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ABSTRACT

This study examined the effects of a prototype of motivationally-adaptive CAI (Computer Assisted Instruction), developed in accordance with the ARCS (Attention, Relevance, Confidence, Satisfaction) model of motivational design, on achievement, perceived motivation (both overall motivation and for each of the ARCS components), efficiency, and continuing motivation. Subjects were 66 tenth grade students. Students used one of three versions of CAI presenting material on genetics--motivationally-adaptive CAI, motivationally-saturated CAI, or motivationally-minimized CAI. Motivationally-adaptive CAI showed higher effectiveness, overall motivation, and attention than the other two CAIs. For relevance, motivationally-adaptive CAI was higher than motivationally-saturated CAI, but not higher than motivationally-minimized CAI. For confidence and satisfaction, motivationally-adaptive CAI was not higher than the other two CAIs. For efficiency, both motivationally-adaptive CAI and motivationally-minimized CAI were higher than motivationally-saturated CAI, but only the efficiency of the motivationally-adaptive CAI was identified as having practical importance. For continuing motivation, there were no significant differences among the three CAIs, but a significant correlation was found between overall motivation and continuing motivation across three CAIs. These findings support the contention that the ARCS model is useful for developing motivationally-adaptive CAI. Motivationally-adaptive CAI can be an effective, efficient, and motivating form of instruction that may also enhance learners' continuing motivation. (Contains 51 references.) (Author/MES)

THE ARCS MODEL FOR DEVELOPING MOTIVATIONALLY-ADAPTIVE COMPUTER-ASSISTED INSTRUCTION

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The purpose of this study was to examine the effects of a prototype of motivationally-adaptive CAI, developed in accordance with the ARCS model of motivational design, on achievement, perceived motivation (both overall motivation and each of A, R, C, & S components), efficiency, and continuing motivation. Students studied one of three versions of CAI: motivationally-adaptive CAI, motivationally-saturated CAI, or motivationally-minimized CAI. Motivationally-adaptive CAI showed higher effectiveness, overall motivation, and attention than the other two CAIs. For relevance, motivationally-adaptive CAI was higher than motivationally-saturated CAI but not higher than motivationally-minimized CAI. For confidence and satisfaction, motivationally- adaptive CAI was not higher than the other two CAIs. For efficiency, both motivationally-adaptive CAI and motivationally-minimized CAI were higher than motivationally-saturated CAI, but only the efficiency of the motivationally-adaptive CAI was identified as having practical importance. For continuing motivation, there were no significant differences among the three CAIs, but a significant correlation was found between overall motivation and continuing motivation across three CAIs. These findings, first, support the contention that the ARCS model is useful for developing motivationally- adaptive CAI. Second, motivationally-adaptive CAI can be an effective, efficient, and motivating form of instruction which may also enhance learners' continuing motivation. Related discussions and recommendations for future study are provided.

Computer mediated-instruction is being widely used as more advanced computer and communication technology becomes available. Learners, either school-aged or adult, now learn and will have to learn more from computer-mediated instruction such as computer-assisted instruction (CAI), intelligent tutoring systems, integrated learning systems, or network-based learning environments. This trend shows that computers as instructional media are becoming now a routine part of instructional delivery systems.

However, two recent concerns regarding the wide spread used of computers have indicated the need to deal with motivation to learn during the computer-mediated instruction. One concern is that as computers are becoming widely used for instructional delivery, their novelty effects will disappear (Keller & Suzuki, 1988; Keller, 1997). Students will no longer be fascinated with learning from computer-assisted instruction as much as they once were. Then the question is how to get hold of their motivation during the computer-mediated instruction.

Several advocates of adaptive CAI have raised the other concern, which is how to include adaptive responses to student motivation. They have pointed out that few previous efforts to design adaptive CAI have considered learner motivation as a factor for which subsequent instruction is prescribed (del Soldato & du Boulay,1995; Hativa & Lesgold, 1991; McCombs, Eschenbrenner, Jr., & O'Neil, Jr., 1973). Their main concern has been that although possible benefits of developing adaptive CAI have been found, one limitation of prior efforts (e.g., Atkinson, 1976; Holland, 1977; Houlihan, Finkelstein, & Johnson, 1992; Mills & Ragan, 1994; Ross & Morrison, 1988; Tennyson & Christen, 1988; Tennyson & Park, 1980) is that the students' motivation to learn is disregarded or assumed to be embedded in the cognitively adaptive CAI. Therefore, they have proposed the development of a motivationally-adaptive CAI that is adjusted to motivational changes for better learning outcomes, i.e., increased achievement and positive attitude toward learning.

Three approaches to the design and development of a motivating CAI can be found in the literature. The first is the Computer Feature Approach, in which specific computer features and novelty effects (Clark, 1983) are assumed to increase the appeal of CAI. For example, Brown pointed out, "the student is rewarded by the use of the machine itself" (Brown, 1986, p. 28). Also, it has been contended that "the cumulative effects of entities such as color, graphics, and animation can be instructionally and motivationally powerful" (Relan, 1992, p. 619). The second is the Principle Seeking Approach, in which prescriptive motivational design principles and tactics for CAI are identified or developed diverse theoretical and practical perspectives. For example, instructional games are recommended for the development of motivating CAI (Dempsey, Lucassen, Gilley, & Rasmussen, 1993; Malone, 1981; Malouf, 1988). Cooperative learning on CAI (Johnson & Johnson, 1986) is also suggested, as is learner control of CAI (Klein & Keller, 1990). The third is the Model Establishing Approach. The relationships between motivational theories and computer features are identified and incorporated into a practical model for designing motivating CAI. For example, Lee & Boling (1996) proposed the framework of motivational screen design. Keller and Suzuki (1988) proposed a set of motivational strategies for designing a motivating courseware based on the

ARCS model. Keller & Keller (1991) and Keller & Keller (1992) later developed this into a framework for designing motivating multimedia instruction.

All of these three approaches may be used for the development of a motivating CAI. However, they all have limitations. The Computer Feature Approach does not address the decreasing motivational effects of computer features whose novelty effects will disappear as learners become more familiar with computers. The Principle Seeking Approach has a value in that it provides more specific and practical guidelines. However, it is limited in that its approach tends to focus on limited and specific aspects of motivation, whereas motivation to learn needs to be understood more comprehensively. For example, not all CAI programs can be developed as instructional games. The Model Establishing Approach appears to be the most useful in that it provides a frame of reference that will guide instructional designers. But it is also incomplete in that it suggests that all the motivational strategies need to be identified and pre-sequenced before instructional delivery.

Furthermore, there is a common problem across the three approaches. That is, they do not address the continuously changing nature of motivation to learn. One of the reasons for this could be that all of the decisions about what types of motivational tactics to include have to be made at the design stage and cannot be modified once the instruction is ready for delivery. This means that every student receives exactly the same package. However, students who are highly motivated before starting CAI will not always remain motivated throughout the whole learning process. And conversely, some students who are not motivated before beginning CAI may become motivated as they proceed through the process. Therefore, it would be highly desirable to enable the CAI package to be responsive to motivational differences within the same learner at different points in time.

Regarding these problems of the three traditional approaches, a recommendation has been made consistently in the literature of motivation that we should provide optimal motivational strategies to learners (Brophy, 1987; Lepper,1988). If learners are already motivated, they should not be exposed to any more unnecessary motivational tactics (Astleitner & Keller, 1995; Keller, 1983, 1987 a,b,c). In that case, just sustaining their motivation is recommended. In contrast, learners' motivation should be enhanced when they are de-motivated. In this study, as a way of providing optimal motivational strategies, the idea of adaptive provision of motivational strategies was tested on computer-assisted instruction.

A few pioneering efforts have discussed and tried the development of motivationally adaptive CAI (Astleitner & Keller, 1995; del Soldato and du Boulay,1995; Rezabek, 1994). However, these efforts have several shortcomings First, few have been supported by positive empirical data with respect to increased performance and motivation. For example, Rezabek just discussed the use of intrinsic motivational strategies for the development of motivationally-adaptive instructional system. Astleitner & Keller (1995) suggested a simulation approach for designing motivationally-adaptive CAI, but they mainly provided ideas on how a computer can predict motivational states. Reporting the positive formative evaluation results on the program called "MORE", del Soldato and du Boulay (1995) suggested the need for further study on its effects on performance and motivation. Therefore, studies to investigate the actual effects of motivationally-adaptive CAI on outcomes such as achievement, perceived motivation, continuing motivation, and efficiency need to be conducted.

Second, the content of instruction has been mostly composed of a battery of test-items. For example, del Soldato and du Boulay (1995) developed an intelligent tutoring system where the system presented test-items to be solved by learners, and then both instructional strategies and motivational strategies were prescribed based on student performance. However, there is no reason that contents in the motivationally-adaptive CAI should be limited to test-items. Therefore, there needs to be a study that investigates the possibility of developing motivationally-adaptive CAI which teaches diverse types of content such as verbal information, concepts, principles, etc. (Gagne, 1985). Regarding this need, del Soldato & du Boulay suggested that "a richer domain representation, including, for example, a wider variety of links between topics, would provide space for further elaboration of motivational tactics." (p. 373)

Third, the previous ideas suggested by Astleitner & Keller (1995), and del Soldato and du Boulay (1995) require challenging efforts for instructional designers to understand and utilize and utilize their models for designing instruction. For example, Astleitner & Keller's approach requires instructional designers to obtain parameters, such as incentive value, to be used for simulation. Del Soldato and du Boulay's approach may require instructional designers to face the complexity of programming intelligent-tutoring systems. Therefore, it would be desirable to produce a generic, motivationally-adaptive CAI which can be designed in a simpler and more generalizable way. This product would provide confidence to instructional designers in dealing with motivational problems in designing CAI because they would not need to worry about all the complicated computer-related logic and calculations.

Finally, there is a need to use an integrated model which will guide instructional designers. Park (1996) points out that a micro-adaptive instructional system using computer technology has been based on "a particular model or theory of learning, and its adaptation of the learning environment is rather sophisticated (p. 646)." Likewise, also for the development of motivationally-adaptive CAI, we need to find a practical model that is theoretically validated and practically field-tested. In fact, one reason that there has not been much effort made to design a motivationally-adaptive CAI may be the lack of a practical model which can guide the diagnosis and prescription (Astleitner & Keller, 1995). Although McCombs, Eschenbrenner, Jr., & O'Neil, Jr.(1973) drew attention to the need for designing the motivationally-adaptive CAI in 1973, it was not until recently that actual efforts were made to develop such a system.

In this study, the ARCS model is used as a framework for the development of motivationally-adaptive CAI. Motivation is something inside the learner's mind, and it is important to stimulate or sustain learners' motivation to learn for their active learning. As a way of addressing this issue, the ARCS (Attention, Relevance, Confidence, and Satisfaction) model was proposed by Keller(1979,1983,1987a,b,c). He developed it as a conceptual tool and process for designing instruction that is appealing, in addition to being efficient and instructionally effective.

Generally, in the case of external adaptation, an adaptive CAI needs to have two functions which are essential to meet instructional needs (Ross, Rakow, and Bush,1980; Carrier & Jonassen, 1988). First, an adaptive CAI needs to diagnose the state of learners. That is, learner characteristics to which instruction is adapted must be continuously identified and measured. Second, the adaptive CAI should have the capability to provide the most appropriate instruction to address the identified state of learners. Similarly, motivationally-adaptive CAI should have the same two characteristics.

For example, CAI cannot be motivationally adaptive if it fails to identify the learner's motivational levels at more than one point of time in learning. Because the learner's motivational level can continuously change throughout instruction, any CAI which is developed based on a one-time motivational analysis prior to developing a course may not work. Also, motivationally-adaptive CAI should be able to provide instruction which is precisely adapted to meet the learner's motivational state.

This need requires us to use the ARCS model differently from the way it has been used for motivational design. In fact, the ARCS model has been applied to the enhancement of different types of instruction with respect to content and method of delivery. For example, with respect to delivery, it has been applied to classroom instruction, self-directed learning materials, and mediated instruction such as CAI (Keller & Keller, 1991; Keller & Suzuki, 1988). Its primary application has been in the initial development of materials based on the entry-level motivation of students

With this in view, the central question of this study is to investigate whether the ARCS model can help instructional designers design CAI which is motivationally individualized or adaptive to the learners' motivational needs. Keller's ARCS model seems to provide a basis for meeting the above two functions, i.e., diagnosis and prescription, of a motivationally adaptive CAI. For the former, audience analysis is emphasized, and for the latter, Keller & Suzuki (1988) propose sets of prescriptive strategies based on the ARCS model.

Moreover, the ARCS model is developed from a thorough literature review on motivational theory. The four components, attention, relevance, confidence, and satisfaction, are based on a general macro theory of motivation (Keller, 1979,1983) and have been verified through several validation studies and discussions (Bickford, 1989; Keller, 1984; Means, Jonassen, & Dwyer, 1997; Klein & Freitag,1992; Newby, 1991; Nwagbara, 1993; Small & Gluck, 1994; Visser & Keller, 1990). Mostly, the use of the ARCS model has been supported by empirical results showing increased motivation, achievement, and continuing motivation. However, no study has been conducted to investigate the use of the ARCS model for the development of the motivationally-adaptive CAI. To apply it, there are two major steps: diagnosis of motivational states and prescription of tactics.

Diagnosing Motivational State

Keller (1983,1987 a, b, c) emphasized the importance of audience motivational analysis before designing motivational enhancements to instruction. The learner's motivational level can be estimated based on the designer's personal experience, objectively assessed from collected and analyzed data, or by both (1987b). An audience motivational analysis is generally conducted for each component of attention, relevance, confidence, and satisfaction, although the decisions as to how specific to be will depend on the criticality of the decision, the anticipated obstacles, and the consequences of failure.

For example, for an instructor-led course, the process questions (Figure 1) presented by Keller (1987a or b) can be used as checklists because they are well categorized into four components of motivation (ARCS), enabling comprehensive check-ups. Designers can use those questions for their "best guess" process or for developing an instrument for measuring motivation. In either case, it is the designers' initial responsibility to identify the learners' levels of motivation. An instructor can then more or less continuously monitor motivation and change tactics as necessary. This fact has an important implication for instructional designers when they try to use the ARCS model for designing the motivationally-adaptive CAI: there should be measurement tools embedded in the instructional program which continuously monitor learners' motivational change as an experienced tutor does. For example, the audience analysis needs to be conducted several times throughout the instruction.

Figure 1 Process Questions and Motivational Strategies (adapted from Keller, 1987a)

Questions for Components	Suggested Strategies
Attention	
• What can I do to capture their interest?	• Create curiosity, wonderment by using novel approaches, injecting personal and/or emotional material.
• How can I stimulate an attitude of inquiry?	• Increase curiosity by asking questions, creating paradoxes, generating inquiry, and nurturing thinking challenges.
• How can I maintain their attention?	• Sustain interest by variations in presentation style, concrete analogies, human-interest examples, and unexpected events.
Relevance	
• How can I best meet my learner's needs? (Do I know their needs?)	• Provide statements or examples of the utility of the instruction and either present goals or have learners define them.
• How and when can I provide my learners with appropriate choices, responsibilities, and influences?	• Make instruction responsive to learner motives and values by providing personal achievement opportunities, cooperative activities, leadership responsibilities, and positive role models.
• How can I tie the instruction to the learner's experiences?	• Make the material and concepts familiar by providing concrete examples and analogies related to the learner's work.
Confidence	
• How can I assist in building a positive expectation for success?	• Establish trust and positive expectations by explaining the requirements for success and the evaluative criteria.
• How will the learning experience support or enhance the students' beliefs in their competence?	• Increase belief in competence by providing many, varied, and challenging experiences which increase learning success.
• How will the learners clearly know their success is based on their efforts and abilities .	• Use techniques that offer personal control (whenever possible) and provide feedback that attributes success to personal effort.
Satisfaction	
• How can I provide meaningful opportunities for learners to use their newly-acquired knowledge and skill?	• Provide feedback and other information that reinforces positive feelings for personal effort and accomplishment.
• What will provide reinforcement to the learners' successes?	• Use verbal praise, real or symbolic rewards, and incentives, or let learners present the results of their efforts ("show and tell") to reward success.
• How can I assist the student anchoring a positive feeling about their accomplishments?	• Make performance requirements consistent with stated expectations, and provide consistent measurement standards for all learners' tasks and accomplishments.

Two issues arise when audience analysis is conducted by the computer. One is the need for comprehensive assessment of motivation, the other is the method of assessment. As far as comprehensiveness is concerned, although motivational levels of all four components (attention, relevance, confidence, and satisfaction) can be assessed in the case of the instructor-led course, CAI has some limitations in this regard.

The reason for measuring motivation in adaptive CAI is to provide formative input that can be used to determine what motivational tactics to use in the subsequent part of the program. The measures of attention, relevance, and confidence can easily be used for formative feedback. Measures of satisfaction that are taken at intervals during the program could also be used for formative feedback and for the selection of subsequent motivational tactics, but in many respects satisfaction measures will be more summative in nature. This will be especially true in relatively short episodes of instruction. Although the analysis of satisfaction can be conducted several times, it is difficult to provide adaptive motivational strategies to address the measured level of satisfaction. Satisfaction could be eliminated from this initial study of adaptive CAI without affecting the theoretical or practical foundation of the study. It is important however to use all three of the other categories because of their interactive nature. If the treatment were long, with several lessons or units of work, then it would be important to monitor satisfaction of each point.

Second, the assessment method to be used in audience analysis is another concern. Although Keller (1987b) contends that the full range of measurement possibilities can be considered, in the case of CAI there is an inevitable limitation that it is the computer, not a human tutor, who assesses or monitors the learner's motivational change.

In this study, self-report measures were used for embedded audience analyses throughout the instruction. Although self-report measures can have problems with respect to reliability and validity, the researcher judged that it might be the simplest method which can be easily understood and utilized by most instructional designers. Keller (1987b) says that straightforward self-report measures can be very useful when they focus on an identified area of concern. For example, in this study, each learner was asked to report his or her motivation in terms of its direction and magnitude with respect to attention, relevance, and confidence. In addition, as a way of complementing the weakness of self-report measures, measures of performance scores on the quiz were also used in conjunction with their motivational self-assessments.

Prescribing Motivational Strategies

Based on the ARCS model, Keller and Suzuki (1988) suggested a set of motivational strategies for designing a CAI program. They say that CAI developed with the ARCS model is expected to be motivating compared to ones not developed in accordance with the ARCS model. Of course, any CAI can be motivating provided that the instructional designer's skills, experience, and creativity are adequate whether or not they have any knowledge of the ARCS model. The ARCS model simply tries to codify this knowledge gained from the research literature and the examples of successful practitioners. However, there can be a benefit to using the ARCS model, or some other systematic approach to motivational design for guidance and for documenting results in a way that can be used by others. This is where Keller's ARCS model and motivational strategies suggested by Keller and Suzuki could be used with its systematic but holistic problem solving approach. Motivational strategies, well organized in terms of ARCS components, are expected to help ensure the motivational quality of CAI.

However, little research has been done on whether the adaptive use of motivational strategies suggested by Keller & Suzuki can increase the appeal and effectiveness of CAI by being adjusted to motivational changes of learners, compared with those used in a CAI program which is not motivationally-adaptive. Visser and Keller (1990) applied the ARCS model in an adaptive way and reported promising results for an instructor-led course. Their application was "based on continuous diagnosis of the audience and subsequent formulation or reformulation of a solution (p. 472)."

Building on this concept and other research, the purpose of this study was to investigate the use of the ARCS model in developing a motivationally-adaptive CAI which is appealing, will enable learners to study more effectively and efficiently, and will enable learners to have more continuing motivation. To achieve this purpose, it was necessary to prepare a prototypical CAI that is motivationally-adaptive and to compare it to two different motivationally non-adaptive versions of CAI. The first non-adaptive version (motivationally-saturated CAI) is enhanced with a full set of motivational strategies, and the second (motivationally-minimized CAI) has virtually no motivational strategies added.

It was expected that the motivationally-adaptive CAI would be most motivating to learners because it was designed to a) avoid providing excessive motivational strategies that would distract or annoy learners who already found the instruction to be motivating, and b) to overcome motivational deficiencies among learners who were bored or otherwise demotivated by the content. It was also expected that the motivationally-adaptive CAI would be most effective in terms of learning achievement, and successful in producing the highest continuing motivation. Finally, the efficiency of the three versions of CAI s was determined by comparing achievement to time spent on the lesson. It was expect that the motivationally-adaptive version would be most efficient.

Method

Subjects and Design

Subjects were 66 tenth grade students from the Developmental Research School (DRS) affiliated with a large university in the Southeastern United States. Students are selected and admitted to the DRS to be representative of Florida's school-age population in terms of academic ability, race, sex, and socio-economic status. Subjects were selected from three different classes taught by the same biology teacher. The classes represented two different levels of ability, with the higher being the college prep group.

Subjects who had been identified by the biology teacher as not having studied the contents were randomly assigned to three conditions of one independent variable (motivationally-adaptive CAI, motivationally-saturated CAI, and motivationally-minimized CAI). The dependent variables were effectiveness (learning), efficiency (amount of learning per time spent), motivation (both overall motivation and each of attention, relevance, confidence, and satisfaction), and continuing motivation.

Materials

Three versions of hypercard computer-assisted instruction were developed that contained the same contents on Genetics. The contents were adopted and modified from three sources: a print-based biology instructional module developed by Osman (1992), a hypertext CAI developed by Park (1993), and a textbook entitled *Biology* (Goodman et al., 1989). Genetics was chosen for three reasons. First, the content of the instruction needed to be facts, concepts, and principles (Gagne, 1985) as mentioned earlier in this paper. Second, the reading ability level was appropriate to tenth grade students (Park, 1993). Third, it was judged that the content needed to be somewhat technical and must not be easily understood without student effort. It was confirmed through interviews with biology teachers that, although the students appeared to know much about genetics, in fact, their understanding of the details tended to be poor.

Each version of CAI included three sections: first, (Introduction, Gregor Mendel, Mendel's Experiment, The Principle of Dominance); second, (The Principle of Segregation, The Principle of Independence Assortment, The Principle of Chance and Probability), and third, (Predicting the Results of Genetic Crosses, The Punnett

Square). Students using the three versions of CAI were asked by the computer for their motivational attitudes just prior to beginning each of the three sections. Each time, they were asked about their attitudes toward the interestingness (attention), usefulness (relevance), and confidence in learning the instruction. Immediately following the motivational analysis, they were presented with their assigned version of the instructional material (motivationally-saturated, adaptive, or minimized). At the end of the instruction, they were asked the continuing motivation question. The flow of events is illustrated in Figure 2

Figure 2 Flow of instruction in three versions of CAI

1. Present the introduction and first embedded motivational analysis

I find the subject of genetics interesting.	Yes or No
Learning genetics will be useful to me.	Yes or No
I feel confident that I can learn genetics.	Yes or No

2. Present the first section of instruction and four-item quiz

3. Present the second embedded motivational analysis

I find the subject of genetics interesting.	Yes or No
Learning genetics will be useful to me.	Yes or No
I feel confident that I can learn genetics.	Yes or No

4. Present the second section of instruction and four-item item quiz

5. Present the third embedded motivational analysis

I find the subject of genetics interesting.	Yes or No
Learning genetics will be useful to me.	Yes or No
I feel confident that I can learn genetics.	Yes or No

6. Present the third section of instruction

7. Present the continuing motivation survey

8. Present the post-test and simplified IMMS survey

For the motivationally-minimized version CAI, any motivational strategies embedded in Osman's text, Park's CAI, and the textbook were eliminated. This was to ensure that the developed CAI would not have any motivating features for the students. However, through the formative evaluation with experts in instructional design, strategies that were judged as contributing to instructional effectiveness were kept to maintain the inherent quality of the instruction. The motivationally-minimized CAI included 3,017 expository words and 210 sentences with several inserted technical drawings. The Hupercard stack size was 112 k, and it contained 59 cards.

The motivationally-minimized CAI was not expected to be highly motivating to students except in two possible situations: when the topics of the content themselves are motivating to learners, or when the computer itself may have motivating effects. However, these two situations were not expected to affect a large number of learners because of the technical nature of the content. It was also expected that there would be a minimal novelty effect of using the computer because of the previous computer-usage experience of learners as confirmed by their teachers. In any case, any effects of these types were expected to be a constant across treatments.

Motivationally-saturated CAI was developed from the motivationally-minimized version. Using the ARCS model, the motivational strategies presented by Keller & Suzuki (1988) and those obtained from interviews with two biology teachers were reviewed, and all the appropriate ones (24 strategies in total), as judged by the researchers, were incorporated into instruction for enhancing and sustaining attention, relevance, and confidence. The criteria used for the selection, based on Keller (1987b), were that motivational strategies should:

- not take up too much instructional time,
- not detract from the instructional objectives.
- fall within the time and money constraints of the development and implementation aspects of the instruction,
- be acceptable to the audience,
- be compatible with the delivery system,
- be appropriate for the contents,
- not take up much CPU memory,
- be developed using hypercard 2.2,
- not bother multiple learners in the classroom.

The strategies finally selected are presented in Figure 3. The motivationally-saturated CAI contained 3,306 expository words and 273 sentences. It also included additional words (1,835) and sentences (247) for motivational strategies, with technical drawings and tables inserted. The stack size was 393 k, and it contained 107 cards.

Figure 3. Selected Motivational Strategies

Attention Enhancing Strategies

AE1	Use inverse and flash in text and patterns in pictures as attention getters
AE2	Engage the learner's interest by using question-response-feedback interaction that requires active thinking
AE3	Present problem solving situation in a context of exploration and partial revelations of knowledge

Attention Sustaining Strategies

AS1	Keep instructional segments relatively short with progressive disclosure
AS2	Make effective use of screen display to facilitate ease of reading
AS3	Intermingle information presentation screens with interactive screens
AS4	Use a consistent screen format but with occasional variation
AS5	Use visual enhancement functionally to support the instruction and general theme of the lesson
AS6	Avoid dysfunctional attention-getting effects such as a flashing word that distracts learner's concentration
AS7	Use underlines, italics, or bigger font sizes for the headings or key words

Relevance Enhancing Strategies

RE1	Use examples from content areas and situation that are familiar to the learners
RE2	Clearly state the objectives in terms of the importance or utility of the lesson

Relevance Sustaining Strategies

RS1	Use personal pronouns and the learners' name when appropriate
RS2	Use graphic illustrations to embed abstract or unfamiliar concepts in a familiar setting

Confidence Enhancing Strategies

CE1	Use words and phrases that help attributes success to the learners' effort and ability
CE2	Clearly present the objectives and the overall structure of the lesson
CE3	Explain the evaluative criteria and provide opportunities for practice with feedback
CE4	Mention the prerequisite knowledge, skills, or attitudes that will help the learner succeed at the task
CE5	Tell the learner how many items are going to be in a test or drill, and whether it will be timed.
CE6	Provide summary
CE7	Use a menu-driven structure to provide learner control over access to different part of the courseware

Confidence Sustaining Strategies

CS1	Allow the learner to escape and return to the menu at any time, and if feasible, to page backwards.
CS2	Give the learner control over pacing by hitting a key to go from one screen to the next
CS3	Match learning requirements to prerequisite knowledge and skills to prevent excessive challenge or boredom.

One thing to be mentioned is that motivational strategies used in this study were classified into two categories of enhancing and sustaining strategies. This distinction was necessary because Keller (1983, 1987 a, b, c) distinguishes "enhancing motivation" from "sustaining motivation." He says that strategies for motivational enhancement are provided to learners who are not motivated, while strategies for sustaining motivation are provided, as kind of hygiene factors, to learners who show the desired levels of motivation. For example, in the case of the component of 'attention,' " animation, inverse, flash, sound and other audio and visual capabilities of the computer" (from Figure 3) were categorized as attention-getting strategies. However, "consistent screen format, but including occasional variation" were categorized as attention-sustaining strategies.

Because the motivationally-saturated CAI incorporated all the motivational strategies (both enhancing and sustaining strategies) for all three components (attention, relevance, and confidence), it might seem that the motivationally-saturated CAI would maximize learner motivation. However, research based on application of the ARCS model (e.g., Visser & Keller, 1990) did not support the excessive use of motivational strategies. For example, if a student already feels confident, the confidence enhancement strategies are not recommended to be used in instruction. In this study, the title, "motivationally-enhanced CAI" was simply defined as one which has motivational strategies for both enhancing and sustaining across all three components: attention, relevance, and confidence. Satisfaction was not considered here, as discussed earlier in this paper.

Motivationally-adaptive CAI had all the same features as the motivationally-saturated CAI, except that it adaptively provided the learners only with the appropriate motivational strategies. With the motivationally-minimized and motivationally-saturated CAI, all the students were given the same package through the three sections of the instruction, regardless of the results of the embedded audience analyses. However, with the motivationally-adaptive CAI, if a learner was analyzed as having low confidence, high attention, and high relevance, this version provided the instruction which aimed to enhance and sustain confidence, while sustaining the attention and relevance level. More specifically, at the outset, learners were asked to report their initial motivation (First Embedded Motivational Analysis). They indicated whether the instruction was attention-getting, relevant, and appropriately challenging. This resulted in one of eight possible combinations of responses (see Column 1 in Figure 4). Students were then given the appropriate combination of sustaining and enhancing motivational strategies (see Types 1, 3, 5, 7, 9, 11, 13, and 15 in Column 4 of Figure 4). The feedback associated with each of these types was not given after the First Embedded Motivational Analysis as it did not apply at that time.

After reporting their motivation the second and third times (Second and Third Embedded Motivational Analysis), each student took a four-item quiz. The quiz was provided to check whether the self-reported confidence level was consistent with the performance scores on the quiz. For example, a student who reported high confidence and obtained a high quiz score was considered to have matched responses, but a student who reported high confidence and had a low quiz score was given a different type of feedback. The results of this quiz were categorized into two levels (see Column 2 in Figure 4): pass (scores higher than 2.5) vs. fail (scores lower than 2.5). The joining of eight combinations of motivational responses and two levels of quiz outcomes resulted in a total of sixteen types of student response (see Figure 4, Column 4). The appropriate type of motivational enhancements and feedback were then implemented for each student.

Measurement

Motivation (both overall motivation and each of attention, relevance, confidence, and satisfaction) was measured through a simplified version of Keller's (1993) Instructional Materials Motivational Scale (IMMS), which measures the motivational features of instructional material in terms of attention, relevance, confidence, and satisfaction. Internal consistency estimates for the IMMS total score and subscales are generally in the range of .81 to .96. The simplified IMMS used for this study had 16 items, four items for each component of attention, relevance, confidence, and satisfaction respectively. The reliability coefficient, Cronbach's Alpha, for the overall motivation measure was .92, and it was .79, .73, .70, and .85 for attention, relevance, confidence, and satisfaction, respectively.

Figure 4 Types of Instruction for Adaptive CAI

A = Perceived attention;
R = Perceived relevance
C = Perceived confidence
Y = Yes, I have attention, relevance, or confidence
N = No. I don't have attention, relevance, or confidence
NP= Enhancing strategies are not provided but sustaining strategies are provided.
P = Both enhancing strategies and sustaining strategies are provided.

Column 1			**Column 2**	**Column 3**			**Column 4**
Perceived Motivation			**Quiz: 4 items**	**Motivational Strategies**			**Types**
A	**R**	**C**	**Score**	**For Attention**	**For Relevance**	**For Confidence**	**Type**
Y	Y	Y	> 2.5	NP	NP	NP	1
				* Say, "Very Good score!", then provide the next topics. * If the score is 4, say "Excellent score."			
			< 2.5	NP	NP	NP	2
				*Say "Good try. Try hard to raise your scores.", then provide review + next topics.			
Y	Y	N	> 2.5	NP	NP	P	3
				* Say, "Very Good score! Your confidence should be growing stronger.", then provide the next topics with confidence strategies. * If the score is 4, say "Excellent score."			
			< 2.5	NP	NP	P	4
				* Say, "Good try. Try hard to raise your scores and confidence level." then, provide review + next topics with confidence strategies.			
Y	N	Y	> 2.5	NP	P	NP	5
				* Say, "Very Good score! Was it irrelevant to you?", then, provide next topics with relevance strategies. * If the score is 4, say "Excellent score."			
			< 2.5	NP	P	NP	6
				* Say, "Good try. Try hard to raise your scores. Was it irrelevant to you?", then provide review + next topics with relevance strategies.			
Y	N	N	> 2.5	NP	P	P	7
				* Say, "Very Good score! Was it irrelevant to you? Your confidence should be growing stronger.", then, provide next topics with relevance and confidence strategies. * If the score is 4, say "Excellent score."			
			< 2.5	NP	P	P	8
				* Say, "Good try. Try hard to raise your scores and confidence level. Was it irrelevant to you?" then provide review + next topics with confidence and relevance strategies.			
N	Y	Y	> 2.5	P	NP	NP	9
				* Say, "Very Good score! Was it boring to you?", then, provide the next topics with attention strategies. * If the score is 4, say "Excellent score."			
			< 2.5	P	NP	NP	10
				* Say, "Good try. Try hard to raise your scores. Was it boring to you?", then provide review + next topic with attention strategies.			
N	Y	N	> 2.5	P	NP	P	11
				* Say, "Very Good score! Your confidence should be growing stronger. Was it boring to you?", then provide next topics with confidence and attention strategies. * If the score is 4, say "Excellent score."			
			< 2.5	P	NP	P	12
				* Say, "Good try. Try hard to raise your scores and confidence level. Was it boring to you?", then provide review + next topics with confidence and attention strategies.			
N	N	Y	> 2.5	P	P	NP	13
				* Say, "Very Good score! Was it boring and irrelevant to you?", then, provide the next topics with attention and relevance strategies. * If the score is 4, say "Excellent score."			
			< 2.5	P	P	NP	14
				* Say, "Good try. Try hard to raise your scores. Was it boring and irrelevant to you?", then provide review + next topics with attention and relevance strategies.			
N	N	N	> 2.5	P	P	P	15
				* Say, "Very Good score! Your confidence should be growing stronger. Was it boring and irrelevant to you?" then provide next topics with attention, relevance, and confidence strategies. * If the score is 4, say "Excellent score."			
N	N	N	< 2.5	P	P	P	16
				* Say, "Good try. Try hard to raise your scores and confidence level. Was it boring and irrelevant to you?" then provide review + next topics with attention, relevance, and confidence strategies.			

Learning achievement (effectiveness) was measured by a posttest of learners' understanding of the instructional content (facts, concepts, and principles). The test included 13 multiple-choice items which were adopted and revised from a test with 24 items used in a prior study (Park, 1993). Park reported the reliability of the test as .78, using the K-R 20 formula. In order for students to complete all the requirements within the experimental time, the number of test items was reduced to 13 items with each item being worth one point. Two subject matter experts (biology teachers) validated the test according to the learning objectives using a table of specifications for the content of instruction. Cronbach's alpha of the test was .69. The reduction in reliability compared to Park's (1993) could be due to either the reduced length of the posttest or the differences in the subjects.

Continuing motivation was measured by asking students whether they wanted to learn more in the future on the same or similar content (Figure 2). Students were told to report their continuing motivation on a Likert-type item with five anchors (1 = Strongly Disagree, 2 = Disagree, 3 = Not Sure, 4 = Agree, 5 = Strongly Agree). The item asked, "The lesson was motivating to me. I would like to learn more about the same subject matter later."

Efficiency was obtained by multiplying 1,000 to the ratio of performance on the post test to study time. The computer tracked the time (measured in seconds) used by each student. For instance, if a student scored 8 using 2,000 seconds, 8 was divided by 2,000, and then multiplied by 1,000. His efficiency was 4.

To control for the confounding effect of prior achievement, students' scores in science on the Metropolitan Achievement Test 7 were obtained and used in an analysis of covariance for effectiveness and efficiency.

Procedure

One month before the experiments, the students were measured on their pre-motivation to learn genetics. This was done to conduct audience motivational analysis as recommended by the ARCS Model. The one-way ANOVA revealed no significant difference among randomly assigned groups for their motivation to learn genetics ($F = .4024$, $p = .6706$). Also a significant difference was not found among groups on scores for attention ($F = .3839$, $p = .6830$), relevance ($F = .4652$, $p = .6304$), confidence ($F = .6718$, $p = .5149$), and satisfaction ($F = .0956$, $p = .9090$).

The experiments were conducted at a learning resource center in a university building near the students' school. Three 80-minute sessions (one session a day) were set up in accordance with the students' regular class periods. Students participated in the one of three motivational design conditions to which they were randomly assigned. They were instructed to study the materials with the emphasis that posttests and a survey would be given after their learning. The computer assignment and explanation took about 10 to 15 minutes. They were also told to raise their hands when they were ready for the test. Then, learners were allowed to study as long as they wanted, and the computer recorded their use of time. The average time used by students was 30.49 minutes (Minimum: 14.6; Maximum:46.52). When students finished the lesson, their continuing motivation was measured on the computer, which was followed by both the post-test and the simplified IMMS.

Data analysis

To test for differences in motivation (both overall motivation and each of attention, relevance, confidence, and satisfaction) and continuing motivation among learners in three versions of CAI, one-way analysis of variance (ANOVA) was used. To check the results of ANOVA of the four sub-components of motivation, a one-way MANOVA was conducted. This was done because the sub-components of attention, relevance, confidence, and satisfaction showed significant correlation's. The MANOVA results agreed with those obtained from the ANOVA. To test for differences in effectiveness (learning achievement) and efficiency, one-way analyses of covariance (ANCOVA) were used with students' science scores on Metropolitan Achievement Test 7 as a covariate. Both ANOVA and ANCOVA were followed by Fisher's LSD pairwise comparison procedure if a significant difference was found among treatments. Alpha was set at .05 for all statistical tests. All these analyses were done with the Statistical Package for the Social Science (SPSS Windows V. 6.0).

Results

Motivation

One-way ANOVA conducted on overall motivation scores revealed a significant difference for the treatments, $\underline{F}(2, 57) = 4.46$, $\underline{p} < .05$. Approximately 14% of the difference in motivation was explained by the treatments. Observed power was .74. Fisher's LSD pairwise comparison procedures revealed that students in the motivationally-adaptive CAI (M=52.73, SD=12.09) showed higher motivation than those in both motivationally-saturated (M=43.63, SD=9.38) and motivationally-minimized CAI (M=42.84, SD=13.75).

Regarding attention, one-way ANOVA revealed a significant difference for the treatments, $\underline{F}(2, 57) = 5.07$, $\underline{p} < .01$. Approximately 15% of the difference in attention was explained by the treatment, and observed power was .80. Fisher's LSD pairwise comparison procedures revealed that students in the motivationally-adaptive CAI (M=13.36, SD=3.36) showed higher attention than those in both motivationally-saturated (M=10.95, SD=3.19) and motivationally-minimized CAI (M=10.00, SD=3.96).

Regarding relevance, one-way ANOVA revealed a significant difference for the treatments, $F(2, 57) = 4.24$, $p < .05$. Approximately 13% of the differences in relevance was explained by the treatment, and observed power was .72. Fisher's LSD pairwise comparison procedures revealed that students in the motivationally-adaptive CAI (M=12.50, SD=3.47) showed higher relevance than those in motivationally-saturated CAI (M= 9.42, SD=2.97). There was not a significant difference for confidence and satisfaction.

Effectiveness

The correlation coefficient, Pearson r, between science scores and posttest scores was .5402 ($p = .001$). One-way ANCOVA conducted on achievement scores revealed a significant difference for the treatments, $F(2, 56) = 5.28$, $p < .01$. Approximately 16% of the difference in achievement was explained by the treatments. Observed power was .82. Fisher's LSD pairwise comparison procedures revealed that students in the motivationally-adaptive CAI (M=7.18, SD=2.50) performed significantly better than those in both motivationally-saturated (M=5.84 SD=3.11) and motivationally-minimized CAI (M=6.68, SD=3.35).

To investigate the validity of the rationale for the assumption that increased motivation will produce more effectiveness, the correlation between overall motivation and adjusted posttest scores was calculated. The observed posttest scores were transformed into adjusted scores for the covariate on the validated assumption of homogeneity of regression coefficient. The correlation coefficient Pearson r was .2546 ($p=.05$). This implies that about 6.5% of the achievement variance can be explained by the differences in overall motivation when the confounding effects of the covariate are systematically taken out. This explained variance is larger than the 2.5% that was reported by Bickford (1989), who used the ARCS model for printed material instruction non-adaptively.

Continuing Motivation

Although the students in the motivationally-adaptive CAI (M=3.18, SD=1.10) showed higher continuing motivation than both the motivationally-saturated (M=2.42, SD=1.07) and motivationally-minimized CAI (M = 2.63, SD =.96), one-way ANCOVA conducted did not reveal a significant difference for the treatments, $F(2, 57) = 2.93$, $p = .06$. Approximately 9% of the difference in continuing motivation was explained by the treatment. Observed power was . 549.

Efficiency

The correlation coefficient, Pearson r, between science scores and the efficiency measure was .4728 ($p=.001$). One-way ANCOVA conducted on efficiency revealed a significant difference for the treatments, $F(2, 55) = 5.17$, $p< .01$. Approximately 16% of the difference in efficiency was explained by the treatment, and observed power was .81. Fisher's LSD pairwise comparison procedures revealed that students in both the motivationally-adaptive CAI (M=4.01, SD=1.65) and motivationally-minimized CAI (M=4.62, SD=2.25) showed higher efficiency than those in the motivationally-saturated CAI (M=3.11, SD=2.11).

Table 1 *Means and Standard Deviations for Dependent Variables*

Variables		CAI Versions Minimized	Saturated	Adaptive	Total
Motivation[1]					
Overall Motivation	n	19	19	22	60
	M	42.84	43.63	52.73	46.72
	SD	13.75	9.38	12.09	12.57
Attention[2]	n	19	19	22	60
	M	10.00	10.95	13.36	11.53
	SD	3.96	3.19	3.36	3.74
Relevance[2]	n	19	19	22	60
	M	11.00	9.42	12.50	11.05
	SD	3.64	2.97	3.47	3.56
Confidence[2]	n	19	19	22	60
	M	11.95	12.00	13.95	12.70
	SD	4.02	2.98	3.32	3.53
Satisfaction[2]	n	19	19	22	60
	M	10.42	11.26	12.95	11.62
	SD	4.22	3.36	3.92	3.94
Effectiveness[3,5]	n	19	19	22	60
	M	6.68(6.25)	5.84(5.52)	7.18(7.94)	6.60
	SD	3.35	3.11	2.50	2.99
Continuing Motivation[4]	n	19	19	22	60
	M	2.63	2.42	3.18	2.77
	SD	.96	1.07	1.10	1.08
Efficiency[5]	n	19	19	22	60
	M	4.62(4.45)	3.11(2.89)	4.01(4.42)	3.91
	SD	2.25	2.11	1.65	2.05

*1: range for overall motivation (16-80)
*2: range for attention, relevance, confidence, and satisfaction (4-20)
*3: range for effectiveness (0-13)
*4: range for continuing motivation (1-5)
*5: adjusted scores for a covariate in parenthesis

Discussion

The purpose of this study was to investigate the effects of a motivationally-adaptive CAI developed in accordance with the ARCS model. For this purpose, a prototypical motivationally-adaptive CAI was developed and compared to a motivationally-saturated CAI and a motivationally-minimized CAI for its effects on motivation (overall motivation, attention, relevance, confidence, and satisfaction), effectiveness, continuing motivation, and efficiency.

Results indicated that motivationally-adaptive CAI was superior to the other two CAIs for the enhancement of overall motivation and attention. Students in the motivationally-adaptive CAI may not have been deprived of motivational intervention or may not have been overly manipulated. Therefore, the results support the suggestion that the amount of motivational emphasis or strategies need to be optimal rather than excessive or scarce (Brophy, 1987; Keller,1983, 1987 a,b,c; Lepper, 1988; Suzuki & Keller, 1998).

In fact, despite the emphasis on the optimal use of motivational strategies in the literature, few systematic ways on " how to" have been suggested for motivational enhancement of instruction. Wlodkowski (1981) has demonstrated how to preplan to incorporate motivations strategies into specific parts of a lesson. The ARCS model provides an audience analysis process that facilitates preplanning of motivational tactics that are adapted to learner requirements. However, in both models, adaptation of the plan can be done only in instructor-led settings and depends on instructor insight to maintain the appropriate levels. The results of this study suggest that the adaptive use of motivational strategies based on direct student input can also succeed and can be incorporated effectively into computer-assisted instruction.

More specifically, the motivationally-adaptive CAI was adaptive in two aspects that allowed for the optimal provision of motivational strategies. First, the distinction between sustaining strategies and enhancing strategies was a unique feature of the program. Through the occasional (three times) embedded audience analyses, students self-reported as being motivated were provided only with sustaining strategies, while students diagnosed as not having optimal motivation were prescribed with enhancing and sustaining strategies. This way, students were expected to receive only the exact amount of motivational intervention that was needed.

Second, the program was adaptive in terms of appropriate types of motivational strategies. Students were diagnosed for their self-perceived attention, relevance, and confidence level based on their "Yes" or "No" responses to each corresponding question. This came up with 8 types of student motivational profiles. For example, for the first audience analysis at the outset of instruction, if a student responded "Yes" to attention and relevance questions and "No" to the confidence question, he was provided with instruction which included sustaining strategies for attention and relevance while enhancing and sustaining strategies for confidence.

This kind of elaborated adaptation was expected to be more effective to motivate learners than other approaches such as those suggested by del Soldate & du Bouley(1995), who focused only on confidence, because the elaborated adaptation dealt with motivation more comprehensively rather than narrowly focusing on specific aspects of motivation. In this study, motivation was prescribed for attention, relevance, and confidence. Although satisfaction was not prescribed due to experimental constraints, the results support the contention for comprehensive and adaptive prescription that has been lacking in the previous efforts.

Regarding the other sub-components of motivation, the adaptive use of motivational strategies was partly supported. For relevance, students in the motivationally-adaptive CAI showed higher scores than the motivationally-saturated CAI but not the motivationally-minimized CAI. Regarding confidence and satisfaction, although students in the motivationally-adaptive CAI showed the highest scores, significant differences were not found among three CAIs.

These findings may be explained as follows. In the case of relevance, the fact that students in the motivationally-saturated CAI showed the lowest relevance score supports the contention that motivational strategies need to be prescribed optimally, i.e., adaptively. In the motivationally-saturated CAI, strategies for all three components, attention, relevance, and confidence were provided and distributed throughout the instruction. This means that students had to be exposed to much more additional content than those who were either in the motivationally-adaptive or motivationally-minimized CAI.

For example, the number of total words used in the motivationally-saturated CAI was 5,141, while the motivationally-minimized CAI had only 3,017 words. Of the difference (2,124), 1,835 words were used for motivational strategies, and this extra burden of words might have hindered the relevance strategies from influencing students. That is, students who were distracted by all the motivational strategies may not have noticed the relevance that was intended to be provided by a relatively small number of relevance strategies. Furthermore, when few number of relevance strategies were integrated with other strategies, their own effects could have been reduced. Also, most of the relevance strategies that were provided in the text format may not have been salient to learners unless the students had high motivational needs for relevance of the contents. In contrast, students in the motivationally-adaptive CAI were provided relevance strategies only when they were looking for the usefulness or value of the content.

The fact that there was no significant difference for relevance between the motivationally-minimized CAI and the motivationally-adaptive CAI was interesting and drew the researchers attention. The question was what would have produced the unexpected relevance level in the motivationally-minimized CAI. One possible explanation would be that students' exposure only to the content, without distraction, possibly allowed them to recognize the relevance as they learned more about the content even though they were not given specific relevance strategies. This inference may be supported by the fact that students in the motivationally-minimized CAI showed higher achievement than those in the motivationally-saturated CAI who were distracted by all the motivational strategies. However, the difference in achievement between these two treatments was not significant, so additional research would have to be done to confirm or negate this inference.

In sum, the inference is that there might have been increased relevance which came from the students' achievement in the motivationally-minimized CAI, and its amount might have been approximately the same as the small amount of relevance saturated in the motivationally-adaptive CAI. One possible rationale for this inference is that the average relevance score across the three treatments was 11.05 (SD=3.56), which is at 44 percentile, below the mid-point of the range (4-20). This implies that overall relevance reported across those three treatments is quite low, and possibly has floor-effects. Therefore, although the relevance level for the motivationally-adaptive CAI was 12.50 (SD=3.47, at 53 percentile) which is slightly above the average, it was not significantly larger than that (11.05) for the motivationally-minimized CAI. To resolve this, further research would be necessary.

Another interesting finding is that there were no differences in confidence among the three conditions. This can be interpreted in two ways. First, it is possible that the confidence strategies prescribed were not strong enough to address the motivational needs. In fact, this is a possible inference in that all the powerful computer features could not be used due to the restraints of experimental conditions. Second, provision of review opportunities would have resulted in non-significant differences in confidence among the three conditions. Research results show that review opportunities are effective strategies for increasing students' confidence (Bickford,1989). Therefore, review opportunities that were provided before and after taking each quiz may have evenly contributed to maintaining or enhancing learners' confidence across the three conditions. Further investigation of this inference needs to be done in future studies.

Regarding satisfaction, there were no differences among the three treatments. However, this finding did not get the researchers' attention because each CAI version was designed not to contain satisfaction strategies. Without systematic manipulation of satisfaction, students may have provided their own satisfaction on a random basis.

Aside from the motivational benefits of the adaptive use of the ARCS model, another expected benefit is to increase achievement scores. Although motivation to learn is not the only predictor of student achievement, it seemed reasonable to predict that if motivationally-adaptive CAI is more motivating than the other two CAIs, it would also show the highest effectiveness. The results of this study supported this expectation.

Regarding continuing motivation, Keller (1983, 1987a, b) points out that the more highly motivated the learners are during their learning, the better chance of their having high continuing motivation after their learning. However, although students in the motivationally-adaptive CAI showed the highest continuing motivation, the amount was not enough to be significantly different from those of students in the other two CAIs. Considering the positive test results for overall motivation, the motivationally-adaptive CAI should have produced more continuing motivation than the other two CAIs.

One interpretation of this inconsistent finding is that motivationally enhanced treatments is not the sole predictor of continuing motivation. If other confounding factors influenced continuing motivation, it would be difficult to have significant differences across the three conditions. Also, the observed power for ANOVA on continuing motivation was .549. This shows that a larger sample size would have revealed the significant differences among the three conditions, and a longer treatment may also be beneficial.

The above interpretation is also indirectly evidenced by the correlation (Pearson r, .6573, p=.000) between overall motivation and continuing motivation, although not all of the treatments conditions had a significant correlation with continuing motivation.. The motivationally-adaptive CAI showed the highest correlation (.8155, p= .0000), while the motivationally-minimized CAI was also significant (r=.6424 (p = .003). It is interesting that the motivationally-saturated CAI showed the lowest correlation, .3426, which was not significant (p=.151). These correlation's may indicate that the motivationally-adaptive CAI has more chance of increasing both motivation and continuing motivation than the other two CAIs. Why the motivationally-saturated CAI did not show significant correlation between motivation and continuing motivation should be further investigated.

For efficiency, it was expected that learners in the motivationally-adaptive CAI would need less time to finish their learning than those who had to go through all the motivational strategies in the motivationally-saturated CAI. Also, it was expected that the motivationally-minimized CAI would require less time to finish than the other conditions because no motivational strategies were provided. The ANCOVA on efficiency showed that there are differences across the three treatments, and Fisher's LSD analysis revealed that the motivationally-adaptive and motivationally-minimized CAIs showed higher efficiency than the motivationally-saturated CAI. These findings support the need for providing motivational strategies adaptively for efficiency. The excessive provision of motivational strategies in the motivationally-saturated CAI resulted, as expected, in lower efficiency than the motivationally-minimized CAI, while the motivationally-adaptive CAI showed the same efficiency with the motivationally-minimized CAI.

Overall, the idea of motivationally-adaptive CAI was empirically supported by the data in terms of its effectiveness, efficiency, and overall motivation. The data also indicated that there is a significant correlation between motivation and continuing motivation. These findings support the adaptive provision of motivational strategies in CAI.

One theoretical implication of these findings is that motivation to learn can be a useful indicator of learning readiness. Indicators of learning readiness used in previous studies in adaptive CAI have been mostly cognitive variables (e.g., Atkinson, 1976; Hativa & Lesgold, 1991; Houlihan, Finkelstein, & Johnson, 1992; Mills & Ragan, 1994; Ross & Morrison, 1988; Tennyson & Christen, 1988; Tennyson & Park, 1980). However, the results of this study support the contention that motivation could be a strong predictor of learners' future performance and motivation because students' motivation at one point of time is a reflection of all their previous experience in both affective and cognitive domains. That is, students' previous attitudes, values, learning style, IQ, GPA, abilities, and aptitudes have influence on their current motivation to which motivational strategies can be prescribed adaptively.

As an initial attempt to design and develop a motivationally-adaptive CAI, this study has limitations that might reduce the generalizability of the results and conclusions. First, the potential range of motivational strategies could not be fully actualized due to constraints of available hardware and software. For example, after instruction, many students commented on the lack of colors, animation, and sounds for more motivational features. Some important conditions (Astleitner & Keller, 1995) for motivated learners such self-created task solution, opportunities for advanced topics, and control over important parts of the learning environment were not used.

Second, the time for the experiment was short. The average time was 30.49 minutes across three conditions (motivationally-minimized CAI: 24.37, saturated CAI: 35.45, adaptive CAI: 31.21). Considering the limited use of motivational strategies as discussed above, this short term exposure to motivational strategies could have been another reason for showing several insignificant differences despite the overall positive results that were found.

Third, the use of self-report methods for measuring motivation were limited in that they required students to indicate their perceived motivation level, which might have been different from their actual amount of effort which is a more accurate measure of motivational behavior. Also, the embedded motivational analyses may have been intrusive, requiring students to stop their process of learning. A more natural way of measuring motivation would be desirable.

Fourth, too much information presented within a short period of time may have caused cognitive overload which reduced the achievement and motivation across all three conditions. Astleitner & Keller (1995) pointed out that an excess of information makes it more difficult for the learner to maintain a sense of control and comprehensibility in the learning environment.

Fifth, motivational strategies used in this study may have not addressed the real motivational needs of students, resulting in fewer effects than expected. For example, students reported their motivational state for each component of attention, relevance, and confidence, and motivational strategies were prescribed based on this information. However, there might be a need to focus on the sub-categories of each component for more reliable diagnosis and prescription. For example, confidence is composed of the sub-components of motive matching, goal orientation, and familiarity. If motivational analysis can be done for each of these sub-components, adaptive CAI might be more effective in enhancing students' confidence.

Despite the limitations in this prototype development study, there was overall support for the adaptive treatment, and there are several areas that would be useful for continued study. First, this study showed that about 14% of perceived motivation was explained by treatments with limited use of computer features. It is recommended that future studies will utilize more powerful computer features such as sound, color, animation, video, and interaction. The motivationally-adaptive CAI could then be even more motivating to learners.

Second, it is recommended to elaborate the ARCS model or to devise new models which can be used for the development of motivationally-adaptive CAI. Although this study pioneered the use of the ARCS model for the development of motivationally-adaptive CAI, there is a need for further development of this or other models that can be used for the design and development of motivationally-adaptive courseware for computer, multimedia, or network-based learning environments (Astleitner & Keller, 1995). A future elaboration of the model should incorporate a more detailed and transparent motivational diagnosis system and a more reliable prescription system with a database of situation-specific motivational strategies. For example, motivational strategies for conventional CAI may be different from those for multimedia learning environments, which utilize multi-sensory effects.

Third, research is necessary to investigate the relationship among pre-motivation, prior achievement, cognitive aptitude, perceived motivation, computer attitude, and continuing motivation in motivationally-adaptive CAI in comparison with non-adaptive CAI. Continuing research on these issues will provide the foundation that will foster research efforts for designing and developing a more advanced motivationally-adaptive CAI.

In conclusion, the results of this study indicate the possible value of the ARCS model as a guiding process for designing motivationally-adaptive CAI. It also demonstrates that self-reports of motivation can be a valid indicator of learning readiness to which motivational strategies are adaptively prescribed. And, the study demonstrates that it is feasible to design motivationally-adaptive instruction for a self-paced learning setting, such as CAI. Further research should lead to more sophisticated and effective applications of motivationally adaptive design.

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