Information Technology in Childhood Education Annual (2003), 173-186

Teacher-Directed Software Design: The Development of Learning Objects for Students with Special Needs in the Elementary Classroom

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Working with special education teachers in elementary settings student instructional designers created three instructional tools based on the concept of "Learning Objects." Graduate and undergraduate students under the supervision of two faculty members in their university's Department of Teaching and Learning worked with local teachers to produce flexible, computer-based, interactive instructional activities, designed for use in both one-to-one and group settings. The following is a description of why and how the Learning Objects were created, as well as discussion of the project goals and implications for further study in this area.

Small, self-contained instructional activities or "Learning Objects" are currently a subject of consideration within the Instructional Design community (Beck, 2001). According to the Wisconsin Online Resource Center

(2001), Learning Objects: (a) are self-contained instructional activities; (b) offer just-enough, just-in-time instruction; and, (c) are well suited to the creation of customized instruction. Learning Objects do not necessarily have to be computer-based, but the traditional database approach to computing is well suited to Learning Object production, distribution, and presentation. Since Learning Objects are discrete entities that can be organized any number of ways (depending on the instructor's perceived need), they are eminently suited to organization and storage within a database-type of structure (an "object-base"). If the production format is compatible, computer-based Learning Objects can be organized, stored, and distributed using standard protocols (e.g., http—the transfer protocol of the World Wide Web [WWW or Web]). Taking a Learning Object approach to the design and production of instructional media addresses the resource limitations common to most elementary learning settings while allowing for the development of genuinely useful and usable instructional media (Brown & Miller, 2001). Just as teachers use manipulatives, dry markers, and overhead transparencies in their everyday instruction, teachers can similarly use Learning Objects.

Learning Objects can be used in instruction on an individual basis or projected onto a screen for group instruction. They are flexible tools that can be paused during instruction to demonstrate, model, or add further elaboration. Students can also interact independently with Learning Objects, just as they can independently explore any teaching and learning tool, such as Cuisenaire rods, microscopes, or maps. The power of the Learning Object, however, is more completely realized when teachers mediate the interaction in order to facilitate concept attainment (Miller, Brown & Robinson, 2001).

THE NEED FOR FLEXIBLE LEARNING TOOLS AMONG STUDENTS WITH SPECIAL NEEDS: A CASE FOR LEARNING OBJECTS

Students with special needs, such as learning disabilities, mild mental retardation, and behavioral problems often struggle when attempting to understand abstract concepts. In addition, these students often require more extended practice to master concept understanding (Olson & Platt, 2000). Attention deficits and motivational factors can further complicate the teaching and learning process (Hickson, Blackman, & Reis, 1995). The teachers of these students are often challenged by the task of designing instruction that will facilitate concept understanding and developing activities that will reinforce and maintain learning. With new computing technologies, instructional tools can be developed that are not only effective and flexible, but also motivating to students (Lindsey, 2000).

Most special education teachers have used computers and software for teaching functional and academic skills, as well as drill and practice. (Russell, Corwin, Mokros, & Kapisovsky, 1989; Okolo, Bahr, & Reith, 1993; Babbit & Miller, 1996; Gleason, Carnine, & Boriero, 1990; Stevens, Blackhurst, & Slator, 1991). The software used for these purposes tends to be very structured, controlled, and sequenced (Bottge & Hasselbring, 1993). Because of these characteristics, most software programs leave little room for the teacher to decide where these software programs fit in the curriculum. However, it is possible to make computer-based, flexible learning tools that can be easily integrated into a curriculum and that facilitate effective concept instruction.

The computer has been an effective tool in motivating students and is very compatible with effective instruction for students with mild disabilities. However, much of the computer-based instructional software currently available focuses on one of two areas: providing drill and practice activities on skills; or following a specific curriculum sequence that may or may not relate to the goals and objectives determined by the classroom teacher and/or the student (Brown & Miller, 2001). The application of Learning Objects, specially created, brief (single-concept) computer-based instructional tools, appears ideal as a means of addressing these issues.

LEARNING OBJECT PRODUCTION IN A RESEARCH SETTING

As part of a funded research project, a university in the northwest set out to study the feasibility of creating Learning Objects for classroom instruction for students with special needs. Funding allowed researchers to support collaborative teams of graduate and undergraduate students interested in instructional design and in-service classroom teachers. During the 2000-2001 academic year, three teams of education and technology students designed and developed three computer-based flexible learning tools for three teachers of students with mild disabilities.

The process of design and development involved a series of ongoing team meetings with the assigned teacher, alternating with design work in the computer lab on the university campus. In the initial stages of design, the teams interviewed the teachers to obtain information on: (a) what concepts were being taught, (b) what the teachers believed they needed to effectively teach these concepts, and, (c) student characteristics that would impact the design.

The student teams began with paper sketches of possible learning tools, before attempting any computer-based Learning Object production. The

data from the teacher interviews, as well as principles of effective instructional design, were integrated into the paper designs. Over a six-month period, using the software authoring program *Director 8.0*, students designed the actual learning tools. Teachers provided input on all aspects of the Learning Object design, from the screen colors, to the types of objects to be manipulated on screen, to the instructional and learning demands of the task. The objects were disseminated to the teachers on CDs and online through a web site developed for the project (http://education.wsu.edu/widgets/).

DESIGNING THE LEARNING OBJECTS: A KNOWLEDGE OBJECT APPROACH

A Learning Object is one portion (the "multimedia object" portion) of a Knowledge Object as described by Merrill (1999). Merrill defined a Knowledge Object as "a container for the information components thought to be required to adequately solve a particular type of problem" (Merrill, 2001, p.37). Each Knowledge Object should be made up of essentially the same components: a name, portrayal, and description (Merrill, 1999). The portrayal portion of the Knowledge Object, "is one or more multimedia objects (text, audio, video, graphic, animation) that will show or represent the knowledge object to the student," (Merrill, 1999, p. 402). The organization of this Learning Object production project followed this approach by generating three components for each object produced: a title, the instructional media itself (i.e., the Learning Object) and a brief description of why the Learning Object was created and how it worked (Figure 1 or http://education.wsu.edu/widgets/).

Part of the ongoing discussions (bi-weekly meetings) during the production of the Learning Objects focused on whether the computer tools being created were to be used as "stand-alones" or with a qualified instructor present (offering guidance and feedback to the learner). It was generally decided that the tools were intended for use with a qualified instructor present and participating in the event. This philosophy is in keeping with Merrill's assertion that "a learning environment without instructional overlay is only part of an instructional transaction and is therefore incomplete" (Merrill, 1999, p. 415). This perspective was not clear to all the participating teachers. One teacher initially expressed interest in abdicating all instructional responsibility to the computer. It was generally agreed that the teacher should provide instructional overlay by guiding students, keeping them on-task, and determining whether the instructional media was truly fostering learning.

Figure 1. A Learning Object presented in Knowledge Object format

The three Learning Objects designed during the course of the project specifically addressed concepts of multiplication, number sense, and money.

Multiplication with Sets Learning Object

This Learning Object was designed to teach elementary students with special needs the concept of multiplication with sets (Figure 2). The teacher of these students desired more flexible tools for teaching the concept of multiplication, in addition to his traditional manipulatives and semi-concrete materials. In the past, when the teacher asked his students to represent the algorithm of "3x4" by coloring in parts of a graph paper, the students often colored in three squares across and four squares down, missing the concept of "sets" or "groups." Outlining and coloring sets incorrectly reinforced the misunderstanding of multiplication sets. The team designed a tool that would limit these types of mistakes and provide a visual and interactive method of understanding that the algorithm "3x4" represented three sets of four (or four sets of three).

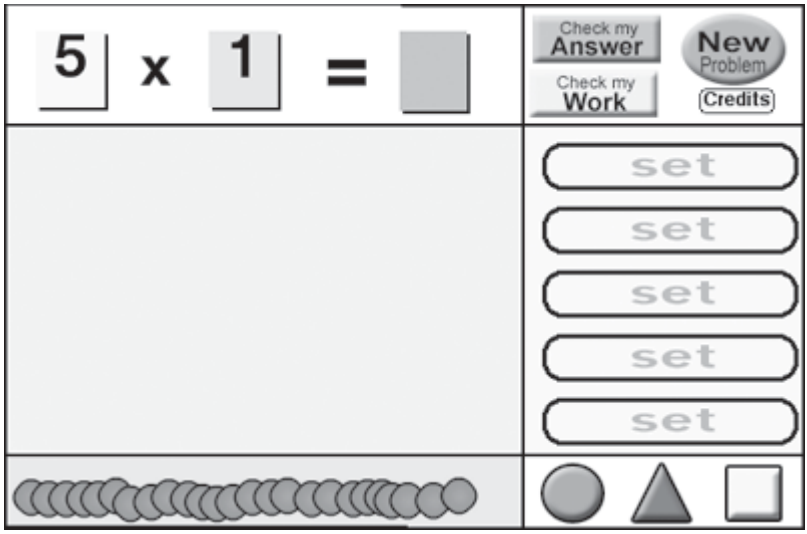

Figure 2. Multiplication with Sets Learning Object

The "work table" for this tool is the computer screen with objects and set holders that the student can move into and out of sets. The operations are flexible in that they can be reversed. In addition, an automatic check of the student's response is provided, the student's workspace is checked for accuracy, and the program assesses whether or not the correct "sets" of objects are present.

Number Sense Learning Object

One of the teachers in this project was challenged by teaching number sense to elementary school students with special needs. A tool was needed for the instruction of number recognition and the counting of objects, as well as one that would facilitate a deeper understanding of number-object relationships, such as the concept that four objects represent the concept of "4." The Number Sense Learning Object was designed to meet this instructional need (Figure 3). This Learning Object allows students to click on a numeral from the bar along the bottom of the workspace, and the corresponding number of objects appear one at a time on the workspace opposite the numeral. The program is designed to proceed sequentially through numbers to "20" automatically if no specific number is chosen. This tool can be used to

teach both sequential or random number recognition and counting corresponding objects. If the teacher would like to add further clarification or explanation, the pause button can be used at any time to stop the sequential progression. The use of instruction with manipulatives during the program pause can also be integrated to reinforce concept understanding.

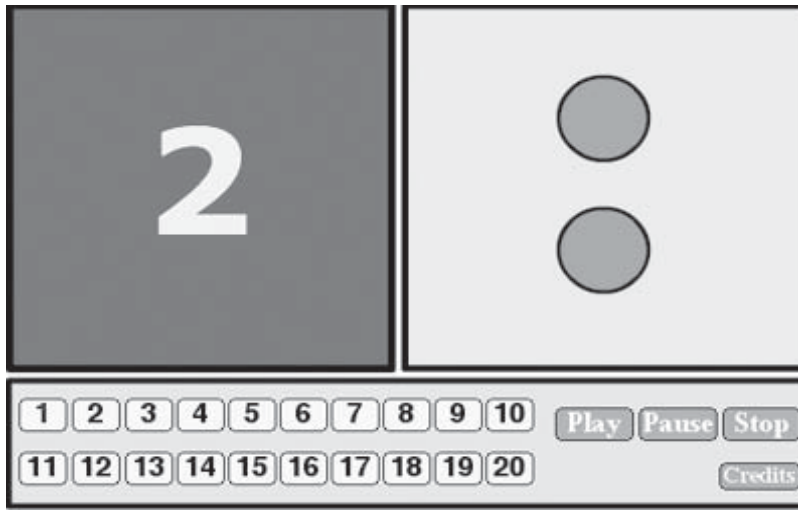

Figure 3. Number Sense ("Counting 1 to 20") Learning Object

Dollars and Cents Learning Object

The Dollars and Cents Learning Object was designed to assist in the instruction of money concepts and estimation (Figure 4). This Learning Object presents a picture of an item to be purchased with the cost shown in a price tag. The money available for the purchase is pictured below the object and can be highlighted by the student. The program will indicate if the estimated amount of dollars and change highlighted is within a reasonable range (up to $.25) by selecting the "Check My Work" button. Before a new item is purchased, the teacher can explain the concepts that were previously shown, add further elaboration about the transaction, and reinforce the money identification process.

The teacher for whom this software was designed had observed several of her students with special needs during purchasing activities. The students routinely gave clerks 20, 10, and 5 dollar bills for items that cost 50, 25, and

15 cents. The teacher was challenged by the task of explaining the concept of estimating, as closely as possible, the amount of money to offer for a specific item. A tool was needed that would allow students a variety of practice activities in estimating the cost of an item to the closest 50-cents. The teacher also wanted a tool that would assist in the instruction and reinforcement of the concepts of money identification, addition, and subtraction. Dollars and Cents was designed for those students with emerging skills in money recognition and purchasing and to facilitate the understanding of estimation in making purchases.

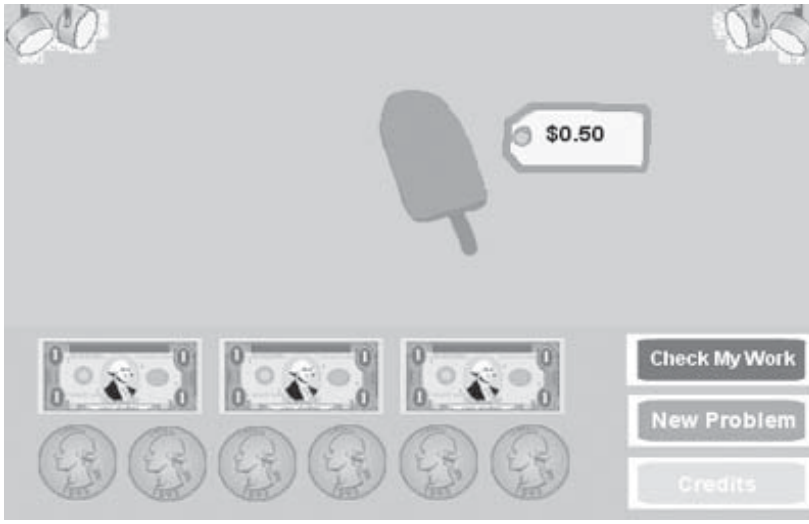

Figure 4. Dollars and Cents Learning Object

THE PRODUCTION PROCESS

No production process is without its myriad of challenges and setbacks, however creating the three Learning Objects in this instance was relatively straightforward and accomplished with a minimum of complications (Brown & Miller, 2001). Project funding was received in October, 2000. Research preparation began immediately upon receipt of funds, and the design and development of the Learning Objects was conducted between January and May of 2001.

PARTICIPANT SELECTION

A request for proposals was distributed among university students, inviting them to submit a brief outline of their interests and experience with instructional media production, as well as some indication that they would have time in their schedule to work on a project of this nature. Three student teams were selected from the proposals submitted, two pairs of graduate students and an individual undergraduate. Three of the participants were in education degree programs, one was in a business degree program, and the undergraduate was majoring in English. All of the participants were carrying full course loads. All five participants had some experience in digital media development (making web pages, *PowerPoint* presentations, simple programming, and digital image manipulation) but none had much experience with an authoring tool such as *Director*.

Simultaneous to the student selection process was the process of identifying participating teachers. Three teachers from a local school district agreed to take part in the project. The student teams were assigned to an individual teacher with the understanding that the students were serving as instructional media producers, supporting the teachers' and students' needs.

PRODUCTION MODEL AND PARAMETERS

It was generally agreed upon that the Learning Objects would be produced using *Director* software (although Macromedia *Flash* was also presented as an option). Since the ultimate goal was to make the objects widely available through the Web and CD-ROM distribution, it was further agreed that the objects be limited to a web-safe color palette and that they be no larger than 500 x 330 pixels.

The teams generally followed an Analysis, Design, Development, Implementation and Evaluation (ADDIE) production model. The analysis phase included interview and discussion with the client and classroom observation as well as expert review from Special Education and Instructional Design experts. The design phase included the creation of storyboards and paper-based mock-ups (shared frequently with the teachers to receive feedback) as well as experimenting with low-fidelity *Director* files in order to test whether specific functions could be accomplished (e.g., the random generation of numbers, the ability to constrain small polygons to the borders of a larger polygon), (Robinson, Brown, & Miller, 2001). Development involved the actual line-production of the Learning Object and some simple usability testing to ensure the finished product was free of severe or high programming bugs

(Buie, 2001). For the purposes of this project, design and production of the Learning Objects were included in Phase One; and implementation and evaluation are considered part of Phase Two.

TECHNICAL SUPPORT

During the production period, the student teams met biweekly with the principal investigators. During those meetings, the teams reported their progress on articulating ideas with the teachers, shared design sketches, discussed mock-ups, and examined low-fidelity computer-based versions of their work. In the early stages of production, the meeting times were also used to hold workshops on the use of the *Director* software. In the later stages of the project, the workshops became more like "show and tell" and trouble-shooting sessions (Brown & Miller, 2001; Robinson, Brown, & Miller, 2001). Students were also made aware that they were welcome to receive support and advice from the faculty. Support given through e-mail consisted primarily of the passing of Lingo scripts (the programming language used by *Director*).

PRODUCTION OUTCOMES

All three teams were able to produce effective Learning Objects within the five-month, January to May, production time. When surveyed and interviewed, all of the teachers involved were pleased with the finished products, and the objects received a good deal of positive response from other classroom teachers and instructional design professionals as well. A small group of instructional design professionals from around the United States were asked to review the students' work and found the designs and their production to be sound.

In interviews, all of the students participating in the project reported feeling that they had learned a great deal about computer-based instructional media production and instructional design (Brown & Miller, 2001). One student expressed fascination with the entire instructional media production process, saying, "I thought it would be a challenge to make something complicated; it was a greater challenge to make something simple!" (It is the authors' contention that the finished object only appears simple because it is well designed; it is actually a quite sophisticated authoring feat). Another student reported this to be, "One of the most satisfying experiences I've had

as a student," expressing excitement at her newfound media production abilities and an interest in creating more Learning Objects.

During the course of the project, it became clear that one of the most critical elements for the teams that led to the successful completion of the Learning Objects was having access to and support from someone more expert than they in media production. An obvious shift in attitude/affect of the students considered "high proficiency" was observed when they discovered that one of the principal investigators was a sophisticated user of *Director*. These students became more excited about creating a Learning Object using *Director*, asking more questions and experimenting further with advanced interactivity functions (Brown & Miller, 2001). A greater willingness among the participants to talk and share was evident as the project progressed. Excitement grew significantly as students realized that the paper-and-pencil drawings could indeed be turned into working models.

The teachers involved in the project received all three Learning Objects on CD-ROM compatible with both Macintosh and PC operating systems, and are able to access the Learning Objects online through a Web site created specifically for this purpose (http://www.education.wsu/widgets/). The production aspect of this project was considered a success for having served as an authentic experience in designing instruction using innovative technologies for education students and an opportunity to work in a meaningful way with teachers.

DISCUSSION

Development and use of Learning Objects in elementary classroom settings proved to be an exciting educational experience for teachers and students. In interviews with the teachers at the end of the project, all three felt that the Learning Objects developed were flexible enough to be used for a variety of instructional purposes with a wide range of learners. The teachers expressed a high degree of satisfaction in having additional motivating and effective teaching and learning tools in their "instructional toolbox."

With regard to the situation in which high-proficiency graduate and undergraduate students demonstrated an attitudinal shift upon realizing that one of the principal investigators was a sophisticated media producer, the authors suspect this is often not the case in education-oriented media production projects. One or more students may often bear the burden of being the most technologically expert members of the project, with faculty members serving as guides in areas other than line production (Brown & Miller, 2001). If a student cannot solve a production problem, the project often

fails. It should be noted, however, that the majority of instructional media projects fail regardless of the presence of expert resources (Winograd, 1996). It may be of importance to pursue this issue further to better understand how to create and support activities that effectively teach instructional media production skills.

The Learning Objects were designed with the philosophy that the real power of these tools lies in the "instructional interactions" that take place between the teacher and student (Cuban, 1986). Teacher mediation in the use of the Learning Objects was seen as a critical component to their design. The design teams wanted to develop tools that teachers could tailor to the individual students' needs, not tools that students merely "reacted to" (Miller, Brown, & Robinson, 2001). The Learning Objects were designed with the assumption of teacher empowerment in the planning and implementation of technological applications. The design and development emphasized learning *with* technology rather than learning *from* technology (Jonassen & Reeves, 1996; President's Commission of Advisors on Science and Technology, 1997).

Most educators today review and receive software programs, and then are faced with the task of trying to "fit" the software into existing curriculum. The unique aspect of this project was involving the teachers from the very inception of the Learning Objects. All of the teachers had the opportunity to impact the design of the programs, from the colors used, to the objects represented, to the interaction demands of the Learning Object. The teachers felt empowered to create and specify the type of learning tool that would best meet their students' needs. As a result of this collaborative and interactive effort, the design teams were able to produce three effective, flexible, and exciting learning tools.

RECOMMENDATIONS FOR FURTHER STUDY

This project was designed to examine the feasibility of creating Learning Objects for classroom instruction using collaborative teams of teachers and instructional media producers. Taking a user-centered design approach, the study examined whether teachers and instructional designers developed increased sophistication in the design of the computing tools for instructional purposes. Although the teachers involved in the project were encouraged to assess the effectiveness of the Learning Objects through individualized pre and posttests, this project was designed to examine the collaborative involvement in *designing* Learning Objects. The next logical step is to extend this study by conducting field-based research on the effectiveness of the

Learning Objects created in this project. The application of a rigorous experimental design would be necessary to demonstrate the impact on student achievement.

Learning Objects are flexible, easily accessed and stored, effective tools in concept instruction. This is a new type of computer-based instructional and learning tool, one that can be designed to meet specific purposes and are appropriate for a wide range of students. The Learning Objects designed in this project are a beginning in what could be a vast repertoire of tools designed to meet disparate instructional needs. Technological advances, such as affordable and highly portable touch screens (similar to those currently used in personal digital assistant [PDA] devices), will allow design teams, including teachers, a much wider range of possible applications for Learning Objects. Future research should explore both the design and efficacy of similar Learning Objects across curriculum disciplines and student populations.

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Note

This project was made possible through funding from the Arc of Washington Trust Fund.