the term learner control rather than interactivity when characterizing hypermedia learning environments. Nevertheless, as should become clear in the following sections the latter *are* interactive learning environments.

Hypermedia learning environments consist of network-like information structures, where fragments of information are stored in nodes that are interconnected and can be accessed by electronic hyperlinks (Conklin 1987; Rouet *et al.* 1996). In the case of purely text-based systems the term hypertext is commonly used, whereas hypermedia systems are characterized by different representational formats (e.g., video, animation, sounds) that may address the visual as well as the auditory information processing channel. Since several years, there is a "growing interest in the extension of hypertext to the more general concept of hypermedia, in which the elements which are networked together can be text, graphics, digitized speech, audio recordings, pictures, animation, film clips, and presumably tastes, odors, and tactile sensations" (Conklin 1987, p. 18). Thus, from a technical point of view, hypermedia can be seen as an augmentation of hypertext, in which multimedia elements are included (cf. Rouet and Levonen 1996). Therefore, in the remainder of the paper, we will not make a distinction between hypertext and hypermedia unless this seems warranted due to the specific properties of hypermedia systems (e.g., when assumptions are made concerning the impact of different representational codes on hypermedia learning). Thus, we will review hypertext as well as hypermedia studies, because our focus is on the "hyper"-part of the concept (i.e., the notion of interlinked information nodes) regardless of how the information within these nodes is represented from a semiotic perspective. Nevertheless, it has to be kept in mind that some authors have argued that there is no simple transfer from research on hypertext to hypermedia as these media require different cognitive processes (e.g., representational literacy, Barab *et al.* 1996; Cognition and Technology Group at Vanderbilt 1996).

Another distinction that is more important for the current paper pertains to the difference between hypermedia and multimedia. Contrary to multimedia learning environments, where control over the order and selection of information is established by the system, hypermedia environments are capable of being explored by learners in multiple ways. Therefore, multimedia environments are often characterized as linear compared to the non-linear information access offered in hypermedia environments, where learners can select and sequence information according to their personal needs and preferences. This type of interactivity of hypermedia environments is referred to as learner control in the respective literature and is seen as a major advantage of hypermedia and its defining feature compared to more traditional forms of learning environments (Shapiro and Niederhauser 2004).

There are numerous studies that have aimed at empirically investigating whether learner control improves performance compared to system-controlled instruction. However, these studies differ largely with regard to the way learner control has been implemented. According to Gall and Hannafin (1994), "learner control is not unidimensional, but depends fundamentally on the nature of the decisions to be made" (p. 218). This is in line with the idea that learner control implies different ways of interacting with multiple representations.

Thus, several aspects of learner control can be distinguished (cf. Lunts 2002; Merrill 1980): Firstly, learners may be allowed to determine the order in which they would like to access different information units (*sequencing*). Secondly, learners may decide on which contents to receive (*selection* or *content control*) and thirdly, on how a specific content should be displayed, for instance, by determining whether to represent it in a verbal or in a pictorial format (*representation control*). In addition to these three aspects of learner control, a basic level of learner control can be established by having learners decide over the pace of information presentation (*pacing*, e.g., by allowing learners to play, pause, stop, or replay dynamic representations). Pacing, however, is not limited to hypermedia, but can be found in many multimedia environments as well.

Rather than aiming at providing evidence in favor or against hypermedia learning like other reviews in this area have done (Chen and Rada 1996; Dillon and Gabbard 1998), the current paper attempts to highlight some conceptual and methodological issues hypermedia designers as well as researchers should consider in their work. We will start by exploring possible arguments for why an increased learner control with regard to the aforementioned three dimensions—and therefore for why hypermedia—may aid learning in the next section.

Promises of Learner Control in Hypermedia Environments

Several arguments have been brought forward for why hypermedia environments should be more effective than system-controlled learning environments.

(1) *Hypermedia structures mirror the mind*. Landow (1992) has suggested that "one of the great strengths of hypertext lies in its capacity to use linking to model the kind of connections that experts in a particular field make. By exploring such links, students benefit from the experience of experts in a field without being confined by them" (p. 127f.). Similarly, Jonassen and Grabinger (1990) initially assumed that "access to the information is facilitated by the associative organization of the information in hypermedia, which may resemble the associative structure of the mind" (p. 9). There have been theoretical arguments as well as empirical evidence, however, against this oversimplified assumption (Tergan 1997). For instance, Whalley (1990) has argued that hypermedia structures and (models of) mental structures are not comparable as the latter are more complex and, in addition to the former, contain information on the context and importance of information. Jonassen himself has shown empirically that designing hypermedia based on an expert's representation of the content does not improve learning compared to other ways of presenting the content (Jonassen and Wang 1993). Dillon (1996) nicely summarizes the current state-of-the-art concerning the "hypermedia-mirrors-mind" hypothesis: "If one could convey meaning and organization in the knowledge sense merely by recognizing the layout of the physical page or screen to highlight associations, then we would have far fewer learning problems to worry about" (p. 29).

(2) *Increased interest and motivation*. It is often argued that involving learners in the decisions regarding their learning process should increase their interest in the content domain and foster their motivation to learn. For instance, Alexander and Jetton (2003) note that "when making a case for hypermedia and learning, researchers and educators often use words like self-determination, choice, interest, and stimulation to capture the motivational qualities of hypermedia" (p. 220). Snow (1980) summarizes this position by saying that "feelings of self-efficacy and self-determination, and the skills involved

in self-evaluation and the taking of independent responsibility, are enhanced by experience with control" (p. 152). Accordingly, hypermedia is assumed to foster interest and motivation.

(3) *Adaptation to preferences and cognitive needs*. According to Merrill (1980), learner-controlled hypermedia environments enable instruction that is adapted to the learners' preferences and cognitive needs, for instance, to their prior knowledge level. That is, learners can select and sequence information according to already existing affective and cognitive structures. In its most extreme form, it has even been suggested that "learners make better decisions than teachers or instructional designers because they have a bigger stake in the educational outcome and intimate knowledge of their learning preferences" (Niemiec *et al.* 1996, p. 158). Less radically stated, "the advantage non-linear interactivity affords, whether in the form of hypertext or hypermedia, is that it allows users the opportunity to configure the information space to conform to the intentions they currently have" (Barab *et al.* 1996, p. 379).

(4) *Affordances for active and constructive information processing*. Learner control may support a deeper processing of the information presented, because it forces learners to continuously evaluate which of the information may help them to achieve their learning goals and to decide between different information units (Patterson 2000). Moreover, the multilinear access to information affords learners to put more effort into identifying the relationships between different information units and integrating them with prior knowledge as it is the case for linear media (e.g., textbooks), where the author provides the argumentative structure for the learner. Shapiro and Niederhauser (2004) have thus suggested that the effects of hypertext learning can be well conceptualized on the basis of Kintsch's Construction-Integration Model of text comprehension (Kintsch 1998), where the construction of a mental representation of the text and its interrelations as well as its integration with prior knowledge form the main prerequisites for deeper understanding (i.e., the existence of a situation model of the text). Finally, providing access to the network-like information structure of hypermedia facilitates cognitive processes of contrasting and comparing information from multiple perspectives (Gerjets *et al.* 2006b), which is supposed to lead to more flexible cognitive structures, where pieces of knowledge can be reassembled to accommodate a variety of different tasks. This idea of enabling learners to criss-cross the conceptual landscape has especially been promoted by the Cognitive Flexibility Theory (CFT; Jacobson and Spiro 1995; Spiro and Jehng 1990). To summarize, learner control is assumed to engage students in the learning experience and to help them constructing their own meaning of the materials rather than being passive recipients of the information (Jonassen and Grabinger 1990; McGuire 1996).

(5) *Acquisition of self-regulatory skills*. Learner control may not only support the acquisition of content knowledge, but may also train students' abilities to self-regulate their learning process (Azevedo 2005). "Granting the user control of the learning situation permits individuals to evaluate consequences associated with the self-directed learning and to learn better how to learn" (Barab *et al.* 1996, p. 379). According to Winne (Winne and Hadwin 1998; Winne and Perry 2000), self-regulated learners efficiently manage their learning by setting goals and monitoring, regulating and controlling their cognition, motivation, and behavior in order to achieve these goals. Enabling the acquisition of these metaskills during learning by providing learner control and feedback is thus one important criterion that learning environments for self-regulated learning may have to meet.

Although there are some studies that have been considered success stories in hypermedia learning (e.g., Jacobson *et al.* 1995; Jonassen *et al.* 1992; Yeh and Lehman 2001), comprehensive reviews on the effectiveness of hypermedia (Chen and Rada 1996; Dillon and Gabbard 1998; Dillon and Jobst 2005; Gabbard 2000) and of learner control in general (Lunts 2002; Niemiec *et al.* 1996), respectively, have yet failed to show that learner control in hypermedia environments consistently yields these envisioned outcomes. Due to space limitations, these studies will not be described in detail here. They usually compare hypermedia versions with a high level of learner control to versions with a low level of learner control or even no control options at all. Learning tasks range from vocabulary learning to complex domains like literature or history, which are investigated in laboratory and—more often—in classroom settings. In the current review we will focus on studies that have used learning outcomes rather than affective or navigational variables as dependent measures to corroborate our arguments, unless otherwise noted.

From our perspective, there are at least four possible reasons for the ambiguity of results regarding the effectiveness of hypermedia for learning, which refer to the occurrence of usability problems in hypermedia learning environments, the role of learner characteristics as moderators for the effectiveness of hypermedia, a lack of conceptual foundations, and methodological shortcomings of hypermedia research. In the remainder of the paper, these four problems will be elaborated in greater detail. Whenever possible, we will report theoretical and empirical research studies that have been trying to overcome these problems.

The Role of Usability Problems

Learner control in hypermedia environments has been shown to involve several usability problems like *disorientation*, *distraction*, and *cognitive overload* (Astleitner and Leutner 1995; Conklin 1987; Kim and Hirtle 1995). Moreover, it has been argued that the same hypermedia features that may be potentially effective for learning can be detrimental at the same time. Accordingly, Rouet and Levonen (1996, p. 20) have suggested that “hypertext efficiency involves a trade-off between the power of the linking and the searching tools it provides and the cognitive demands or costs these tools impose on the reader.” Mayes *et al.* (1990) have postulated that these extra demands cannot be avoided as they result from one of the most beneficial features of hypermedia—the freedom to decide when and which information to access. In a similar line of reasoning, Salomon *et al.* (1991, p. 4) have described the freedom provided by open-ended learning environments like hypermedia systems as a kind of a double-edged sword when they postulated that “the more open-ended the activities afforded by a tool, the more freedom the learner has in becoming, or not becoming, mindfully engaged in them.” Thus, it is commonly believed that while to some extent these difficulties in learning with hypermedia are caused by a bad instructional design and can thus be overcome by technological solutions, a certain level of usability problems is inherent to hypermedia. Therefore, these inherent difficulties can only be overcome by preparing learners for the challenges they have to meet when interacting with hypermedia environments.

Disorientation

Problems of disorientation occur when users do not know where they are in the network, where they want to go next in the network, and how they can get there (Conklin 1987; Dias *et al.* 1999; Edwards and Hardman 1989; Foss 1989). According to Astleitner and Leutner (1995), “linking nodes produces a multidimensional learning environment with a spatial extension which causes spatial disorientation or the phenomenon of lost-in-hyperspace: the learner does not know where he actually is, where he comes from, and on which path through the hypermedia-system he can reach a desired node” (p. 388).

Foss (1989) proposes three types of disorientation problems that express themselves in a specific navigational pattern: (1) Navigational disorientation problems are caused by a lack of knowledge concerning the structure of the hypermedia system, its extensions, and ways of accessing information. These problems are associated with frequent loops and inefficient paths to target nodes. (2) The embedded digression problem is evident in a disorganized screen layout with multiple windows open at once and repeated backtracking to previously seen information pages. This problem is caused by high cognitive demands, which in turn may impair planning, managing, and executing digressions. (3) The art museum problem results from superficial processing of the information retrieved (i.e., short reading times), which yields an incomprehensive and incoherent cognitive representation of the content and impaired memory for details (cf. conceptual disorientation, Mayes *et al.* 1990). This is analogous to superficially processing the exhibits in an art museum. While most authors see disorientation as something to avoid, Bernstein (1991) has suggested that “disorientation is not inherently wrong; indeed, a degree of disorientation, deliberately introduced and thoughtfully controlled and guided, can be a powerful tool for writers” (p. 293), because it may increase users’ interest and engagement in the learning task. Contrary to that claim, however, Edwards and Hardman (1989) as well as Beasley and Waugh (1996) showed that learners who reported a higher sensation of disorientation also achieved lower learning outcomes.

Foss (1989) claims that disorientation is inherent to hypermedia because it is a direct result of the large and complex data structures where only a small part of the available information is visible at once. Thus, the amount of disorientation or confusion is assumed to increase with the number of navigational choices being available (Gall and Hannafin 1994). In line with the latter reasoning, Zhu (1999) demonstrated that a higher number of links contained in the hypermedia environment resulted in worse learning outcomes than did fewer links, while the granularity of the nodes (i.e., the amount of information per node) had no reliable impact on learning. Moreover, self-reported disorientation could be predicted from inappropriate navigational styles (i.e., flimsy and laborious navigation, Herder and Juvina 2004).

Despite Foss’ (1989) assumption that disorientation is endemic to hypermedia, most of the research on disorientation has aimed at finding technological solutions to this problem by developing different navigational tools and structured overviews (e.g., Beasley and Waugh 1995, 1996; Boechler and Dawson 2002; Dee-Lucas and Larkin 1995; Dee-Lucas 1996; Hofman and van Oostendorp 1999; McDonald and Stevenson 1999; Potelle and Rouet 2003; Shapiro 1999). It is beyond the scope of this article to discuss the solutions that have been proposed to reduce disorientation in hypermedia learning; reviews on this issue have been provided by Kim and Hirtle (1995), Dias *et al.* (1999; on navigational tools) and Salmeron *et al.* (2005; on structured overviews).

Distraction

It has been noted that learners browsing hypermedia environments often access information by following their interest which may change according to the context currently provided by the environment (context-sensitive browsing, Hirashima *et al.* 1997). That is, learners may form transient browsing goals that guide their information utilization behavior (Carmel *et al.* 1992). Whether this behavior is seen as a good or a bad thing, very much depends on the overall learning goal: If there is a specific learning goal that can be accommodated by a limited subset of information, then the learner's main task is to identify this information as fast as possible and to try understand the conveyed message. In this case, problems of distraction arise "when users notice too many relevant topics to explore in parallel or too many interesting things that distract attention away from the main task" (Foss 1989, p. 4). Hammond (1993) characterizes learners whose navigational choices are motivated by the current context, as rambling "at random through the hypertext" (p. 55). In this case, the necessity to avoid distraction and to concentrate effort onto the main task may result in resource-demanding processes of metalevel decision making and action control (see below). In line with this reasoning, Gerjets and colleagues (Gerjets *et al.* 2006a; Scheiter *et al.* 2000) showed empirically that distraction due to a goal intention that competes with the learning goal for execution impaired learning and problem-solving performance in a hypertext environment on probability theory. In line with current theories of volitional action control, these impairments were found only when learners worked on simple tasks, whereas they were better able to maintain their learning goal when working on more complex problems. Interestingly, overt distraction behavior (i.e., retrieval of pages not related to the learning task) was not a necessary prerequisite for performance impairments. Drawing upon the cognitive information-processing architecture ACT-R (Anderson and Lebiere 1998), these impairments could be explained and computationally modeled by assuming that the existence of a strong competing goal would increase cognitive load and thereby result in the application of less resource-demanding, but more error-prone information processing strategies (Gerjets *et al.* 2003). To conclude, this study shows that distraction during learning with hypermedia may hinder performance if the learning task is very specific (i.e., solving mathematical word problems).

However, if the learning goal is to get a broad understanding of the topic (i.e., an open-ended learning task), then the connotation of interest- and context-driven navigation behavior might be quite different. In this latter case, sometimes the term 'serendipity effect' is used (e.g., Hammond 1993) to express that learners may unintentionally acquire knowledge as a by-product of browsing the hypermedia environment. While this type of learning may be of value in some settings, most authors argue that its potential benefits are much lower than the danger of being distracted (Conklin 1987; Hammond 1993).

Cognitive Overload

Cognitive overload can result from the freedom provided by hypermedia environments to control the interaction with the system. The term refers to the assumption that metacognitive or executive skills necessary for hypermedia navigation may require cognitive resources that will no longer be available for the pursuit of the currently performed main task (Mayes *et al.* 1990). In particular, enhanced learner control may first cause difficulties in goal maintenance and thus require "additional effort and concentration necessary to maintain several tasks or trails at one time" (Conklin 1987, p. 40). Secondly, difficulties in information selection, information sequencing, and pacing may likewise result in cognitive overload. Based on the *Cognitive Load Theory* (cf. Sweller *et al.* 1998) it has been assumed that students' "decisions about which content to access, the sequence for reading it, and the rate of reading" (Niederhauser *et al.* 2000, p. 238) impose additional cognitive load onto the user. Niederhauser *et al.* (2000) showed that the extensive use of hyperlinks to compare and contrast information in a hypermedia environment inhibited learning, presumably because the necessary strategic decisions absorbed cognitive resources that could no longer be devoted to the content of the environment.

Only very few attempts have been made to investigate the issue of cognitive overload in hypermedia learning more directly. An exception is the study by Wenger and Payne (1996), who applied a dual-task paradigm to differentiate between different types of cognitive resources that might be claimed by learning with hypermedia. They demonstrated that hypermedia does not induce a greater working memory load than traditional text in general; rather, it requires a different balance of processing resources. In particular, they showed that a numerical secondary task did not affect the superiority of hypermedia over traditional text with regard to text recall, whereas a spatial secondary task reduced the hypermedia's effectiveness. The authors interpret their results by assuming that the spatial secondary task taps the same cognitive resources that are needed to process the relational information underlying the network-like content structure. In line with this reasoning it has been shown that spatial abilities improve hypermedia effectiveness (Chen 2000; Chen and Rada 1996; Nilsson and Mayer 2002).

To conclude, usability problems like disorientation, distraction, and cognitive overload may all hamper the potential effectiveness of learner control in hypermedia environments. The distinction between the three categories of problems has been first introduced by Conklin (1987). It suggests that these usability problems are distinct from each other, which seems to be an inappropriate assumption. For instance, cognitive overload is certainly also caused by learners' attempts to orient themselves in the hypermedia environment and is therefore closely related to disorientation problems. Similarly, the need to maintain a current goal and avoid distractions may result in cognitive overload. Moreover, following seductive side paths in a hypermedia environment does not only result in distraction, but also may cause disorientation, for instance, when learners try to find their way back to the initial entry point. Thus, the three types of problems address qualitatively different aspects, but should not be seen as independent problems.

In the next section the growing evidence that the opportunity to control one's process of learning is not equally suited for all learners will be discussed. An important conclusion derived from this discussion is that individual learner characteristics may moderate the effectiveness of learner control and thus of learning with hypermedia. At least part of this moderation may be traced back to the fact that learners with less suitable characteristics for the type of learning required in hypermedia environments (e.g., with low levels of prior knowledge) experience more of the usability problems described in the current section. This pattern of evidence is quite familiar for researchers, who consider instructional design from a cognitive load perspective. According to Cognitive Load Theory (Sweller *et al.* 1998), disorientation and distraction may cause a high level of extraneous cognitive load, which is assumed to hinder learning. However, if learners possess a sufficient level of prior knowledge, their intrinsic cognitive load is substantially decreased and they will be less susceptible to detrimental effects of extraneous cognitive load.

The Moderating Role of Learner Characteristics

It has often been assumed that increased learner control will accommodate individual differences by enabling learners to adapt instruction to their preferences and needs. In particular, "hypermedia has long been advocated as a way of 'leveling the playing field' and allowing all learners to proceed in a manner that suits their unique learning process" (Dillon and Jobst 2005). However, empirical research has shown that rather than compensating for unsuitable learning prerequisites of some learners, hypermedia tends to increase the gap between good and poor students (cf. Matthew Effect, Stanovich 1986). Hypermedia seems to be especially suited to improve learning for students with higher *prior knowledge*, better *self-regulatory skills*, and more positive *cognitive styles* and *attitudes towards learning*, who are better able to make use of hypermedia's enhanced freedom (Dillon 1996; Gall and Hannafin 1994; McGrath 1992; Rouet 1990). Clark and Mayer (2003) have thus proposed a learner-control principle that advises to use high levels of learner control only for learners with high prior knowledge or high/sophisticated metacognitive skills.

Prior Knowledge

There is accumulating evidence that learners with low levels of prior knowledge in comparison to learners with more favorable learning prerequisites have *more difficulties in navigating hypermedia systems* (e.g., Kelly 1993; Last *et al.* 2001; Lawless and Kulikowich 1996; McDonald and Stevenson 1998a; Mills *et al.* 2002), *apply superficial processing strategies* (Chen and Ford 1998), *produce worse learning outcomes* (Alexander *et al.* 1994; Kraus *et al.* 2001; Lawless and Brown 1997; Lee and Lee 1991; Niederhauser *et al.* 2000; Potelle and Rouet 2003; Shin *et al.* 1994; Shyu and Brown 1992, 1995), and *require more instructional support* (e.g., additional advisement, hierarchical hypermedia structures, overviews; Barab *et al.* 1997; Calisir and Gurel 2003; de Jong and van der Hulst 2002; McDonald and Stevenson 1998a, b; Potelle and Rouet 2003; Shapiro 1999; Shin *et al.* 1994). A comprehensive overview on the different studies investigating the relationship between prior knowledge and hypermedia effectiveness is provided by Chen *et al.* (2006). These authors conclude in their review that, on the one hand, students with high prior knowledge require no additional support in handling the hypermedia environment, are able to impose structure by themselves and to choose flexibly between different ways of accessing information, and benefit only from those navigational tools that help to locate specific information (e.g., search engines). Less knowledgeable students, on the other hand, benefit from additional support and pre-structured paths. Moreover, hierarchical overviews help them to integrate their knowledge. Accordingly, some authors have concluded that hypermedia is only suited for more able students (Clark and Mayer 2003; Spiro and Jehng 1990).

A possible explanation for these findings has been offered by referring to schema theory, whereby schemas (i.e., prior knowledge) are characterized by their ability to guide the construction of meaning (Gall and Hannafin 1994; Lawless and Brown 1997). In this line of reasoning, Gall and Hannafin 1994 have suggested that prior knowledge may guide learner-controlled behavior in that "individuals with extensive prior knowledge are better able to invoke schema-driven selections, wherein knowledge needs are accurately identified a priori and selections made accordingly [...] Those with limited prior knowledge, on the other hand, are unable to establish information needs in advance, making their selections less schema-driven." (p. 222). Similarly, Alexander and Jetton (2003) have argued that the more familiar students are with the domain in question, "the more capable they are of separating pertinent from nonpertinent and important from nonimportant information" (p. 218).

Another explanation for the moderating effects of prior knowledge in hypermedia learning can be based on Kintsch's Construction-Integration Model (CIM, Kintsch 1998), which is being used as a theoretical framework in this context (cf. Shapiro and

Niederhauser 2004). According to this model, learners with high prior knowledge benefit from less coherent information presentations, whereas learners with low prior knowledge require a coherent representation to construct meaning from a text as they are not able to overcome gaps in the text structure on their own (McNamara and Kintsch 1996; McNamara *et al.* 1996; Pazzani 1991). Coherence in texts is established by all devices that highlight the micro- and the macrostructure of information (e.g., argument overlap among subsequent sentences, advance organizer, headings etc.), These devices are typically absent in hypermedia environments, where the users have to interpret the link structure to develop a coherent representation of the content, which is why hypermedia may only be suited for high prior knowledge learners. In accordance with this argumentation, Salmeron *et al.* (2005) demonstrated that low prior knowledge participants learned more by reading a hypertext in a high coherent reading order, whereas high-prior-knowledge students learned more by reading the hypertext in a low-coherence order. Based on the CIM it can also be explained why some authors have failed to confirm the moderating role of prior knowledge in hypermedia learning. For instance, Barab *et al.* (1996) found no impact of prior knowledge in a task that mainly consisted in locating information rather than acquiring deeper understanding. The authors argue that for tasks, where models of problem solving can be better used to predict performance than models of language processing like the CIM (Kintsch 1998), prior knowledge should not act as a moderator of hypermedia effectiveness and efficiency. Additional support for this assumption comes from a study by Rouet (2003) who also found only limited evidence for the impact of prior knowledge on the performance for information search tasks.

Other knowledge prerequisites that have been shown to positively influence hypermedia learning concern the learners' spatial abilities (Chen 2000; Chen and Rada 1996; Nilsson and Mayer 2002) and their level of computer experience (Hill and Hannafin 1997; Pazzani 1991; Reed and Oughton 1997).

Self-regulatory Skills

More recent developments with regard to the identification of theoretical frameworks for hypermedia learning have suggested to use the concept of self-regulated learning to examine the effectiveness of learner-controlled computer environments in more detail (Azevedo 2005; Bendixen and Hartley 2003; Hartley 2001). Self-regulated learning can be characterized as including metacognitive, motivational, and behavioral processes that result in the active participation of individuals in their own learning (Boekaerts *et al.* 2000; Winne and Hadwin 1998; Zimmerman and Schunk 2001).

Hypermedia environments impose high demands in terms of self-regulated learning onto students. "Hypermedia browsers must be able to monitor their own comprehension of the information presented in hypermedia, select appropriate strategies for correcting any misconceptions, and develop information seeking strategies that facilitate integrating information and synthesizing information from the hypermedia" (Jonassen and Grabinger 1990, p. 20). Accordingly, it has been suggested that learners who are better able to cope with these demands, because they possess self-regulatory skills, benefit more from hypermedia learning than students who lack the respective skills (Azevedo 2005; Bendixen and Hartley 2003; Hartley 2001; Schwartz *et al.* 2004; Young 1996). Azevedo (2005) claims that if "learners do not regulate their learning when using hypermedia environments we may erroneously conclude that the environments are inherently ineffective, when in fact what is needed is to foster students' self-regulation while using these powerful but complex learning environments" (p. 203).

While these assumptions seem to be intuitively plausible, there are only a few studies that have examined the relationship between self-regulation and hypermedia learning until now. Bendixen and Hartley (2003) used a hierarchical regression analysis to identify possible predictors for the outcomes of learning with their hypermedia environment. While they found that general abilities, reading comprehension, and certain beliefs about the nature of knowledge and learning (i.e., epistemological beliefs; Schommer 1990) were useful to predict learning outcomes, metacognitive awareness as measured by a questionnaire was not. On the other hand, Young (1996) showed that learners with different levels of self-regulated learning strategies reacted differently towards variations in learner versus system control. Under learner control, learners with low levels of self-regulated learning strategies showed poorer performance than those with better skills, while there were no respective differences under system control. Schwartz *et al.* (2004) demonstrated that metacognition predicted learning outcomes within a hypermedia environment only if this environment required an active metacognitive knowledge to construct meaning within the unfamiliar structure. Thus, they suggested that metacognitive skills are a necessary, but not a sufficient condition for learning in a hypermedia environment; rather, the structure of hypermedia (i.e., whether it requires a high degree of self-regulation or not) also matters. Finally, Azevedo and colleagues (see Azevedo 2005 for a comprehensive overview) have demonstrated in a number of studies that self-regulatory skills matter in hypermedia learning by showing that this learning can be facilitated by providing adaptive scaffolds that activate existing self-regulatory skills. Similar results for the effectiveness of metacognitive scaffolding in hypermedia learning in particular when assessing far transfer performance have been obtained by Jacobson *et al.* (1995), Lin and Lehman (1999), Beaufils (2000), and Bannert (2003).

One prerequisite for the implementation of effective, but possibly resource-demanding self-regulatory strategies is that learners are sufficiently motivated and interested to invest the effort in respective activities. Thus, according to the aforementioned definition, self-regulated learning does not only comprise metacognitive, but also motivational processes, which may moderate the effectiveness of hypermedia learning. In this line of reasoning, Alexander *et al.* (1994) note in their review that learning with linear as well as nonlinear text forms improved the more motivated and interested learners were. Similarly, Lawless and Kulikowich (1996, 1998) identified one unsuccessful group of learners in their analysis of user behavior who seemingly lacked motivation for engaging in the learning task while more motivated and interested students also scored better on the posttest.

Cognitive Styles and Attitudes Towards Learning

A variety of different cognitive styles have been discussed as possible moderators for the effectiveness of hypermedia learning (e.g., passive versus active learners, Lee and Lehman 1993; learning style, Melara 1996; deep versus shallow processing, Shute 1993; field dependence, Dufresne and Turcotte 1997; Jonassen and Wang 1993; Lin and Davidson-Shivers 1996). The underlying assumption in this area of research is that not "all students will be equally willing to explore hypermedia environments to obtain information" (Lee and Lehman 1993, p. 36; Paolucci 1998). However, the empirical results on the moderating role of cognitive styles are equivocal at best and the meta-analysis by Chen and Rada (1996) revealed no reliable impact of cognitive styles despite their prominent role in the literature. Similar conclusions were drawn by Dillon and Gabbard (1998) in their review. It is yet unclear whether the concepts themselves are not important to hypermedia learning, or whether methodological and conceptual problems have caused these results (e.g., assessment methods with only low reliability and validity, inadequate subject samples etc.).

Rather than discussing the impact of cognitive styles again in this review we will focus on a construct that has received less attention in the hypermedia literature yet, although first evidence seems to be promising. This construct refers to the conceptions that learners have with regard to learning and knowing, namely epistemological beliefs (Schommer 1990). According to authors like Schommer (1990), Bendixen and Hartley (2003) or Jacobson and Jehng (1999, unpublished manuscript), naïve epistemological beliefs can be distinguished from more complex beliefs on five independent dimensions: Students with naïve epistemological beliefs tend to believe that (a) absolute knowledge exists and will eventually be known (certain knowledge), (b) knowledge exists as discrete facts (simple knowledge), (c) authorities have access to otherwise inaccessible knowledge (omniscient authority), (d) learning occurs either in a quick or not-at-all fashion (quick learning), and (e) the ability to acquire knowledge is static/innate (fixed ability). It is commonly believed that students with more complex epistemological beliefs will be more willing to invest mental effort in comparing and contrasting different sources of information, reflecting on the validity of information, and in finding as much information as possible to satisfy their learning goals (Bendixen and Hartley 2003; Jacobson and Spiro 1995).

In accordance with this assumption, Jacobson and Spiro (1995) demonstrated that learners with more complex epistemological beliefs had better transfer scores than those with simpler epistemological beliefs after having learned with a hypertext that allowed accessing information from multiple perspectives (i.e., criss-crossing hypertext). Moreover, when comparing the transfer results of learners with complex epistemological beliefs across different hypertext conditions, better outcomes were achieved in the criss-crossing hypertext in contrast to hypertext versions that allowed only for a minimum of learner control. Similarly, Jacobson *et al.* (1995) showed that learners who regarded learning as an active process of constructing meaning outperformed students with a simpler set of epistemological beliefs. Finally, Bendixen and Hartley (2003) found that beliefs in omniscient authority and in fixed abilities (i.e., naïve epistemological beliefs) were both associated with lower achievement scores in their hypermedia learning environment. Interestingly, the belief that learning takes place either quick or not at all was related to better learning outcomes in their study.

To conclude, several learner characteristics have been found to influence whether learners will benefit from the opportunity to exceed control over their learning with hypermedia environments. Most importantly, learner control seems to be suited only for students with a high level of prior knowledge and self-regulatory abilities, and potentially, more complex epistemological beliefs. However, there are no clear-cut rules for hypermedia developers yet as to how to design learning environments for students that differ with respect to the aforementioned characteristics. Up to now, this lack of concise knowledge on the relationship between learner characteristics and design features seems to prevent the design of effective hypermedia systems that automatically adapt to learners' characteristics, that is, adaptive hypermedia systems (Brusilovsky 2001). Therefore, the respective literature—which mainly addresses hypermedia design from an Artificial Intelligence perspective—is not included in this review.

Lack of Conceptual Foundations

Beyond usability problems and the moderating role of learner characteristics, another reason for the equivocal results obtained with regard to hypermedia effectiveness may be found in the lack of conceptual foundations that could inform hypermedia design. Two aspects of hypermedia design can be distinguished. First, one needs empirically guidelines regarding the design of interactive multimedia components contained in the nodes of the hypermedia network (e.g., text, pictures, animations, video, and their combinations). Here, current theories of multimedia learning may provide helpful guidelines for designers (Mayer 2005). Second, and probably more inherent to hypermedia learning, is the question of why and how to provide the learner control options characterizing hypermedia (i.e., sequencing, content control, and representation control) to students.

Most of the current research lacks a clear conceptual foundation that allows deriving testable hypotheses on how effective hypermedia should be designed. In particular, there is hardly any information on whether the suitability of hypermedia might be confined to specific *instructional approaches* or on constraints regarding the *content domains* that can be effectively taught by using hypermedia. Much of the research on hypermedia learning can be criticized for not specifying the instructional approach chosen and the cognitive structures, processes, and resources necessary to benefit from this approach (De Vries and de Jong 1999; Gerjets *et al.* 2006b). Without these specifications, findings with regard to the relative merits of presenting learning materials in hypermedia environments are of rather limited value as it is not clear whether these findings might be generalized over different instructional approaches. An example from our own research may illustrate this point: Based on an augmentation of cognitive load theory with respect to learner-controlled settings (Gerjets and Hesse 2004; Gerjets and Scheiter 2003) we combined hypermedia research with cognitive task analyses in order to compare instructional conditions that differ in the cognitive processes that they support and in the cognitive resources needed (Gerjets *et al.* 2006a, b; Scheiter *et al.* 2006). The learning approach that we focused on is the acquisition of problem schemas from worked-out examples. For this learning approach, research literature is available that addresses the cognitive processes involved as well as the cognitive resources needed for successful learning. Furthermore, pivotal cognitive processes in schema acquisition from worked-out examples like comparison processes and elaboration processes seem to be particularly apt for hypermedia-assisted learning. This knowledge from different research areas served as a conceptual foundation for our work on hypermedia learning.

The argument in favor of cognitive task analyses has also been brought forward by proponents of the *Cognitive Flexibility Theory* (CFT, Jacobson and Archodidou 2000; Jacobson and Spiro 1995; Spiro and Jehng 1990). Within the CFT, first different cognitive processes are identified that seem crucial to advanced knowledge acquisition and then, based on this analysis, the potential of hypermedia to support these processes is explicated. According to the theory, hypermedia environments may offer multiple perspectives on a topic, help to illustrate abstract principles by providing cases that can be compared and contrasted, and counteract learners' tendencies of oversimplifying knowledge and compartmentalizing rather than interrelating different sources of information. Hypermedia environments are thus "best suited for advanced learning, for transfer/application learning goals requiring cognitive flexibility, in complex and ill-structured domains" (Spiro and Jehng 1990, p. 167). In line with this argument, hypermedia systems designed according to CFT principles promoted knowledge transfer, but did not lead to better memory for factual knowledge (Jacobson and Spiro 1995; Jonassen *et al.* 1992). It is important to note that contrary to the wide use of CFT as an argument in favor of hypermedia learning in the literature, the theory constrains the usefulness of hypermedia to specific learning goals, learners, and domains.

Another attempt to argue in favor of hypermedia learning by highlighting its suitability to implementing a specific instructional approach has been suggested by Hoffman (1997), who has proposed to use hypermedia for designed instruction based on the *Elaboration Theory* (Reigeluth and Stein 1983). The main idea of Elaboration Theory is that pivotal concepts are introduced at the beginning of instruction as a so called epitome, which is then elaborated in more detail in the further course of learning. The theory incorporates aspects of learner control by assuming that the epitome can help learners in making an informed decision regarding the selection of information (e.g., by selecting hyperlinks). Thus, based on Elaboration Theory, hypermedia environments should include overviews to be processed in the beginning and should incorporate a clear hierarchical structure for elaborating the contents of the overview.

Finally, but restricted to hyper*text* learning, *Kintsch's CIM* (1998) has been used to argue why a deliberate use of hyperlinks may aid the active construction of knowledge. In particular, hypermedia's low coherent information presentations are supposed to stimulate inference processes with regard to the relationship between different nodes. These inferences are supposed to be a pivotal aspect of knowledge construction and thus may improve learning outcomes at least for learners with high prior knowledge (Salmeron *et al.* 2005).

These frameworks, which describe specific instructional approaches and their underlying cognitive processes, thus may help to design effective learning environments, whereas without these frameworks hypermedia may often be deployed in ineffective ways.

Methodological Shortcomings

As has been bemoaned by many authors, the equivocal pattern of results regarding hypermedia effectiveness might be caused by the fact that there are severe methodological problems in hypermedia research (Dillon and Gabbard 1998; Shapiro and Niederhauser 2004; Tergan 1997). Many studies have small sample sizes, their experimental variations are confounded, and the choice of dependent variables seems inappropriate, rendering an unambiguous interpretation of the results impossible. With regard to the latter aspect, Landow (1990, p. 42) criticizes: "If hypertext's greatest educational strength as well as most characteristic feature is connectivity, then tests and other evaluative exercises must measure the results of using that connectivity to develop the ability to make connections." However despite this justified methodological critique it has been shown that even if one focuses on the methodologically strong papers like, for instance, Dillon and Gabbard did in their 1998 review on hypermedia learning, the picture does not change in favor of hypermedia. Therefore, these methodological problems can not solely explain the equivocal results on hypermedia effectiveness.

As will be argued in the remainder of the section, the effectiveness of hypermedia depends on how sequencing, content control, and representation control are being used by learners. However, many researchers apply a research methodology to hypermedia learning that takes for granted that all students in a given experimental condition will roughly make the same experiences without considering individual differences with respect to learners' utilization behavior. Contrary to this assumption, learner-controlled instruction will increase the variability among students, because each student can decide to use the hypermedia environment in a more or less sensible way. Aggregating results across students who utilize the information in an either unsuitable or suitable way may thus result in a null effect, when comparing hypermedia to linear instruction. We would like to suggest that if one is interested in the effects of learner control, more attention should be paid to differences in utilization behavior and to how these differences are related to learning outcomes as the learning success in hypermedia environments should depend “on which nodes are chosen at a particular time” (Astleitner and Leutner 1995, p. 387). In line with this reasoning, Hartley (2001) expects that a suitable strategic utilization of cognitive resources in self-controlled learning from hypermedia should have a dramatic impact on learning and understanding in hypermedia instruction and that, accordingly, only the “strategic” learner will benefit from hypermedia. He argues that research on learning strategies in studying expository text has revealed a great deal of knowledge about how good readers learn from conventional linear text and that this research needs to be extended to hypermedia learning.

Contrary to other instructional settings where learner control is offered (e.g., self-paced reading assignments) hypermedia allows capturing the learners’ strategic behavior in a seamless, non-intrusive way by means of log files (Mills 2001). Log files (also known as dribble files, audit trails, or web logs) consist in “computerized records of number of screens visited that are stamped with the amount of time spent on each screen” (Barab *et al.* 1996, p. 382). With regard to the availability of these log files, Alexander and Jetton (2003) note that “one benefit of hypermedia is that it can make students’ strategic moves somewhat transparent (Bolter 1991). For example, computers can maintain a record of the paths students travel through hyperspace, the sites they visit or revisit, the amount of time they spend at certain sites or tasks, and the resources they employ. The computer, in effect, can construct a history of students’ strategic actions” (p. 219). Misanchuk and Schwier (1992) suggest that log file analyses may serve different purposes. They may be used for formative evaluation of instructional design decisions, to conduct basic research in Instructional Design, or even to advise learners on the fly about how choices made and paths taken may affect their learning outcomes. In principle, log files can be used to describe every single aspect of learner-controlled behavior. The sequencing of information can be operationalized as the order of retrieving hypermedia pages, for instance, by assessing the number of transitions between neighboring pages, whereas content and representation control can be measured by the number and type of selections made.

At least three problems may occur during the analysis of the learners’ utilization behavior: First, while these indices provide information on different aspects of learner control, they are often not independent from each other, which makes statistical analyses more difficult. Moreover, often analyses are required that can deal with multiple dependent variables in parallel (e.g., discriminant analysis, Barab *et al.* 1997; cluster analyis, Lawless and Kulikowich 1996; multidimensional scaling, Boechler and Dawson 2002). For instance, Barab *et al.* (1996) demonstrated that students’ navigational profiles could be successfully deployed to predict whether a user had been given a specific information search goal for browsing the system—at least when several strategy indicators (e.g., number of pages retrieved, depth of search) were considered simultaneously by means of a discriminant analysis.

Secondly, in order to describe learner behavior in an adequate way it is often necessary to derive more complex measures from the basic log file-indices. However, these complex measures are often tied to the specific design of the hypermedia environment and can thus hardly be compared across different studies. There are attempts to develop indices that describe user navigation in interactive databases irrespective of a specific design (Canter *et al.* 1985; Herder and Juvina 2004). For instance, Herder and Juvina (2004) suggest distinguishing between three categories of strategies: number of pages visited or revisited, the total average view time, and the navigational complexity (e.g., deviations from a linear path, number of visited links). However, because these indices aim at being applicable irrespective of a specific hypermedia design, they naturally are rather superficial and meaningless unless the author of the hypermedia system has further knowledge as to how to interpret them in a more specific way. From a theoretical perspective, Astleitner and Leutner (1995) developed a framework for describing different learning strategies, which are organized around the three challenges learners face in learning from hypermedia. Thus, learning strategies relate to (a) "attaining a temporarily activated goal, which means to find a particular piece of information somewhere in the hypermedia-system ... (b) ensuring spatial orientation, which means to make sure that a piece of information which has been found can be accessed again from any point somewhere in the hypermedia-system ... (c) acquiring knowledge, which means to realize meaningful learning by semantically integrating accessible pieces of information" (p. 388).

Despite these attempts, a third problem in navigation analyses remains, namely that without relating log file measures to a specific instructional approach, the strategic behavior of students is often hard to interpret. "When learners can go wherever they want in any sequence, the possibility of detecting interpretable paths without the input of learners becomes almost impossible" (Reeves and Hedberg 2003). Thus, optimally, a researcher should be able to say in advance for instance which selection and order of information should be beneficial for learning (cf. Scheiter *et al.* 2006; Spiro and Jehng 1990).

Despite these difficulties the analysis of information utilization behavior can be helpful for gaining further insights on the effectiveness of hypermedia for learning as has been shown by numerous studies (Anderson-Inman and Horney 1998; Balcytiene 1999; Barab *et al.* 1997; Horney and Anderson-Inman 1994; Lawless *et al.* 2002; Lawless and Kulikowich 1996; MacGregor 1999). These studies have shown that learners can be distinguished according to their navigational profiles and that different navigational profiles are associated with differences in learning outcomes. While these authors have characterized the learner groups that they have identified by using different and often idiosyncratic labels, a common picture merges: Students who are using an either passive or an active-but-superficial approach to navigating hypermedia environments score low on learning outcome measures, whereas only an active-and-thorough approach results in favorable learning outcomes.

It seems plausible to assume that differences in navigation behavior are associated with learner characteristics in that learners with more favorable dispositions for learning use hypermedia environments in a more effective way. Results by Lawless and Kulikowich (1996), MacGregor (1999), and Mills *et al.* (2002) support this view as in their studies a more efficient and deeper engagement in hypermedia learning was related to higher domain-specific prior knowledge. On the other hand, Rouet (2003) investigated the influence of task specificity and prior knowledge on university students' search strategies and incidental learning of a hypertext structure. Domain-specific expertise had only a limited influence on students' search strategies, which were however consistent with the type of task students had to complete. Davidson-Shivers *et al.* (1997) found in their analysis of students' use of learning strategies and encoding processes during hypermedia learning a high variability even among high-ability students and respective performance differences. Contrary to the aforementioned studies, they used video recordings, think-aloud protocols, and structured interviews to determine the use of learning strategies and encoding processes rather than relying on navigational profiles alone. This may be the reason why they came up with a more differentiated view than Lawless and Kulikowich (1996) and MacGregor (1999). Beyond prior knowledge, interest in the topic affects the way learners make use of the information provided to them. In particular, interest determines the pacing and selection of information (Dillon 1991; Barab *et al.* 1997)-although these effects might not be as strong as expected (Lawless *et al.* 2002; Mills *et al.* 2002).

To conclude, hypermedia research needs to consider variables that may moderate the effectiveness of learning with these non-linear environments. Two important types of moderators may include learner characteristics and types of learner activities, whereby these moderators may be causally related to each other. Gerjets and Scheiter (2003) as well as Gerjets and Hesse (2004) proposed an augmentation of the Cognitive Load Theory (CLT) to extend this theory to learner-controlled scenarios and thus to describe the aforementioned relationships. The original CLT (e.g., Sweller *et al.* 1998) assumes a direct causal relationship between a specific instructional design, cognitive activities, and the resulting pattern of cognitive load, which in turn determines learning outcomes. In its augmented version, it is proposed that whether an instructional design results in either helpful or harming cognitive load depends on learners' strategies of information utilization. Moreover, learner characteristics (e.g., prior knowledge, computer attitudes, epistemological beliefs) are included as factors that may influence strategy selection. This augmented version of the CLT is intended to serve as a framework for analyzing information utilization strategies in hypermedia environments and may thus help to address the described conceptual caveats in hypermedia research.

Summary and Conclusions

The goal of this paper was to analyze the instructional potentials hypermedia environments and to identify possible reasons for the ambiguous results of studies that aim at determining the effectiveness of hypermedia learning. It is often argued that hypermedia has many advantages for learning, which can be traced back to the fact that these environments are highly interactive in that they allow learners to exert control over the sequence of information, the content, and they way this content is represented. This form of interactivity is referred to as learner control in the respective literature on hypermedia learning. Learner control is supposed to aid learning, because respective environments (1) mirror the human mind, (2) increase interest and motivation to learn, (3) enable instruction adapted to learners' preferences and cognitive needs, (4) provide affordances for active and constructive information processing, and (5) foster the acquisition of self-regulatory skills. Unfortunately, reviews on hypermedia learning have yet failed to provide much support in favor of these claims. Possible reasons for the ambiguity of results are related to the fact that the potential effectiveness of self-controlled learning with hypermedia is hampered by (1) usability problems (i.e., disorientation, distraction, cognitive overload), (2) moderating learner characteristics (i.e., prior knowledge and general abilities, self-regulatory skills, cognitive styles and attitudes towards learning), (3) a lack of conceptual foundations, and (4) methodological shortcomings of hypermedia research. Accordingly, the effectiveness of hypermedia learning should depend on how the aforementioned advantages interact with characteristics of the learner, the task, as well as the design of a specific instructional setting (Dillon 1996). Currently it is yet rather unclear under which circumstances the benefits of hypermedia will outweigh its costs. Two important conclusions may, however, be drawn from this review: First, usability problems need to be minimized to the extent that they are not inherent to hypermedia learning environments. Second, learners need to possess several cognitive and affective prerequisites in order to cope with the additional processing demands imposed onto them (e.g., high prior knowledge, good self-regulatory skills, high spatial abilities, high motivation and interest as well as more sophisticated epistemological beliefs). While the claim that hypermedia may be effective only if used in a sensible way seems trivial at first sight, it is nevertheless often ignored in respective research that does not take into account the way users are able to handle the control given to them. Therefore, the following guidelines for further research on hypermedia learning can be derived from the findings reviewed in this paper:

(1) A priori argue for why hypermedia may be an effective technology for fostering learning by conducting task analyses that allow elaborating on the link between the content domain of interest, the instructional approach chosen, pivotal knowledge acquisition processes, and the hypermedia features that aid the implementation of this instructional approach as well as the application of its prerequisite cognitive processes (see section on lack of conceptual foundations).
(2) Provide a thorough description of different learner control features that were implemented in the hypermedia environment (see introductory section).
(3) Take precautious steps to minimize usability problems in particular if the hypermedia environment is designed to teach novice students (see section on drawbacks of learner control in hypermedia environments).
(4) Assess learner characteristics that are important to learning with hypermedia and consider possible interactions between these characteristics, the hypermedia design, and learners' information utilization strategies (see sections on the moderating role of learner characteristics and on methodological shortcomings).
(5) Register and report on learners' use of the hypermedia learner control features. If possible, assign meaning to learners' information utilization strategies in terms of the instructional approach implemented in the environment (see section on methodological shortcomings).
(6) Assign tasks to evaluate the effectiveness of hypermedia learning that are suited to address the specific strengths of hypermedia for the instructional approach implemented (e.g., tasks that measure the ability to identify meaningful relations, to integrate different topics or to construct higher-order knowledge structures; see section on methodological shortcomings).

Research based on these guidelines can be expected to substantially enlarge our knowledge on the instructional promises and drawbacks of learner control in hypermedia environments and, subsequently, to stimulate the development of more sophisticated theories of hypermedia learning.

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