Multi-Media as a Cognitive Tool: Towards a Multi-Media ITS

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Abstract

Cognitive tools are instruments integrated into a learning environment to provide representational support to learners and allow them to focus on the subject matter [5]. Two of these; namely, animation and verbal representation are in a constant contest of effectiveness, without any noticeable differences, except in particular questions concerning conceptual versus procedural knowledge. Therefore, the effects of individual media may change according to both subject matter as well as individual preferences. Here, we offer students a Multi-Media representational module, which has been designed with the aim of incorporating it into a full scale Multi-Media Intelligent Tutoring Systems. Results show that allowing animation and verbal descriptions to interact within the same system may result in improvement of student levels up to 40% from their post classical- classroom session. This is indicative that perhaps, the two media may have ambiguous internal factors that affect learning in a way that disappears when each is analyzed in isolation of the other.

1. Introduction

Intelligent Tutoring Systems (ITS), offer a great deal of flexibility in control, making them highly adaptable to individual student progress. This makes them excellent candidates to play the role of "Cognitive Tools" [5]. These tools are capable of supporting learners by explicitly representing information. They allow learners to see the structure of the cognitive process by externalizing it and freeing memory for the more important learning task at hand. The simplest form of a tool is a pen and paper, where students can write notes to remind them of the numbers involved when performing addition. Therefore it should not be surprising that computer based educational systems impose themselves at the top of the list of Cognitive Tools.

However, the sudden growth of multi-media computer systems necessitated the need for a deeper understanding of the characteristics of each of the different media. Norman [8] indicates that each media has "affordances" and "constraints" that would be either beneficial or counter-active to educational goals. Complexity grows exponentially when the aim of the selection is to include these media into a shell representing an adaptable ITS system. The shell itself would be flexible to individual student needs. Therefore, it should not be surprising to see research start off in highly controlled specific cases.

For instance, Sharples and du Boulay [10] argue that learning medical concepts is normally acquired through induction. This is done by showing students several scenarios and allowing them to generalize their own models over the possible cases. The problem with this approach is that it leads students to over generalization because they are not always exposed to the extreme possibilities. However, when students are exposed to a controlled set of images through a computer-based tutor then highlighting the extreme cases becomes possible and the problem is alleviated.

Another experiment tested if individual differences have any effect on solving syllogistic reasoning problems. These are usually in the format, A is related to B with a premise, B and C are related with a second premise, then the subject's task is to say what, if anything, follows from the given information. These problems can be solved either through drawing a diagram, Euler's circles or through natural deduction using symbols. Monaghan and Stenning [7] categorized subjects according to their performance in the paper-folding test (PFT) as designed by French, Ekstrom & Price [3]. The test requires subject to visualize the array of holes that result from a simple process. A paper is folded a certain number of folds, a hole is made through the folds then the paper is unfolded. Students are asked to select the image of the unfolded paper that shows the resulting arrangement and results are discriminated along a median split as high versus low visualization abilities. Students of both groups where then split into two groups and taught how to solve syllogisms either through Euler's circles, which is graphical, or through natural deduction, which is serial.

Following this, students were given a test with 8 syllogisms each, selected to cover a range of difficulties. They were instructed to solve them in one of the two ways according to the way they were taught. Results showed that those who scored high on the PFT test made fewer errors when taught to solve them using Euler's circles than their serialist counterparts, who scored low on the PFT test when given the same teaching method. Oddly enough, this influence only seemed to take place in the final stage or in the translation of the results from the graphical modality into sentential form. The most important result is that most subjects would either perform better when taught verbally or when taught through diagrams according to their abilities or preferences. Additionally, those with visualization abilities seem to need a stage of "translation" from one modality to the other. This leads to one main conclusion. The ideal way of describing a process to students must allow for possible individual differences.

2. Verbal/Pictorial vs. Animated

Now that both methods of representation seem necessary, a question arises as to whether one can subsume the other and present itself as the "ideal" method of teaching the behavior of processes. In short, **is animation the "ideal" way?** Well, evidently from research, there seems to be a serious difficulty in getting clear-cut results to say that animation is more effective than verbal/pictorial representation or vice versa.

Pane, Corbett, and John [9] ran a detailed study to assess the effects of dynamics representation in a computer-based system that teaches developmental biology. They compared animation to a textual description that is enriched with carefully selected still images. They found no difference in student performance when declarative questions are given. Another study [6] showed that with respect to teaching algorithms, "active laboratory" sessions seemed to result is better student performances. During these sessions students created their own algorithms and saw them animated. They performed better in "procedural questions" as compared to students who were exposed to animations of previously selected examples.

Two other experiments showed that animations might aid students in procedural knowledge by allowing them to "predict" the next step in an algorithm's behavior. However, similar results were found when students were asked to predict algorithm behavior from static diagrams [2]. Then what role does animation play?

> ***"When the perceptual system cannot directly perceive change over time, it will seek out implicit evidence of change."[4]***

Perhaps these findings are not as surprising as they may seem at first sight, if we presume dynamic mental representations. Freyd [4] showed through several experiments the existence of a memory distortion that represents a shift forward to the next expected state when even one image is shown. One of her experiments involved two static images of a man jumping off a wall. A subject is shown one image first. The subject would then be shown another image and asked whether they are the same. For example, if in the first image, the man is in the air, then subjects would readily identify that the image of the man standing on the wall is not the same. On the other hand, they would take longer to identify the difference if the order of the images was reversed.

This implies that subjects "expected" the second image to follow the first one temporally. This order was maintained in the experiments described above. In fact, the first study on developmental biology [9] replaces an animation with a sequence of four images that show different screen shots of stages in the animation. These images, according to dynamic representation are no different from exposure to the animation itself because a dynamic cognitive representation would fill in the gaps.

If the two representations appear similar, then where lay the difference? The clearest difference is that when images are presented as a cognitive tool, the externalised representation carries less information. Cognition has to account for the "expected" stages to recreate the complete animation, which is cognitively taxing. A more interesting difference though, seems to lie in the predictive ability of animation in showing students the "direction" of thought when images can frequently be unordered. When a sequence is shown, and then an image, a student may be more readily prepared to "predict" as is the usual requirement in procedural type questions.

3. More Choices with Multi-Media?

So far, work has shown that there is a strong reason to believe the existence of individual differences. Therefore, an educational system that provides the two representations that are associated with these differences is unlikely to do worse, than those that include either one or the other. The idea is to cover for individual differences in preferring one representation to the other as well as to provide them both in parallel. Only through this, can any interaction between the two be assessed. If there is no interaction, then one would render the other redundant and the total impact will be no better than that obtained in the positive experiments described. If on the other hand, an interaction does exist and is a negative one, then each of the representations would negatively affect the other. Performance would worsen following a classroom lecture as "confusion" may result. However, if the interaction is a form of fortification then an improvement that exceeds expectations will result. This would imply the existence of a positive interaction between the two modalities.

4. Multi-Media Data Structures Tutoring System

The selected subject matter was Data Structures including the concepts of Stacks, Queues, Lists and Trees. The system is a precursor for a Multi-Media Intelligent Tutoring System, which is currently under development. These topics were presented to students in both media simultaneously; animation and verbal description. The screen was therefore divided into two windows; one containing a carefully written description of the concept and the other an animation that the student can start, stop, and partially control.

The module itself is represented as a Java Applet with the aim of placing the system on the Internet. It has several sections each concerned with one of the topics listed above and each in turn has several screens associated with it representing Terminology, Operations, Examples and Quiz. The Terminology page explains the basic terminology students need to learn for that data structure and is purely verbal. The Operations page shows and explains through text and animation the basic operations that can be performed. Examples include preset examples represented again through both animation and verbal representation. The Quiz page is a student self-assessment exercise.

Students are given the full navigational freedom to go to any page they wish and repeat the animations included as many times as they wish within the specified time allotted for the experiment. They also had the ability to control the speed of the animation by selecting a number from 1 to 6. This was included because students complained about the slow speed in the experiments run by Pane, Corbett, and John [9]. The loading time of the applet was somewhat slow but the running time was appropriate since the subject matter covered only the basic essentials of each topic. Students were urged to then think of new possible cases with the basics they were shown.

5. Evaluation of the Module

The multi-media module was tested through an experiment that compared its effects on student performance to standard classroom lectures. Additionally, the experiment tested its effects on students who already attended the classroom lecture. Predictions, made are that it will not result in a lower level of performance than the classroom lecture, while it will be able to result in a highly significant improvement in student performance from their post-lecture test levels.

Students were distributed into three groups based on a quiz they were given earlier in the course to ensure that all groups are comparable. Group 1 attended the lecture only while group 2 attended the lecture and the following day used the module. Group 3 on the other hand, did not attend the lecture and just used the module on the second day. Both groups 1 and 2 took a test at the end of the classroom lecture. All groups took the second test on the second day, which was highly similar to the first test with a difference in the order and wording of the questions.

5.1. Subjects

45 students from the University of Bahrain volunteered to participate in this experiment in exchange for class credit. They were distributed evenly into three groups of 15 students each.

5.2. Materials

Materials included in this experiment concentrated on Stacks as a data structure. They included one classical lecture given to groups 1 and 2. Additionally, use of the multi-media module for that particular data structure by students in groups 2 and 3. Then the tests included 7 questions, which tested comprehension of the various parts of the presentation as well as the ability to recreate or imagine new uses or applications of stacks.

5.3. Results

Group 2, showed a highly significant improvement in test results following using the system when compared to their post-classroom lecture levels. An ANOVA test showed $F = 9.19$ with $p < .005$. No significant differences were found between group 1 who attended the classroom lecture only and group 3 which used the system only. In this case, $F = .598$ with $p < .446$ which shows that they are extremely comparable.

When a comparison is made in individual questions, an interesting phenomenon seems to take place. Students who attended the lecture only, group 1, were only better at the question "Using an example, explain briefly the stack concept and its possible uses?" than students of group 3 who used the system only. This was with a significance of $p < .03$.

Additional information was found by comparing student performance in similar questions in the pretest before using the system and the post-test after using the system. An ANOVA test compared the grades of the same students in both situations on a per question basis. Most of the difference or improvement came from the questions "Using an example, explain the stack concept and its possible use?", "How could we implement a stack in a program?" and "List the data variables and operations associated with the stack?". The significance was $p < .000$ in all three cases.

6. Discussion

Results seem to indicate strong positive interaction between animation and verbal representation with results in such a strong improvement in student levels. This provides strong support to the predictions made here in that having the two modalities in parallel may have better results than having each on its own. The question at which classroom only students did better was interested in showing how representation may imply a "limiting" effect to imagination. When students are presented with examples that take some form, it becomes more difficult for them to break out of the boundaries of that example and find another. Students who used the system seemed to be directed towards how a stack functions rather than application areas and showed this in their responses.

This implies that the effects of animation require further analysis to identify if they include a "channeling" effect that restrains students from broadening their scope of imagination. This is beneficial with respect to some domains and a disadvantage with respect to others. For example, a graphical model of a GRE problem is shown [1] to prohibit common errors simply because it includes "directionality" represented by arrows. The diagrammatic method allows students solving a problem to follow only existing arrows from their start to end. In this case, students are "channeled" into thinking in the correct direction.

The current system, exhibits some of that effect in a beneficial fashion. It also shows the positive effects of including both animation and verbal descriptions in parallel with a highly significant degree of improvement. This is highly promising since this project aims at utilizing this module as the heart of an Intelligent Tutoring System.

7. Future Directions

The tested system was implemented as a Java Applet, which did not take long to show its limitations with respect to flexibility, functionality and speed when placed on the Internet. A follow up system was designed and is being implemented as Java Servlets. These are server side processes that are responsible for filling up the different parts of a frame-based page. These areas are divided into three main areas, one for the verbal description, the second for the animated Flash file and the third for interaction with students. In short, Servlets offer the ability to call any one of the verbal descriptions and the matching animation according to student progress ensuring adaptability. It would be interesting to find out if students would prefer a particular type of animation for a particular section and prefer verbal descriptions for another. Additional tests could be done to students similar to those for individual differences to test if any interaction occurs with the multi-modal representation.

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