MULTIMEDIA ITEM TYPE DESIGN FOR ASSESSING HUMAN COGNITIVE SKILLS[1]

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ABSTRACT

Multimedia content has been used in education applications, e.g. in distance learning, to make learning more intuitive, more interactive and more effective than the traditional presentation formats. Although image, audio, video, graphics, animation and 3D representation can be found in current multimedia implementations, they are designed mainly for learning and not for testing. Most educational tests rely on simple, text-based items (e.g. multiple-choice questions), which focus on assessing a student's knowledge rather than on evaluating the student's cognitive skills and problem-solving abilities. In this paper, we propose a novel design that uses innovative test item types enriched with multimedia content, for evaluating a student's cognitive skills including linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal and intrapersonal.

1. INTRODUCTION

Extensive research is reported in the literature on educational multimedia, covering numerous topics from games to distance learning and online qualifying exams. For example, computer games have been widely used to teach concepts [5, 9, 12, 14]; artificial intelligence techniques have been incorporated in search engines to recommend research papers to learners [17]; active learner modeling [13] has been used to derive information on peer group learning; tele-mentoring is carried out through a collaborative agent [7]; an online learning environment [15, 16] has been used for the Virtual University project.

Most of the literature addresses the use of multimedia for learning and training applications. Most of these studies aim at testing students' knowledge in an area, but not their cognitive skills. This situation changes with the introduction of modern technologies into computer-based testing. Instead of the traditional test items, *e.g.* True-false, multiple-choice and fill-in-the-blank questions, more effective and interactive test formats using multimedia content can be made available. These allow assessing not only the student's knowledge of a subject, but also the student's cognitive skills, i.e. the ability to translate learned knowledge into a new situation and use it to solve problems.

In this paper we propose a multimedia approach to design innovative item types, which can assess students' cognitive skills. In Section 2, we describe the types of skills to be assessed by our innovative test item types. Section 3 distinguishes the item design strategy for testing cognitive skills from the design strategy for testing knowledge. Section 4 illustrates examples of our item type designs, and discusses the testing strategy behind these designs. Finally, Section 5 describes the conclusion and future work.

2. COGNITIVE SKILLS

Each person possesses many cognitive skills, or intelligences [8], but they can only be discovered in the correct context. For example, we cannot assess a student's social skills by watching him/her dissecting a frog. Therefore test item types have to be designed according to the kind of intelligence to be assessed. Gardner [8] introduced seven intelligences, which are skills to resolve problems and to create valuable contribution to the society, entailing the potential for finding problems and acquisition of new knowledge [8] [11]. The seven intelligences are:

1. The ability to use words, orally or in writing, effectively (linguistic intelligence).
2. The ability to use and analyze numbers effectively (logical-mathematical intelligence).
3. The ability to perceive the visual-spatial context and to response correctly based on the perception (spatial intelligence).
4. The ability to use one's body to express ideas and feelings, including using hands to manipulate or coordinate things (bodily-kinesthetic intelligence).
5. The ability to perceive, discriminate, compose, express, transform and invent musical forms (musical intelligence).
6. The ability to observe, understand and distinguish the moods, intentions, agendas and feelings of other people (interpersonal intelligence).

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7. The ability to acquire and be aware of self-knowledge and apply effectively on the basis of that knowledge (intrapersonal intelligence).

3. INTELLIGENT ITEM TYPE DESIGN STRATEGIES

Assessment of learned knowledge needs to focus on two distinct aspects, knowledge retention and associated cognitive skills. Knowledge retention not only refers to the ability to recall learned facts but also the ability to understand the relationships between these facts, i.e. to understand the structure of the learned domain knowledge. Traditional test types, e.g. multiple-choice items, typically only test a student's ability to recognize learned facts in isolation, and in the same form they were learned. In contrast, our test items are aimed at testing a student's deep understanding of a domain, namely the ability to recall facts in novel contexts (requiring the student to develop a domain-independent representation) and the ability to represent the structure of the acquired knowledge (requiring the student to develop a representation at different levels of abstraction).

Cognitive skills consist of multiple components that refer to 1) the ability to translate learned knowledge into a new domain, 2) the ability to combine the facts of a test problem with translated knowledge into an integrated problem representation, 3) the ability to derive a solution plan from this problem representation, and 4) the ability to execute the solution plan. Traditionally, assessments of cognitive skills have concentrated on outcomes, i.e. the final result of a given problem. In contrast, out test items permit a much finer analysis of cognitive skills because they permit recording and assessing the steps a student takes in solving a problem and because they permit analyzing partial solutions.

Taken together, it is clear that traditional tests (e.g. multiple-choice questions or fill-in-gap questions) assess students' knowledge and cognitive skills only in a very limited way. It is thus far from clear how valid these test results are, i.e. how well they can predict a student's ability to recall and apply acquired knowledge at a much later point, in a new and typically more complex context than the one used in training. In contrast, we believe that these concerns can be addressed by relying on a much broader range of test item types, which are designed to probe all aspects of knowledge retention and the associate cognitive skills. Examples of these item types are discussed below.

4. INTELLIGENT ITEM TYPES (IIT)

Researchers and educators have successfully implemented cognitive skill testing in classrooms [1, 2, 4, 6, 10, 11]. Such implementation can benefit students at all levels, including learning-disabled and gifted students. In order to broaden the benefit to computer-based as well as web-based testing, we introduce a number of Intelligent Item Types (IIT).

4.1. Visual-Spatial IIT

Item types for assessing a student's mathematical and logical skill are more commonly used in computer-based testing, and they can be presented using a multiple choice format, provided one only wants to assess the result. In contrast, visual-spatial skills cannot be tested using traditional pencil and paper format because they need to be tested in a dynamic context. Such context can be simulated using computer generated navigation. For example, the boxes in Figure 1 continue to move randomly on the screen, while the student has to link, by drawing arrows between boxes (from corner to corner) so that the box content is in a particular order. In this example, the question is "to drive through these cities from north to south without revisiting". An important consideration is to separate the assessment of visual-spatial skill from knowledge. The student may not know the geography but has high visual-spatial skill. Therefore the question has to be of minimum difficulty, e.g. order the numbers in ascending sequence.

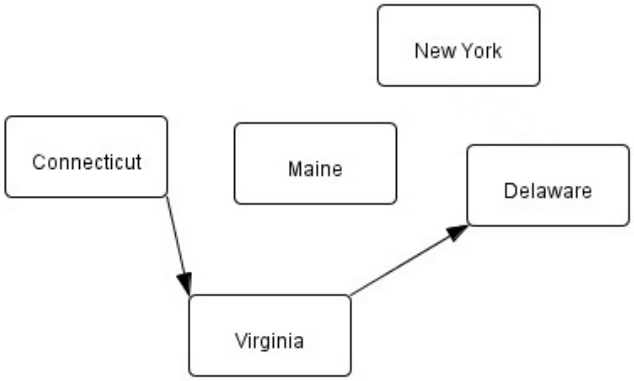


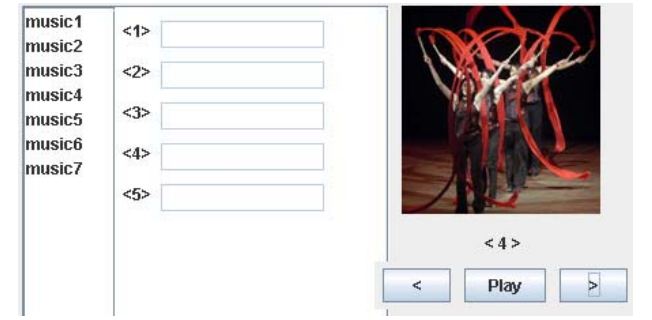
Figure 1: An example of a Visual-Spatial IIT to test a student's ability to perceive visual-spatial context and response correctly.

The level of visual-spatial skill can be evaluated by adjusting the parameters controlling the computer navigation: the speed of the moving boxes and the number of boxes; increasing the speed or the number of boxes will increase the difficulty. The skill is assessed by comparing the time required by a student to complete the task.

4.2. Musical IIT

An example of our Musical Item types requires a student to look at video clips showing different dancing patterns. Figure 2 (b) shows a sequence of Korean, Swan Lake, Irish, Jazz and Ribbon dances. The student needs to associate each dance with the correct music, which is played by clicking on the "music" text. Note that no specific meaning is attached to the text to provide any hint. The student has to transform the musical rhythm he/she perceives to a sequence of artistic

body movements. Musical notes discrimination, or musical instrument and sound mapping can also be used in this item type to test the cognitive skill on music. An alternate format of the video is to use shadow-type dancing figures, like the jazz dancers (The 4th picture in Figure 2 (b)) to avoid disclosing the costume and thus culture as a hint to the music.



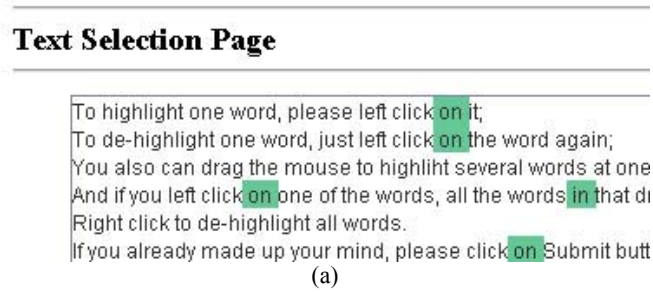
(a)

(b)

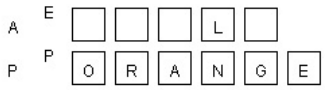
Figure 2: (a) An example of a Musical IIT to test a student's ability to perceive, express and transform musical forms, and (b) A sequence of video expressing different musical composition.

4.3. Linguistic IIT

There are many ways to test linguistic skills. An example is to ask the student to highlight a certain category of words, e.g. preposition (Figure 3 (a)), or to highlight a phrase having certain meaning. Vocabulary can be tested using 2D or 3D puzzles (Figure 3 (b) & (c)). Other examples can be drag-and-drop (drag the correct word from a list and drop it in the correct position in a paragraph), listen and dictate (the student types into a text box what he/she hears from an audio clip) or rearranges words presented in random order into sentences.



(a)



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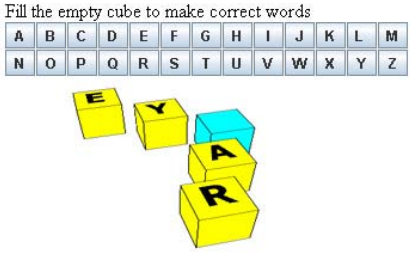

(c)

Figure 3: Use Linguistic IITs to test a student's effectiveness in using words.

4.4. Bodily-Kinesthetic IIT

The availability of computer accessories and supplementary attachments has made computer-based testing more effective. For example, joy-sticks, data gloves and haptic devices open up a new horizon to human computer interaction (HCI). Instead of typing on a keyboard or pressing buttons on a mouse; swinging of the limbs, exercising of the joints, or coordinating of the body parts can also be put into testing. Some devices accept input from the user and display a response on a computer screen. Other devices generate feedbacks as forces reflecting the input strengths, so that the user can adjust his/her input accordingly.

In addition to regular education applications, Bodily-Kinesthetic IIT can also benefit learners with disability and can be used in medical applications. For example, after an elbow surgery, the recovery can be monitored by setting benchmarks so that the patient can see whether he/she can achieve the target position when bending his/her limb (Figure 4).

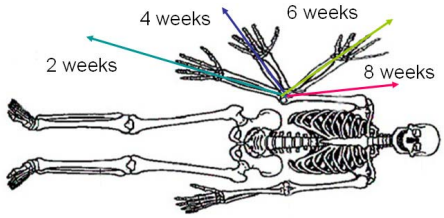

Figure 4: An example of a Bodily-Kinesthetic IIT.

4.5. Other IITs

There are numerous ways to test a student's Logical-Mathematical skill. Figure 5 shows an IIT requiring a student to distribute the numbers into two bins so that the sum in each bin is the same. More bins demands higher skill level.

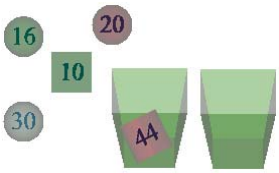

Figure 5: An example of a Logical-Mathematical IIT

Interpersonal skill is mostly relevant in a social context. However, with the advancement in technology, a virtual social environment can be set up, at a single site or across multiple sites using webcams and microphones. For example, the Math item type shown in Figure 5 can be modified for multiple users, to play individually or as a team, collaboratively or competitively. Collaborative editing was discussed in an earlier publication [3]. In fact, majority of the IITs implemented so far can be enhanced for assessing interpersonal skill.

4.6. Testing Strategies

Many students are good at recognizing information from textbooks or at answering questions that resemble the training materials very closely. To enforce a deeper understanding of facts and to probe that acquired knowledge is represented in an abstract form, independent of the training context, testing material should consist of IITs that are designed differently so that a student cannot answer the question simply by memorizing. For example, after a student has learned the Ohm's law and the rules for series and parallel electric circuits, a test item might take the form of Figure 6, which shows an incomplete circuit that has to be connected by placing an ammeter at the right location. Without understanding how to compute voltage, ampere, etc. the student is not able to come up with the correct arrangement.

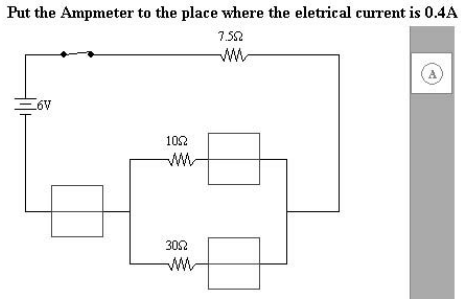

Figure 6: An example of a question to test knowledge translation.

Furthermore, as indicated above, our IITs permit not only the testing of knowledge retention in different formats and different contexts (to test a student's knowledge representation), but also to test in very different and complex contexts (to test a student's cognitive skills).

5. CONCLUSION AND FUTURE WORK

By implementing the intelligent item types, we provide the tools to address the issue of assessing human cognitive skills. This has not been received sufficient attention in the education research community. We discussed the design and testing strategies to obtain accurate assessments, and gave examples to show how these item types are presented. In the current implementation, our item types are designed to test skills separately. The next step is to obtain the students' scores using these IITs and to analyze the results. In future work, we will also include the multimodal approach to analyze how multiple intelligences of different strengths may enhance or degrade a student's performance.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] P. Bolanos, "From Theory to Practice: Indianapolis' Key School applies Howard Gardner's multiple intelligences theory to the classroom," School Administrator 51(1):30-31, 1994.
[2] T. Blythe and H. Gardner, "A School for all Intelligence," Educational Leadership 47(7):33-37, 1990.
[3] I. Cheng, M. Bates and A. Basu, "Collaborative Online 3D Editing," SIGGRAPH 2003 Webgraphics (Presentation and Abstract), July 2003, San Diego, CA USA.
[4] L. Ellison, "Using Multiple Intelligences to set Goals," Educational Leadership 50(2):69-72, 1992.
[5] K.C. Feng, B. Chang, C.H. Lai and T.W. Chan, "Joyce: A Multi-Player Game on One-on-one Digital Classroom Environment for Practicing Fractions," Proceedings of the Fifth IEEE International Conference on Advanced Learning Technologies (ICALT'05), 2005.
[6] C. Fowler, "Recognizing the Role of Artistic Intelligences," Music Educators Journal 77(1):24-27, 1990.
[7] A. Friedman, M. Zibit and M. Coote, "Telementoring as a Collaborative Agent for Change," The Journal of Technology, Learning and Assessment, Vol. 3, No. 1, May 2004.
[8] H. Gardner, "Frames of Mind: The Theory of Multiple Intelligences," New York: Basic Books.
[9] J.R. Galvao, P.G. Martins and M.R. Gomes, "Modeling Reality With Simulation Games for a cooperative learning," Proceedings of the 2000 Winter Simulation Conference, 1692-1698, 2000.
[10] T. Hoerr, "How Our School Applied Multiple Intelligences Theory," Educational Leadership 50(2):67-68, 1992.
[11] K. Ivers and A. Barron, "Multimedia Projects in Education: Designing, Producing and Assessing," 2nd Edition, Libraries Unlimited, 2002,
[12] R. F. Lyvers and B. R. Horowitz, "A Unique Instructional Tool for Visualizing Equipotentials and its Use in an Introductory Fields Course", IEEE Transactions on Education, Vol. 36, No. 2, 237-240, May 1993.
[13] G. McCalla et al., "Active learner modelling," Intellegent Tutoring Systems 2000, pp. 53-62.
[14] K. Stubbs, "Kana no Senshi (Kana Warrior):A New Interface for Learning Japanese Characters," CHI, 894-895, 2003.
[15] D. Stockley, C. Groeneboer, T. Calvert and L. Harasim, "Virtual-U: An online learning environment," WebNet 1997.
[16] L. Teles, L. Harasim and T. Calvert, "VIEW: An educational tool for the information highway," Ed-Media Conference, 1994.
[17] T. Tang and G. McCalla, "Utilizing artificial learners to help overcome the cold-start problem in a pedagogically-oriented paper recommendation system," AH 2004, pp. 245-254, 2004.