Conclusions of Research Study in Multi-Intelligent Online Learning

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Overview

This paper discusses the conclusions and implications of the research undertaken for the Ph.D. in Computer Science and Educational Psychology described in the dissertation entitled *Applying Multi-Intelligent Adaptive Hypermedia to Online Learning* (Dara-Abrams, 2002a). Readers interested in further information can read the companion papers on an overview of the research study (Dara-Abrams, 2002e), the research methodology (Dara-Abrams, 2002d), the design of the multi-intelligent online learning prototype (Dara-Abrams, 2002b), and the formative evaluation of the prototype (Dara-Abrams, 2002c). These documents and the complete dissertation (Dara-Abrams, 2002a) are available online at http://www.brainjolt.com/.

The research study in Applying Multi-Intelligent Adaptive Hypermedia to Online Learning was designed to answer the following research question:

> Can the Theory of Multiple Intelligences be used to support adaptation in an online learning environment?

The research study answered the question by designing an online learning environment that uses the Theory of Multiple Intelligences to support adaptation. The research study and the development of the prototype online learning environment demonstrate that the Theory of Multiple Intelligences can indeed be used to support adaptation in an online learning environment. Therefore, the study provided an affirmative answer to the research question.

In order to answer the research question, the research study was organized into three parts. The first part involved recruiting and working with a focus group online in order to characterize participants in terms of their technical background and their three most developed intelligences. In using a Web-based questionnaire and online focus group approach, a diverse group of participants was engaged who provided data on their learning strengths and issues as well as feedback on the prototype modules after they had tried them out. The wide range in sets of three most developed intelligences within the focus group provided a structure within which to test out a number of approaches to adaptive presentation based on multiple entry points and multiple representations.

The second part of the research study involved developing the requirements, design, and implementation for a prototype online learning environment, instantiating adaptation based on the Theory of Multiple Intelligences. The educational requirements for the prototype included a set of understanding goals, generative topics, and throughlines for the development of the learning module content. The major part of the study involved using these requirements and those from the user characterization in order to develop a prototype framework and learning modules using the Entry Point Framework and multiple representations based on the Theory of Multiple Intelligences (Gardner, 1999).

The third part of the research study involved carrying out a formative evaluation, setting up the framework and learning modules online so that members of the original focus group could return and try out the modules designed to adapt to their specific user attributes. The formative evaluation was conducted in order to determine ways in which the prototype system could be improved. This paper discusses suggestions for the improvement of the prototype system based on data collected during the formative evaluation.

The paper then considers the contributions made by the research study and the prototype. There is also a discussion of the limitations and difficulties of using the approach employed in the research study and in the prototype system. An exploration of future directions follows, indicating research studies that could be undertaken to examine further use of the Theory of Multiple Intelligences to support adaptation in an online learning environment. Implications for online learning are considered and the paper concludes with thoughts on moving toward a true “anyone, anyhow, anywhere, anytime” online learning environment.

Interpretation of Formative Evaluation

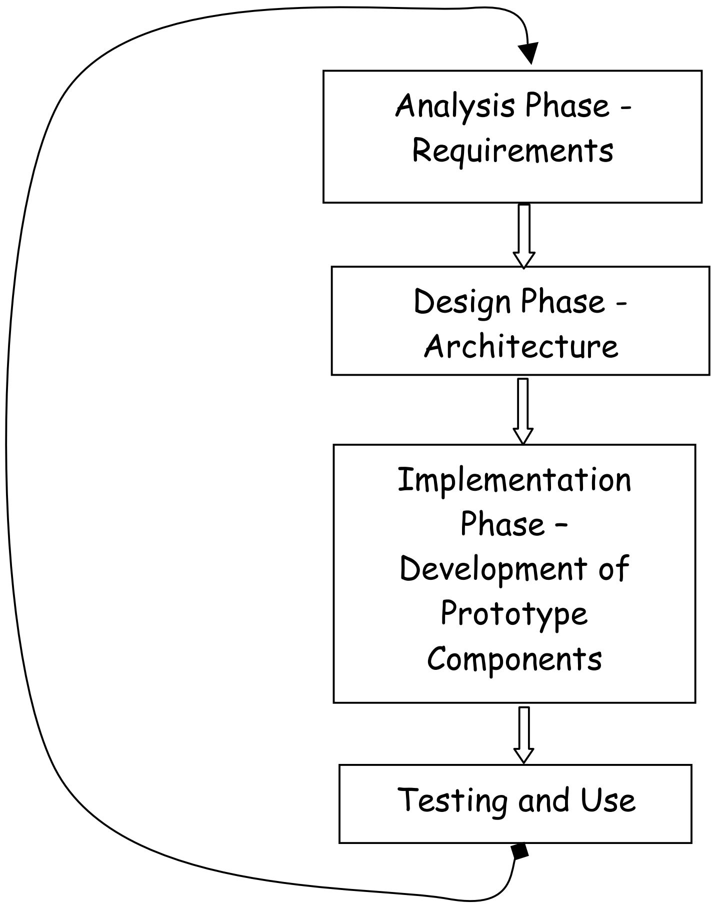
A formative evaluation was carried out using the prototype multi-intelligent online learning modules. The first piece of information that we can glean from the data collected during the formative evaluation is that 33 out of the 34 original participants completed the study, tried out the learning modules, and provided feedback through the feedback questionnaires. One Web User Participant encountered technical difficulties with his computer system and was not able to access the Overview of Web and Internet Technology learning module during the formative evaluation stage.

By design, the adaptation model in the learning modules was supported by the Theory of Multiple Intelligences, which was embodied in the user characterization in terms of each participant’s three most developed intelligences. Using the multi-intelligent adaptive hypermedia learning modules, learning through content representations, which were adapted according to the multiple intelligence attributes in the user model, these 33 participants demonstrated the feasibility of developing an adaptive strategy supported by the Theory of Multiple Intelligences. The use of the learning modules by 33 out of the original 34 participants thus demonstrated that the Theory of Multiple Intelligences can indeed be used to support adaptation in an online learning environment, thereby answering the research question in the affirmative and confirming the hypothesis that that it is possible to design an online learning environment with an adaptive strategy and user model based on the Theory of Multiple Intelligences.

The 33 participants who completed the research study participated in a formative evaluation of the prototype, providing feedback on ways that the prototype can be improved. The prototype was designed and implemented according to software engineering methodology, as depicted in Figure 1. Use and feedback occurred during the formative evaluation stage. As we can see from the diagram, feedback from the Testing and Use Phase is fed back into the Analysis

Phase, revising the requirements, design, and implementation of the prototype system, as a result of the recommendations in the Testing and Use Phase. In interpreting the Formative Evaluation, we travel along the arrow of the feedback loop, examining data collected during Testing and Use/Formative Evaluation in order to determine the information to feed into the requirements for an improved version of the prototype.

Figure 1 Software Engineering Methodology



In interpreting the formative evaluation of the prototype, we will discuss each of the major functional components of the prototype in order to examine ways to improve them:

- Stereotype User Model
- Adaptation Model
- Domain Model
- Web-based Online Adaptive Learning Environment

Stereotype User Model

We will consider the user model in terms of three aspects:

- Range of Users served by the learning modules and environment that need to be characterized in terms of their user attributes for the user model

- Technical Background of Users, the first attribute in the user model
- Most Developed Intelligences of Users, the next three attributes in the user model

Range of Users.

The first requirement on the user model was to be able to handle a variety of users in order to demonstrate that the Theory of Multiple Intelligences could be used to support adaptation in an online learning environment. From the formative evaluation, we can see that the study did indeed include a variety of users, nineteen males and fifteen females of different ethnic and cultural backgrounds, with ages ranging from 17 to 57. The population was quite well educated with two high school seniors and one college student, eleven participants with Bachelor's degrees, nine with Master's degrees, and eleven either currently pursuing a Ph.D. or already having completed one. From the user attributes described in the user model, we can see that there is variation in the intelligences represented as the three most developed, with each of the eight intelligences included in various combinations of the intelligences listed as attributes.

Technical Background of Users.

The first user attribute in the user model indicates the level of technical experience in order to test the use of Web-based online learning modules by both technical and non-technical participants. In order to determine if an adaptive strategy based on the Theory of Multiple Intelligences could be used to support different types of online learning content, people with technology development backgrounds and people without such backgrounds were recruited.

The data collected during the formative evaluation show a range of experience with online learning systems prior to participating in the research study:

- Thirteen members of the total population indicated no prior experience
- Nine participants indicated "a little experience"
- Eight participants indicated a moderate amount of experience
- Three participants indicated extensive experience
- No response from one participant who experienced computer problems.

With a range of prior experience in using online learning systems, improvements suggested in the user feedback during the formative evaluation may be useful for the user population at large.

In the formative evaluation data, we can also see a range of computer experience from two years to 32 years, and a range of occupations from theatre, music, art, and counseling to software engineering, technical support, Webmastering, and technical writing. There is not much difference in the mean number of years of computer experience of 16.7 years for those with careers in the computer and technology field and of 15 years for those with careers outside the computer and technology field. The range in technical background and interests of the participants is more clearly represented by the type of work in which participants are currently engaged.

The user model simplified information on technical background by dividing participants into two groups based on their occupational interests. The division was based on whether a participant is currently involved in the computer and technology development field or whether a participant's work falls outside the computer and technology development field. The two participant groups were provided with different content in the learning modules, with each module designed for a different audience. Based on the assumption that a participant's occupational endeavors indicate the type of content he/she might want to learn, participants were assigned to a particular learning module depending on their current occupations or field of study (in the case of the students). This division into two groups was represented in the user model with one attribute that could be assigned one of two possible values:

- The value of "legacy" to indicate the Legacy Systems Integration learning module for the Technical Participant group
- The value of "user" for the Web User Participant group who would view the Overview of Web and Internet Technology learning module.

Thus, the technical background attribute in the user model relates to audience requirements for each module and does not address the range in experience level or technical understanding.

There was a range in both the Technical Participant group and the Web User Participant group in terms of how difficult users considered the content of their respective modules to be. Of the seventeen participants who used the Legacy Systems Integration learning module, six rated the module very easy, six rated the module easy, and five rated the module moderately difficult. None of the Technical Participants rated the Legacy Systems Integration learning module difficult or very difficult. Of the sixteen participants who used the Overview of Web and Internet Technology learning module, eight rated the module very easy, five rated the module easy, two rated the module moderately difficult, and one rated the module difficult. None of the Web User Participants rated the Overview of Web and Internet Technology learning module very difficult.

Comments from participants can also be considered in order to understand how to improve the categorization of users in terms of their technical background and the content of the learning module they were given. A Technical Participant with 20 years of computer experience, who is currently a Webmaster, rated the module moderately difficult and commented that she needed "more details – each module could have one more layer of detail for those of us unfamiliar with the material and an online glossary." Another Technical Participant with 12 years of computer experience and former work experience in technical support, also felt that the module content was moderately difficult and suggested that the content provide "more clarification of acronyms."

A technical participant who is a technical writer with 25 years of computer experience, rated the content moderately difficult and felt that there were "not enough upfront instructions to get an easy start." A technical participant who is a software engineer with 30 years of computer experience, rated the module content easy, but also commented that he'd "find it easier to understand with more examples, and more detailed examples."

A technical participant who is a software engineer with five years of computer experience, rated the module content very easy and remarked that the module "needs depth." Another Technical Participant who is a sales engineer with two years of computer experience, rated the module content easy, and felt that "the modules could be longer with more information." Thus, we can see some people in the Technical Participant group wanting more depth in the technical content and others asking for more upfront instructions and more detailed examples.

Let us now consider the experience and feedback of the Web User Participant group to see how well the prototype satisfied their user requirements in terms of background and experience suitable for the learning module content. One experienced Web User Participant, with 32 years of computer experience, rated the content very easy and made a recommendation that the module offer "deeper content." Although another Web User Participant with 25 years of computer experience rated the content difficult, he remarked that "even for a non-techie, I (he) had way too much experience for this content." His interest was in learning "to post my own Web page, and other topics, 'advanced' ones for me (him)." As a trainer, this participant may be rating the difficulty of the module content for other less-experienced users.

A Web User Participant with six to seven years of computer experience rated the module content easy, and commented that she "found some of the information on viewing a Web page interesting because I (she) didn't know it." A Web User Participant with 10 years of computer experience rated the module content moderately difficult and appreciated the "opportunity to learn things I (she) didn't know about." A Web User Participant with three years of computer experience, rated the module very easy and commented that he "liked the content of the 1st and 3rd section. It was useful info, practical, de-mystifying."

Based on feedback received from participants, an improvement to the prototype would be to accommodate more types of technical background in the user model, perhaps with participants categorized as novice, intermediate, and advanced. Learners in the Web User Participant group have significantly more computer experience than would be expected in the user population at large. A finer gradation in the technical background attribute of the participants could be used to adapt the module contents through explanation variants which could offer less experienced users more examples and more explanations or alternatively could offer more experienced users more challenging discussions of the underlying technologies. Participants could rate their own level of technical background in terms of novice, intermediate, or advanced levels, which could establish the starting values in the user model. The user model could then be updated as the user's level of understanding increased, either through the adaptive system detecting an improvement and updating the user model accordingly or through explicit modification by the user.

Another dimension that could be improved to better meet the requirements and expectations of the users is the number and type of topics covered in the online learning module content. In the prototype modules, each participant was assigned a learning module based solely on whether the person was currently involved in a technology development career or not. As seen from the comments of such participants as the first Web User Participant mentioned previously, technical topics may hold interest for non-technical Web users as well as for software engineers and others in technology-oriented careers. One possible approach would be to offer individual topics as modular components, so that each user could choose his/her own topics of interest and assemble his/her own customized learning module built from selected modular components. Combined with an enhanced user model that would take into account the level of technical understanding, learning modules could then provide content that would hold interest for each participant, with more detailed explanations or more depth and challenge to suit the level of background and understanding for each particular user.

Most Developed Intelligences.

The characterizations by three most developed intelligences were formulated based on the questionnaire results. One particular Web User Participant assessed his three most developed intelligences as: Musical, Linguistic, and Intrapersonal. For this participant, in the Learning Strengths questionnaire, there were several ties, with the resultant strengths for this Web User Participant listed as: Naturalist, Musical and Logical-Mathematical tied, and Intrapersonal, Spatial, and Bodily-Kinesthetic tied as well. This Web User Participant indicated that he had learning issues with Linguistic, Interpersonal, Spatial, and Logical-Mathematical Intelligences. Providing information through the MIDAS questionnaire, this Web User Participant scored Musical, Naturalist, and Linguistic as his most developed intelligences.

Determining the most developed intelligences to specify in the user model for this participant was difficult. Based on the scores on each of these questionnaires, Intrapersonal, Musical, Linguistic, and Naturalist Intelligences were chosen as this participant's most developed intelligences. However, the user model only uses three of his most developed intelligences: Intrapersonal, Musical, and Linguistic. The deciding factor was the first questionnaire, the participant's self-assessment, since Multiple Intelligence theorists contend that the individual should be the final authority over any instrument (Armstrong, 1993/1999). Given this participant's ratings for the Musical presentation of Topic 1 as most interesting, easiest, most amount learned, most liked, and his comment that he "very much enjoyed the first module," Musical Intelligence appears to be a good choice as one user model attribute. The choice of Musical Intelligence as one of his most developed intelligences is also supported by the fact that this particular participant is a drum teacher.

Furthermore, this participant consistently rated the Linguistic presentation of the third topic as his second choice and commented that he "liked the content of the 1st and 3rd section. It was useful info, practical, de-mystifying." He went on to say he "would have appreciated some metaphor in the descriptions." He then provided a detailed example, using his well-developed Naturalist Intelligence. In his example, he stated: "for example, my thoughts wandered at one point in the first section to how miraculously fast all that communication between ISPs and computers was. At first it impressed me as being like all the bodies of water on earth connected to each other and then I switched to thinking about how my nervous system can bounce information off my spine instead of routing all the way to the brain." In reading this example, filled with metaphors from nature, and knowing that this participant enjoys raising chickens at home, one questions whether it would have been better to include Naturalist Intelligence instead of Intrapersonal Intelligence in the user model as one of the three most developed intelligences for this participant.

Another participant, ST7, presented the same type of challenge in characterizing his most developed intelligences. According to his self assessment, he feels that five intelligences are equally well developed for him: Bodily-Kinesthetic, Linguistic, Musical, Interpersonal, and Naturalist. His learning strengths questionnaire results show Interpersonal, Bodily-Kinesthetic, and Naturalist as his most developed intelligences. He indicated some issues with his Naturalist, Logical-Mathematical, Linguistic, Musical, and Spatial Intelligences. Based on the questionnaire results, Participant ST7 has a user characterization in terms of his most developed intelligences of: Bodily-Kinesthetic, Interpersonal, and Naturalist. Based on the questionnaire data, the adaptive course path for Participant ST7 was: Interpersonal for the first topic, Bodily-Kinesthetic for the second topic, and a combined Naturalist and Logical-Mathematical presentation for the third topic. In the formative evaluation, Participant ST7 rated the Interpersonal presentation of section 1 as the section from which he learned the least and the approach he liked the least. The comment he made was consistent with these ratings when he stated: "the first module, I was not excited about the discussion group part." His suggestion was to "cut out the discussion part." It is clear from his comments that if presented with a choice of ways to learn, Participant ST7 would not elect to participate in a discussion forum. One wonders if it would have been better to include Musical or Linguistic Intelligence in his user characterization rather than Interpersonal Intelligence.

Given such feedback from participants, one improvement to the user characterization would be to make the user model adaptable, allowing each individual to examine and modify his/her own user attributes in the user model. Examination and modification by the user also supports the contention that individuals, rather than any instruments, are the final authority on which intelligences are most developed for each person (Armstrong, 1993/1999). In the Future Directions section, we will discuss other possible approaches for the prototype user model that would support adaptation according to the Theory of Multiple Intelligences without unduly restricting the content representations to only employ what are deemed to be a particular user's three most developed intelligences.

Adaptation Model

The adaptation model was designed to use the Entry Point Framework and multiple representations of the educational content. There are multiple representations of module content in each of the modules. For the Legacy Systems Integration learning module, there are two different representations of Section 1 Front-end Integration, with one representation using Intrapersonal Intelligence and the other using Interpersonal Intelligence. There are four representations of Section 2 Business Services Integration: one utilizing Bodily-Kinesthetic Intelligence, a second using Interpersonal Intelligence, the third using Linguistic Intelligence, and the final representation combining the use of Spatial and Musical Intelligences. There are two representations of Section 3 Back-end Integration: one activating Logical-Mathematical and Naturalist Intelligences and the other activating Bodily-Kinesthetic Intelligence.

For the Overview of Web and Internet Technology learning module, there is one representation of the first topic, Viewing a Web Page, combining Spatial and Musical Intelligences. In addition, there are two representations of the second topic on Online Shopping, with the first representation using Interpersonal Intelligence and the second representation combining the use of Intrapersonal and Bodily-Kinesthetic Intelligences. There are also two representations of the third topic on Locating Information, with one representation primarily utilizing Linguistic Intelligence and the other activating both Logical-Mathematical and Intrapersonal Intelligences. While there were multiple representations of the content, these representations were greatly simplified for the sake of prototyping each approach. The multiple representation approaches are illustrated through annotated screen shots of the actual pages in each learning module in the Prototype Development chapter.

We can consider the rating of sections or topics by participants, comparing the three representations that each participant accessed in his/her own view of the learning module. The rankings by participants indicate a mixture of values among the topics and representations, with rankings dependent on individual preferences rather than on group trends. We can consider user characterization by most developed intelligences to understand each individual user's feedback in light of his/her most developed intelligences. Let us examine these individual preferences with the accompanying narrative feedback to see what we can learn to improve the adaptation model and the use of multiple representations in the prototype.

When we consider the ranking of the representations, it is useful to keep in mind the participant's three most developed intelligences that these representations were designed to activate. For Participant ST1, the most developed intelligences are Intrapersonal, Logical-Mathematical, and Bodily-Kinesthetic. Participant ST1 is a technical trainer and an avid dancer, with a well-developed Bodily-Kinesthetic Intelligence. Participant ST1 rated Section 2 Business

Services Integration with Bodily-Kinesthetic Intelligence as the second most interesting and as the second hardest. However, Participant ST1 ranked section 2 as the part from which she learned the most and as the approach she liked the best. Her comments about the approach from which she felt she learned the most were as follows: “I liked the T/F (true/false) with feedback. Then I knew I understood the material. I liked the thought-provoking questions.” Her suggestion was to “make it all more like section 2. Even on essay answers, provide a sample answer.” Participant ST1’s answer to the last question in the feedback questionnaire amplifies her suggestion by stating that she found it frustrating when there was “no testing of what I (she) read” in section 3.

In their comments, other participants echoed the suggestion for more interaction and feedback in the content representations. Participant ST7 with Bodily-Kinesthetic Intelligence determined to be one of his most developed intelligences, commented as follows: “the first module, I was not excited about the discussion group part. That may be because I was more focused on completing the feedback sections.” Considering the user model, we see that Participant ST10 also has Bodily-Kinesthetic Intelligence listed as one of his most developed intelligences. His comment was that “the Macromedia demonstration was excellent! … maybe make the demonstration more interactive with more options or scenarios.”

Participant ST3 specifically mentioned liking the interactive nature of the learning module. Participants ST13 and ST16, however, felt the module needed more interaction and suggested that the module provide “feedback on the effectiveness of the subject learned – online testing” (ST13) and “include some online testing” (ST16). Participants SU8 and SU11 expressed their disappointment through SU8’s comment that she “had assumed it might be more interactive” and SU11’s comment that he had “expected to be asked to recall the new vocabulary words and I (he) felt a little disappointed at not being tested” (SU11). As Participant ST1 suggested, including more interactive “hands-on” exercises, feedback, and online assessment would improve the adaptive representations, particularly to meet the needs of users with well developed Bodily-Kinesthetic Intelligence.

In the user characterization, we found that all of the Web User Participants had either Musical or Spatial Intelligence (or both) listed in their three most developed intelligences. The first topic on retrieving a Web page was therefore presented through an animated graphical presentation with sound effects. In the formative evaluation, Participant SU14 indicated that the learning module was “not quite reading, not quite a game, but like going to a science museum where the learning is more subtle and engaging.” SU14 then suggested adding “some of the sounds from the first exercise” to the second and third topics. Participant SU11 agreed about the use of sound effects and said he “was eager to see how the little dot would go and I (he) liked the beeping sounds that measure its progress. In terms of grasping the info, this representation was the most clear." Participant ST6 summed up the opinion expressed by other participants that there should be "more pictures, less reading, more animation and more sound."

However, in other formative evaluation data, we note that two Technical Participants (who may have had higher bandwidth connections than the Web User Participants) felt the animations should be slowed down. Participant ST17 stated that "part 2 was difficult because the information was presented extremely quickly." He continued with the comment that he "was also annoyed that the flash animations were very fast-paced, and although the replay option was present, I (he) don't (didn't) think it would be very helpful." Participant ST2 stated that "the animations moved so fast on my (her) computer that I (she) had to reply them several times to read all the text." She suggested that it "might be good to have a 'pause' button or 'click' to continue feature." Participant ST15, who because of his "work in the computer security industry" was "concerned about content that might contain trojans," suggested using other technology for the graphical presentations, such as "JPEGs, MPEGs, and GIFs" instead of Flash animations so that he could "actually see them."

In suggesting another improvement to the module, Participant SU11 commented: "I would have appreciated some metaphor in the descriptions." The representations did not make use of metaphors in the descriptions, and this would be a good improvement to utilize Naturalist Intelligence, which was well developed in some of the participants, such as Participant SU11. The only use of the Naturalist Intelligence in the prototype learning modules was to categorize different concepts, in conjunction with the Logical-Mathematical Intelligence, as presented in the Legacy Systems Integration learning module for section 3. Better use of the Naturalist Intelligence through the development of metaphors in the explanations would not only improve the module content for Participant SU11 but would also be useful for other participants.

The prototype learning modules make use of the Entry Point Framework approach for adaptation, but only on a very basic level. According to Gardner (1999), The Entry Point Framework offers seven different points of entry into any topic: Narrative, Numerical, Logical, Existential/Foundational, Aesthetic, "Hands-on" and Interpersonal. However, only some aspects of the Narrative, Numerical, Logical, "Hands-On," and Interpersonal Entry Points were used through the explanation variants of the content. The adaptation in the prototype could be significantly enhanced through developing materials that would fully engage users through these integrated multi-intelligent entry points. This suggestion is discussed further in the Future Directions section.

<u>Domain Model</u>

The requirements on the domain model were stated in terms of understanding goals using the Teaching for Understanding (TfU) Framework (Perkins, 1998). While the TfU Framework was used to develop the intended learning outcomes and plan the storyboards for the modules, the modules were simplified for the sake of the prototype and did not allow throughlines or generative topics to be explored in the depth necessary to completely achieve the understanding goals. Let us examine the understanding goals set for each learning module.

Legacy Systems Integration Learning Module.

The understanding goals that were established for the Legacy Systems Integration learning module (i.e. what students will come to understand during the module) are listed below:

1) The value and feasibility of integrating legacy systems with the Web rather than merely replacing the older applications with completely new ones.
2) How to integrate older applications through a Web form and a CGI script.
3) How to integrate older applications with the Web through CORBA (Common Object Request Broker Architecture).
4) How to integrate older applications with the Web through RPCs (Remote Procedure Calls).
5) How to integrate older applications with the Web at the back-end with database management systems.

Viewing the screen shots of the learning module content, we see that section 1 addressed goal #2, section 2 addressed goals #3 and #4, section 3 addressed goal #5, and the three sections together addressed goal #1. Let us consider participant feedback to understand how to improve the modules in terms of reaching these understanding goals, using the throughlines and the generative topics. According to Participant ST6's comment during the formative eavaluation, the Legacy Systems Integration learning module gave her "some insight into the approaches to integrating legacy systems with Web based applications." She suggested that "clarification of some of the terms would have been helpful" in order to achieve goal #1.

Participant ST1 echoed the sentiment that it is important to define terms in her reaction to what she found frustrating about using the online learning module, when she stated that "Part 3 was AWFUL…Too many acronyms I was unfamiliar with… The information was too condensed." Participant ST17 agreed that there was too much jargon in section 3 of the module, stating that "part 3 could have gone more in depth, possibly using more examples and less 'techie jargon.'" All of these participants, ST1, ST6, and ST17 were presented with the Logical-Mathematical presentation for Section 3 Back-end Integration and all three rated the third section as the section from which they learned the least, indicating difficulty in achieving goal #5.

Throughlines are meant to carry all the way through the content, tying concepts together to help learners achieve their understanding goals. However, we can see from some of the participants' comments in the formative evaluation that the modules need more overview information and ways to tie the concepts together to help learners understand. While we see that Participant ST14 felt the Legacy Systems Integration learning module was "very straightforward (and) flowed well," we also see his suggestion that the module provide "more general overview on the integration problem (with) more use cases of the different types of integration." He added “module 1 and 3 at least touched upon use cases, module 2 was purely on technology,” making it difficult to achieve goals #3 and #4. Participant ST2 rated the module moderately difficult and stated that “each module could have one more layer of detail for those of us unfamiliar with the material and an online glossary.” Another participant (ST12) found the content very easy, but indicated that “an example tying all three parts together would have been helpful and interesting.” Again, we see a recommendation for more examples in Participant ST12’s remark that “theory is good, but I need implementation examples to really understand,“ and thereby achieve goal #1.

As we also see in the feedback questionnaire data, Participant ST5 stated that he’d “find it easier to understand with more examples, and more detailed examples.” In his comments, Participant ST5 went on to offer a concrete approach to follow throughlines using illustrative business problems as follows: “For each point – for each leaf in the instructional tree – you could have a clear business problem, like the vacation example. For each example you could have before and after information, giving the list of processes, where each one runs, and what all the communication looks like.” Thus, Participant ST5 felt the vacation example helped him achieve goal #2, and other such clear business problems could help him achieve other understanding goals as well.

When asked what he liked about using the online learning module, Participant ST9 stated that the module was “almost idiot proof. Almost!” Participant ST9 offers a “point to ponder” when he states that there were “not enough upfront instructions to get an easy start. Of course, I (he) was in a rush, but in real life others might be in a rush as well.” In his feedback questionnaire, Participant ST11 expressed his feeling that “at some points, the directions were not clear.” However, Participant ST11 went on to state that “overall, I (he) found the modules easy to navigate.” Expressing a similar concern, Participant ST13 stated in his feedback questionnaire, that he “was not sure about the context initially.” As Participant ST9 states, in real life, users of the system may very well be in a rush and it would help to provide upfront instructions and use throughlines to tie concepts together and provide an overview of the material. We can see that in order for learners to achieve the desired understanding goals, the learning modules need to define terms, avoid using technical jargon, and provide examples to illustrate concepts.

Overview of Web and Internet Technology Module.

The understanding goals for the Overview of Web and Internet Technology learning module (that is, what students will come to understand during this module) were:

1) How information travels through the Internet when a Web page is requested.
2) How search facilities work.
3) How online shopping is performed with SSL (Secure Sockets Layer) on the Web.

We can see in the screenshots of the learning module pages that each of these understanding goals was addressed through a separate topic. Topic 1 addressed goal #1, while Topic 2 addressed goal #3, and Topic 3 addressed goal #2. Now let us consider feedback from the Web User Participants to determine how the Overview of Web and Internet Technology learning module can be improved so that learners can achieve these understanding goals. Participant SU12 suggested making the throughlines explicit in her feedback questionnaire. Her recommendation was that the module “have a clearer explanation of what I (she) am (is) going to be getting and a brief statement of the purpose of each module (i.e. learning objectives for the module or something like throughlines that are stated for the learner).” Although the Legacy Systems Integration learning module was designed as three related sections, moving from front-end to back-end in integrating with Web technology, the Overview of Web and Internet Technology learning module was designed as three distinct topics. Participant SU12 thought this design was not a good way to achieve desired understanding goals, stating in her feedback questionnaire that she thought “it was a bit frustrating not to have an overview of what the intent of the three activities were. In other words, I (she) expected the content to be progressive and connected in some way to each other, and they weren’t.” However, in her feedback questionnaire, Participant SU16 stated that she “really liked how thoughtful it was – it was clear that the researcher had thought of each step of the reasoning project and anticipated each step of the interaction. Unlike most online questionnaires and interactive Web pages, I (she) did not feel ‘trapped’ in a feedback loop.” Nevertherless, Participant ST16 added that “a bit more introductory text would be useful – something scannable rather than packed with details.” An overview would thus help achieve the understanding goals.

While Participant SU4 rated the module content easy, Participant SU4 stated she “found some of the information on viewing a Web page interesting because I (she) didn’t know it.” Participant SU2 stated she “was also happy to learn new facts about a system I (she) use(s) daily but really only barely understand.” Participant SU8 felt the first topic was “sort of how I (she) imagined it but nice to see a working demonstration.” All three participants rated topic #1 as the one from which they learned the most, helping them achieve goal #1.

Though participants rated the Logical-Mathematical and Intrapersonal presentation of Locating Information second out of five in terms of how much they learned from the presentation, they rated this particular topic as the approach they liked the least. Participant SU4 “liked the detail of locating information on the Web (even though I (she) knew a lot of it).” However, Participant SU2 mentioned that “the section about locating information on the Web was a bit dry” and said she’d “prefer to learn about this in another format, for example, like either of the first two sections.” While goal #2 was met to some extent, the presentation can be improved.

According to the overall rating for both presentations of the Online Shopping topic, participants felt they learned the least from this particular topic. Participant SU10 stated that she “enjoyed reading the anwers to the online shopping questions” even though she “was not comfortable answering them” herself. According to his feedback, Participant SU1 found that “multiple posting on the ‘online shopping’ segment made it hard to know what the learning objective was, what I was supposed to be learning, and whether I had 'completed' the module, sent all the required replies, etc." Participant SU1's comments can be viewed as a recommendation for an explicit rather than an implicit exposition of goal #3.

According to feedback questionnaire data, the Intrapersonal and Bodily-Kinesthetic presentation of the Online Shopping topic was by far the least interesting of any of the presentations of the three topics. Half the participants used this presentation; of the eight participants who used the Intrapersonal and Bodily-Kinesthetic presentation of Online Shopping, all but one rated this presentation the least interesting topic. The Intrapersonal and Bodily-Kinesthetic approach to the topic was also considered to be the one participants liked the least though the Interpersonal Intelligence approach to Online Shopping was rated the second highest of the five approaches to topics in the feedback questionnaires. These ratings are consistent with the narrative feedback on what was frustrating gathered from the last question on the feedback questionnaires, in which Participant SU16 stated "I feel I missed the second module entirely and when I gave my answer, the feedback made no sense. Was there text somewhere or just a question? There is a strong chance that I was rushing too quickly through this and missed the directions." Participant SU16 also "wasn't sure what the purpose of the second activity about credit card security was." She went on to say "I didn't feel like I learned much, except perhaps gained an awareness that my credit card information isn't really safe any time I give it out. But I wanted to know more about how I can make sure my information is safe when giving it out for online shopping." Clearly, the Online Shopping topic needs to be improved to meet goal #3.

These comments suggest that the TfU Framework helped the researcher develop content and presentations, but the use of the TfU Framework for the domain model and the subject matter covered in the domain should be significantly expanded in order to achieve the stated understanding goals.

Web-based Online Adaptive Learning Environment

The basic requirement on the online adaptive learning environment was the need to support participant use of the multi-intelligent adaptive learning modules. System requirements were determined in terms of time-and-location-independent availability. In other words, the adaptive hypermedia learning framework had to be available to users on a 7 X 24 basis (seven days/week, twenty-four hours/day), and all components of the system had to be available via the Web on the public Internet. Looking at the data collected during the formative evaluation, we find that users were able to access the system from various parts of the United States and Canada, thus demonstrating that the system was distance- or location-independent. Since the framework provided access to the learning modules through the World Wide Web, participants could be located anywhere as long as they had access to the Internet.

The learning framework provided access to the prototype any time of the day and any day of the week. During the formative evaluation, we tracked the date and time that each participant's feedback questionnaire was submitted. The times listed are the participant's local time though the time given on the automated submission of the feedback questionnaire was Pacific Daylight Time (local time on the researcher's server). Inspecting the data, we find that Participant ST10 and Participant ST17 used the framework on the weekend (actually over the Labor Day holiday weekend). The data indicate that the rest of the participants used the framework on weekdays. The framework was used each of the seven days in the week as seen from the data collected during the formative evaluation.

We also find that the time varied throughout the day, from 8:05 AM PDT (Participant SU9) until late at night, with the latest participant logging on at 12:32 AM MST (Participant ST8; note: Arizona does not move to Daylight Savings Time). Another type of flexibility offered by the prototype Web-based framework was to allow users to visit module sections in any order, to revisit sections, or to use learning modules over multiple sessions. During the formative evaluation, we found that 12 of the 33 participants revisited sections and that five of the 33 participants used the learning modules over more than one session.

The online adaptive learning framework was required to determine which module would be presented to the user based on his/her technical background. Then, the framework was required to use the participant's attributes in the user model, including his/her three most developed faculties, in order to present the contents of the learning module in three different ways, as specified in the adaptation model. Based on the prototype design, a participant's user attributes were used to present different versions of each section or topic in the appropriate learning module, in whatever order the participant decided to access the sections or topics.

One improvement to the framework that would be helpful to the researcher would be to collect more usage data. The Course Tracker recorded when users accessed each page, but there is no way of knowing if the user was actively involved in reading or using the page. Participants could have the page up and at the same time, be responding to email or involved in some other task on their machines. This may explain the differences between the amount of time reported by participants for their usage of the module and the amount of time actually recorded by the Course Tracker. It may be useful to include some type of interaction at regular intervals and record periods of inactivity in which there are no keystrokes.

Another system-level requirement was that, as much as possible, the prototype should be constructed using public domain software tools and components. We can see the use of public domain software tools used to implement each of the components of the prototype system. An important requirement in terms of use by members of a diverse participant group was that all prototype system functionality be available online via standard Web browsers. We can see from the list of tools that the online questionnaires and learning modules were made available through standard Web technology and tools, including HTML, CGI Perl scripts, and email. The educational hypermedia application resided on a standard Linux server running an Apache public domain Web server and a MySQL database server. In addition, the Web page variants were implemented with PHP, a public domain server-side cross-platform HTML preprocessor, providing embedded scripting language facilities. The discussion forum was supported by a public domain discussion forum software tool called Phorum.

Contribution of Work

The research study and prototype adaptive learning framework and learning modules contribute to the field of online learning by:

- Demonstrating the feasibility of building an online learning environment on a foundation that integrates cognition and learning theory and educational methodologies with adaptive hypermedia and asynchronous Web technologies.
- Applying the cognitive Theory of Multiple Intelligences to the development of a prototype adaptive hypermedia learning framework and learning modules.
- Exploring in an online learning setting the application of educational methodologies with demonstrable success in classroom settings, including the Teaching for Understanding Framework, the Entry Point Framework, and multiple representations.
- Developing a prototype "anyone, anyhow, anywhere, anytime" approach to online learning, thereby laying the groundwork for a system that eliminates constraints due to variations in the development level of different intelligences among users, variations in learning approaches, distance, and time.

The research study and prototype development form the first step in making such contributions by offering a new approach to online learning, with a user model based on the technical background and three most developed intelligences of the learner. Moreover, the prototype Web-based Multi-Intelligent Adaptive Learning Framework provides a scaffolding within which additional prototypes of multi-intelligent adaptive hypermedia learning modules can be designed and formatively evaluated.

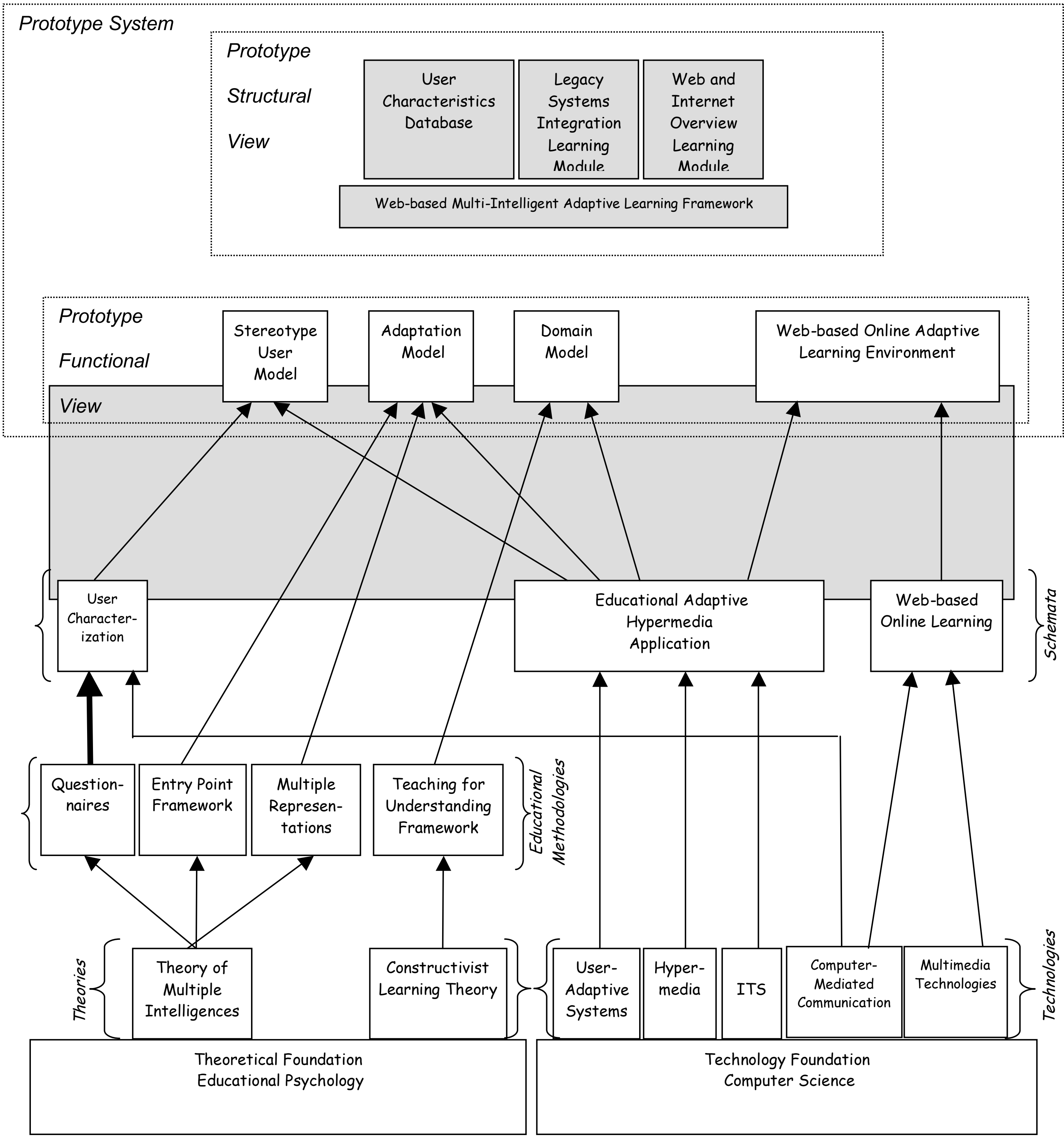
The major contribution of the research lies in its demonstration of the feasibility of integrating the Theory of Multiple Intelligences and the educational methodologies of the Entry Point Framework, multiple representations, and the Teaching for Understanding Framework with adaptive hypermedia and Web-based online learning technologies. Figure 2 depicts the contributions of the research. The shaded box around the arrows illustrates the integration of cognitive psychology theory and educational methodologies instantiated in the prototype.

An ancillary contribution of the research arises from the development and use of a Web-based framework through which the entire study was conducted online. Figure 2 indicates the contribution made by the online study with the bold arrow leading from the "Questionnaires" box to the "User Characterization." The study demonstrates the viability of using a Web-based framework to conduct research studies with both technical and non-technical participants.

As indicated by the shaded arrows, the major contribution of the work derives from the integration of the components underlying the development of the prototype. These components include the Theory of Multiple Intelligences as the theoretical framework, the Entry Point Framework, multiple representations, and the Teaching for Understanding Framework as the educational methodologies, and an educational adaptive hypermedia application and asynchronous Web technology as the schemata. Integrating theory, methodologies, and schemata from the fields of Educational Psychology and Computer Science, the prototype paves the way for further application of cognition and learning theory and educational methodologies to the development of online learning environments.

Planning the learning modules through the Teaching for Understanding (TfU) Framework demonstrates the applicability of the TfU Framework to online learning and provides an example to follow for other online learning content. Using the TfU Framework to design the domain model shows the feasibility of using this curriculum planning tool for online learning as it has been used successfully for classroom-based curriculum. The TfU Framework follows a constructivist learning approach, encouraging learners to develop their own understanding (Perkins, 1998). While the prototype serves a starting point for the use of the TfU Framework in planning online learning modules, the module contents are too limited to make full use of the generative topics and throughlines established in the TfU Framework. Further application of the TfU Framework could lead to supporting truly constructivist approaches to online learning.

Figure 2 Contributions of Research



Demonstrating the feasibility of using the Theory of Multiple Intelligences to support adaptation in an online learning environment leads to the possibility that future online learning systems can be built to take into account differences among individuals in their thinking and learning. As Howard Gardner states in his paper, *Reflections on Multiple Intelligences*, “one of the reasons that MI theory has attracted attention in the educational community is because of its ringing endorsement of an ensemble of propositions: we are not all the same; we do not all have the same kinds of minds; education works most effectively for most individuals if these differences in mentation and strengths are taken into account rather than denied or ignored” (Gardner, 1995, p. 208). Gardner encourages the personalization of education in classroom environments; the prototype demonstrates the feasibility of extending such personalization to online learning environments.

Judah Schwartz, Professor of Education and Co-Director of the Educational Technology Center at the Harvard Graduate School of Education, indicates that:

“Whoever the audience, we can think about choosing content in the following way:

old content using old approaches
new content using old approaches
old content using new approaches
new content using new approaches” (Schwartz, n.d., p.1).

Schwartz contends that much of educational software uses old approaches to old content, with the computer merely substituting for the classroom teacher. Developing content adaptation methods based on the Entry Point Framework and multiple representations demonstrates the feasibility of employing appropriate educational methodologies in order to design and develop old content using new approaches. As Schwartz suggests, many people “confuse the use of new media with new pedagogical approaches” (Schwartz, n.d., p.2). The pedagogical approaches of the Entry Point Framework and multiple representations are currently being introduced successfully in classroom environments (Gardner, 1999). As the prototype demonstrates, they can also be introduced into online learning environments in order to offer old content using new approaches.

Authoring online learning content through multiple representations presses the developer of online learning content to rethink and reformulate his/her own understanding of what he/she is teaching, particularly when a particular representation uses an intelligence that is not as well developed in the module developer. As Schwartz states, “dealing with old material in new ways will press teachers to rethink and reformulate their own understanding of what they are teaching” (Schwartz, n.d., p.2).

The prototype also serves as a starting point in extending “anywhere, anytime” distance-and-time-independent online learning to “anyone, anyhow” learning. Characterizing users in terms of their most developed intelligences allows the user model to differentiate among learners and to personalize their education, as Gardner suggested (Gardner, 1995). Using multiple entry points and multiple representations (Gardner, 1999) as the basis for the adaptation model serves as a starting point to developing "anyhow" learning. Employing explanation variants to present and explain content via multiple educational approaches (Brusilovsky, 1998), the prototype demonstrates the feasibility of implementing multiple representations of educational content.

Thus, the contribution of the research can be seen as the result of integrating cognition and learning theory and educational methodologies from the field of Educational Psychology with adaptive hypermedia and asynchronous Web technology from the field of Computer Science.

Limitations and Difficulties

Developing the prototype multi-intelligent adaptive hypermedia learning modules demonstrates that it is indeed do-able to design and implement multi-intelligent adaptive hypermedia learning modules, adapting content using multiple representations. However, authoring adaptive hypermedia learning modules through multiple representations that make use of various intelligences is an intensive and time-consuming task. Developing each representation involves a great deal of time and attention to design appropriate learning approaches that make use of various intelligences and can be implemented using available technology.

The learning modules that were developed for the prototype are in reality mini or even micro-modules, restricting the content to a small subset of course material in order to develop a proof-of-concept prototype and conduct a formative evaluation to determine ways to improve the prototype. An online educator would want to present far more complex and extensive course materials in a production online learning system. However, the time to craft each segment of content in well-designed multi-intelligent representations may be too extensive for large-scale implementation of "anyhow learning" via adaptive hypermedia multiple representations if each representation needs to be handcrafted, as in the prototype representations.

In addition, the learning approaches used in the mini-modules are greatly simplified compared to the sophisticated types of truly multi-intelligent approaches that a real curriculum designer would want to develop. Weaving in the use of multiple intelligences in ways that an experienced multiple intelligence classroom teacher would be able to, would require a significant expenditure of time and resources to make each content adaptation truly multi-intelligent in its learning approach. One way to address this limitation would be to reduce the number of representations, investing time in developing fewer representations, each of which makes full use of several intelligences.

Another difficulty with the prototype approach stems from the fact that the learning module development process, or authoring task, requires knowledge of three distinct areas:

- The subject matter that is being taught
- Learning approaches in multi-intelligent curriculum design
- Technology facilities to implement multi-intelligent explanation variants.

In order to develop truly multi-intelligent adaptive hypermedia learning modules, the module author must then serve in multiple roles, as a combination of subject matter expert and teacher, curriculum designer, and technology developer. Providing authoring tools and support to accomplish this task would assist a larger number of people in authoring their online learning modules in ways that use multiple intelligences. Another way to address this difficulty would be to form a team, in which a subject matter expert is supported by a curriculum designer who understands how to convey course materials using a combination of intelligences. The curriculum developer, in turn, would be supported by a technology developer with the technical expertise to implement multiple representations of the content using the multi-intelligent approaches specified by the curriculum developer.

Developing curriculum using intelligences that are not as well developed in the course developer could present a significant challenge to course developers. The team approach can also be helpful in addressing the difficulty a course developer may encounter in developing representations of the content that use some of his/her own less developed intelligences.

A further limitation of the prototype approach arises from adapting content according to a user model that is dependent on determining the three most developed intelligences of each user. According to the Theory of Multiple Intelligences, an individual, rather than an instrument, is considered to be the authority in determining his/her most developed intelligences (Armstrong, 1993/1999). Based on participant feedback, it might be more useful to focus on developing truly multi-intelligent curriculum, offering multi-intelligent approaches to the entire user population rather than attempting to refine the determination of the most developed intelligences of users.

Based on constructivist learning theory, the throughlines, generative topics, and understanding goals developed using the Teaching for Understanding Framework aim at developing content that helps each learner develop his/her own understanding of the subject matter. The starting point in teaching for understanding is to develop generative topics. Generative topics are defined as those that are central to a discipline, accessible to a variety of students, interesting to the teacher, and connected to other topics both within and outside the particular discipline (Perkins & Blythe, 1994). While generative topics tend to be broad in scope, the topics for the prototoype learning modules were necessarily limited in scope.

Understanding performances are critical for students to connect their understanding to the achievement of the original understanding goals. These performances also encourage students to engage in and reflect on challenging tasks while demonstrating their understanding (Perkins & Unger, 1999). While the prototype learning modules provide limited reflection in answer to questions that employ Intrapersonal Intelligence, there is no support for performances of understanding. The development of methods to support performances of understanding in an online learning environment would be an appropriate subject for further research.

Another component of the Teaching for Understanding Framework is the practice of ongoing assessment. Ongoing assessment is helpful in monitoring individual and group progress toward the achievement of understanding goals (Perkins & Unger, 1999). Ongoing assessment is not supported in the prototype, and would also provide the basis for useful research in the future.

While all but one of the thirty-four research study participants completed the study, the one remaining participant encountered serious problems with his computer at the time that the learning modules were ready for use. This participant was therefore unable to complete the formative evaluation during the time period of the study. The Web-based framework successfully supported a variety of users, logging on from different locations at different times, using different Web browsers, different platforms, and different Internet Service Providers (ISPs). Thus, the Web-based multi-intelligent adaptive learning framework supported “anytime, anywhere” learning.

However, as the one exception demonstrates, a limitation of any online learning system is that users must have access to a working computer with an Internet connection. Even if the system is designed, as the prototype system was, to work on the lowest common denominator system, there still are many people who do not have access to a computer or an Internet connection. While efforts are underway to address the “Digital Divide” by providing online access through community resources, this is a limitation that needs to be addressed if we, as a society, wish to move toward “anyone learning” (Young, 2001).

Future Directions

The research study raises a number of interesting questions that can be pursued through further research. The work accomplished so far is merely a starting point, indicating that the Theory of Multiple Intelligences can indeed be used to support adaptation in an online learning environment. While the implementation and formative evaluation of the prototype offer insight into possible ways in which the Theory of Multiple Intelligences can be used to support adaptation, further research should be undertaken to systematically explore and test ways that the theory can be used to support adaptation. While the current study addresses the research question of *whether* the Theory of Multiple Intelligences can be used to support adaptation in an online learning environment, subsequent studies should be undertaken to determine *how* the Theory of Multiple Intelligences can best be utilized to support adaptation.

Let us consider the three parts to the research study and examine the ways in which future research could move forward from these starting points. In the first part of the study, an online focus group was conducted to collect data on the technical background and three most developed intelligences of each participant. Further work could be done to determine how best to characterize individuals in the user population. There are a number of questions that could be addressed in terms of the best way to characterize individuals to provide input for the user model.

The clinically-developed MIDAS instrument (Multiple Intelligences Development Assessment Scales) (Shearer, 1996) could be fully utilized if an agreement were reached with the developer to provide the questionnaire online and if the scoring software were upgraded from its current DOS-based implementation to work with a Web-based implementation of the instrument. The MIDAS instrument has been clinically developed in order to offer a standardized approach similar to that used in an inventory of learning styles and may be able to provide useful data to characterize users in terms of their most developed intelligences. However, researchers in the Theory of Multiple Intelligences believe that the individual, rather than any instrument, should be the final authority on how well developed his/her intelligences are (Armstrong, 1993/1999). Therefore, a fruitful direction to pursue may be to focus on how best to collect direct user input and feedback and characterize users based on their input and feedback.

As we saw in the User Model section with Participant ST7 and Participant SU11, the user characterization determined for each individual may not be the best fit for the individual. Creating a feedback loop in the design by allowing participants to examine and modify the contents of the user model may be a useful direction to pursue in future work, perhaps coupling the MIDAS questionnaire with user feedback on the results. It would be useful to examine the impact of making the system adaptable, that is, allowing users to explicitly set preferences for the user model as well as diagnose their own progress and modify the user model as needed (De Bra, 1998; Streitz, 1988).

Moving from the user model to the adaptation model, further research could address how best to employ the user characterization in terms of adapting module content to help different users learn. Future studies should systematically focus on refining the development of learning approaches using multiple representations and testing various multi-intelligent options. An important question to raise in future research would be to test the correspondence between the development of a particular intelligence and a preference for a particular adaptive presentation of learning content. Such a study would allow the testing of the underlying assumptions that were made in this study in the presentation of content in a particular way, with the content presentation directed toward the activation of a particular intelligence.

Another direction to pursue was suggested by a participant in his feedback questionnaire. In his feedback questionnaire, the participant suggested that "perhaps the ability to choose which form to learn the material in would be a cool option." Developing a prototype in which each learner can choose any explanation variant to use and using tracking software, such as the Course Tracker to record the chosen path through the modules, may provide insight into the relationship between a learner's most developed intelligences and his/her choice of learning approaches.

Another possible direction would be to explore the use of presentations that are based on the use of a participant's less developed intellectual faculties. A comparison between presentations using the most developed and the least developed might provide useful information in determining how best to present information to users. In addition, it may be useful to couple more highly developed and less highly developed intelligences and explore what impact such couplings would have on an individual's learning experience. A research study could be conducted to examine how online learning modules could use more of an individual's intelligences and the impact of such a multi-intelligent approach on the learning process.

The Entry Point Framework was used only on a very basic level as discussed earlier in this paper in the section on the adaptation model. Further research could explore different ways that the entry points used in some classroom settings can be utilized in online adaptive presentations. Adaptive presentations could also make use of analogies and metaphors as suggested by Howard Gardner in multiple intelligence classroom teaching (Gardner, 1999). As we saw in the section on the adaptation model, Participant SU11 also suggested using metaphors in content presentations. Research investigating how analogies and metaphors can be used in online learning might prove beneficial, particularly in reaching learners with a well-developed Naturalist Intelligence.

Considering the domain model, future research could examine how best to use the Teaching for Understanding Framework in developing and using throughlines, generative topics, and understanding goals. An exploration of how to use constructivist approaches in online learning could be based on further use of the Teaching for Understanding Framework and a formative evaluation of a prototype designed using constructivist approaches to teaching and learning. Performances of Understanding and Ongoing Assessment, other aspects of the Teaching for Understanding Framework that were not included in this prototype, would be useful to study, prototype, and formatively evaluate in order to examine whether and how these features can be utilized in online learning environments. A related research question to address would be to examine the type of assessment that might be beneficial in online learning settings.

In this study, the researcher served in multiple roles: as course designer and author, instructor, developer, and researcher. For others to build on this research, support for the authoring process would be helpful. One direction further research might follow would be to explore support for authoring adaptive presentation course materials and software tools that could be made available to other instructors who would like to design and author multi-intelligent adaptive hypermedia learning modules. What type of authoring environment would help in the development of multi-intelligent online learning content? How can the tools be used to support development of multi-intelligent explanation variants utilizing intelligences that are less developed in the course developer him/herself?

Further research could be conducted to measure the effectiveness of learning online using adaptive presentations. Effectiveness of learning could be measured for:

- Representations that activate the user's most developed intelligences
- Representations that activate the user's least developed intelligences
- Representations coupling the user's most and least developed intelligences

- Representations combining various intelligences with user selection.

An important consideration in online learning is to determine appropriate topics to teach through online learning approaches. Research could be done with varying the type of subject matter to determine how to deliver different types of content in a multi-intelligent adaptive hypermedia online learning format. In addition, a research question that could be pursued would be to examine which types of subject matter are suitable for such an online learning approach. Are there specific approaches that work better with certain types of subject matter? Are there certain characteristics of the subject matter being taught that can be used as indicators for which areas will translate well into a multi-intelligent adaptive hypermedia online learning format?

If we expand the field of investigation and move from the area of online learning to the general question of how users interface with online information, research could be conducted to determine whether and how the Theory of Multiple Intelligences could be used to support adaptive user interfaces. Perhaps, the Theory of Multiple Intelligences can be applied in a manner that improves user interfaces in general, rather than just classroom or online learning.

Implications for Online Learning

Developing the prototype multi-intelligent adaptive learning framework and modules yields an affirmative answer to the research question, which then signifies that the Theory of Multiple Intelligences can indeed be used to support adaptation in an online learning environment. Using cognition and learning theory, and specifically the Theory of Multiple Intelligences to inform the adaptive hypermedia design of the online learning system has important implications for online learning.

The affirmative answer to the research question and the instantiation of theory and methodology from Educational Psychology in the prototype framework and learning modules demonstrate the benefit of building an online learning environment on a foundation that integrates cognitive theory, educational practice, and technology. According to Judah Schwartz, "judiciously chosen traditional content, implemented in thoughtful and engaging new ways that both promote and scaffold new learning and teaching approaches, is the key to bringing the new technology, and in the end new content as well, into the lives of our students and teachers in a serious way" (Schwartz, n.d., p. 2).

Developing multiple representations using adaptive hypermedia content adaptation methods informed by the Theory of Multiple Intelligences, allows traditional content to be implemented in "thoughtful and engaging new ways." With a multi-intelligent adaptive hypermedia framework, such as the prototype framework, the scaffolding is provided for new learning and teaching approaches. Basing the curriculum design on the educational methodologies of the Teaching for Understanding Framework, the Entry Point Framework, and multiple representations, users of online learning systems can benefit from new learning and teaching approaches that are already being used successfully in classroom settings (Gardner, 1999;

Perkins, 1998). The hope then is that new content will also be developed using new approaches, benefiting from the reformulation necessary to build multi-intelligent learning modules.

Toward Anyone, Anyhow, Anywhere, Anytime Learning

While current online learning systems provide “anywhere, anytime” learning, the prototype developed for this research study aims at extending this concept to “anyone, anyhow” learning. The development of the prototype multi-intelligent adaptive learning framework and learning modules demonstrates the feasibility of adapting online learning content based on a user model representing individual variations in most developed intelligences. Yielding an affirmative answer to the research question “Can the Theory of Multiple Intelligences be used to support adaptation in an online learning environment?” the actualization of the prototype user model indicates a possible direction through which “anyone learning” may be developed. The implementation of explanation variants presenting multiple representations of learning module content using multiple intelligences points in a potential direction through which to address the implementation of “anyhow learning.” However, as one participant remarked, the prototype learning modules “are just a taste of what’s possible.” As demonstrated by the formative evaluation, the Theory of Multiple Intelligences provides the basis for a promising approach to online learning. Significant progress toward true “anyone, anyhow, anywhere, anytime” learning may be achieved by integrating theory, methodology, and technology through further application of the Theory of Multiple Intelligences, the Teaching for Understanding Framework, the Entry Point Framework, multiple representations, adaptive hypermedia, and Web technology.

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