Scientific/Technical Report
Science Literacy Project

Award number—DE-FG02-06ER64286
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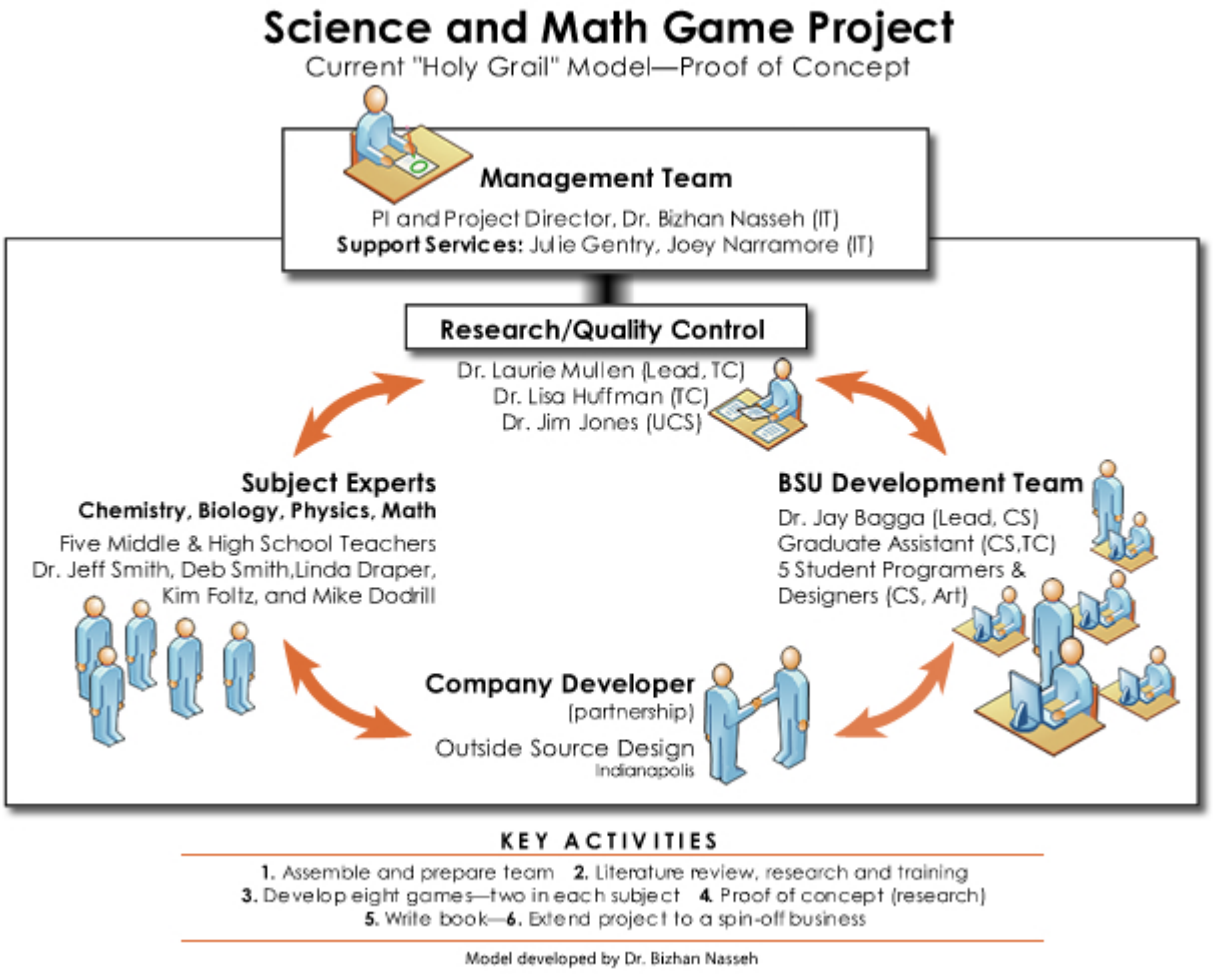
Ball State University
August 2006 to August 2008

Executive Summary:

The Science Literacy Project became possible with a grant from the Department of Energy. The Science Media Program will merge Ball State University's nationally recognized capabilities in education, technology, and communication to develop new, interactive, game-based media for the teaching and learning of science and scientific principles for K-12 students. The University established a team of educators, researchers, scientists, animators, designers, technology specialists, and hired a professional media developer company (Outside Source Design) from Indianapolis. After six months discussions and assessments the project team selected the following 8 games in Mathematics, Physics, Chemistry, and Biology, two from each discipline. The assembled teams were innovative and unique. This new model of development and production included a process that integrated all needed knowledge and expertise for the development of high quality science and math games for K-12 students. This new model has potential to be used by others for the development of the educational games. The uniqueness of the model is to integrate domain experts' knowledge with researchers/quality control group, and combine a professional development team from the game development company with the academic game development team from Computer Science and Art departments at Ball State University. The following is the model that was developed and practiced in this grant. The developed games went through feasibility tests with selected students for improvement before used for the research activities.
The eight games are as follows.

- Biology Games (Photosynthesis, Cell Division)
- Chemistry Games (Density, Conservation of Mass)
- Mathematics Games (Perimeter and Area, Variables)
- Physics Games (Vectors, Mass and Weight)

More details on these games are available at http://www.bsu.edu/slp/



Research Summary:

In spring 2008, school identification and game testing took place. The subject population included 7th grade classes at Delta, Alexandria, and Yorktown Middle Schools in Indiana. The 331 participants (171 females, 160 males) were selected in collaboration with school administrators based on their willingness to participate, technical viability (location, infrastructure etc.), quantity of students, and the geographic characteristics of the local neighborhood. All seventh grade students with an approved consent forms participated. Each of the eight games was randomly assigned to individual classrooms at participating schools.

A written pretest was administered to assess student level of knowledge and misconceptions held with respect to the learning objectives. A member of the research

team presented verbal directions for the pretest to the students. One week later, each student accessed the computer game online and participated in the activities. Two weeks later, the same member of the research team returned to the classroom to administer the written post-test to assess the impact of the modules on student learning of the material. Data collected include the student's pre-assessment knowledge, online game play, and post-assessment. Information concerning the activities each student engaged in within the module, the level of repetition, and types of errors or choices made were recorded. Demographic characteristics of the students, such as gender, grade level, general ability level in subject, and measures such as free/reduced lunch or educational classifications (e.g., learning disabled, gifted, etc.) were matched to the data gathered on the students from each module anonymously.

Student learning:

Overall, the data on student learning gains on the pre and post-test scores are not consistently significant. The following games, Tightrope Walker (balancing chemical equations), Gravity Patrol (mass vs. weight), Pirate Math (variables), Dense Invaders (density of matter), and Area Adventures (perimeter and area) had inconsistent and large discrepancies in student interaction and pre-post scores. There are exceptions however. In the Chlorofill game, students increased their test score mean from 13.17 (73.17%) at pretest to 14.26 (79.22%) at post-test with differential impact on boys and girls. Results showed over a one point gain overall ($F_{(1, 61)} = 12.19$, $p = .001$), and a differential impact for boys and girls ($F_{(1, 61)} = 5.76$, $p = .019$). Girls increased from a mean score of 14.25 on the pretest to 14.66 on the post-test while boys improved over two points from an initial score of 13.84 to a post-test score of 16.03.

The results from Vector Ice indicate that the students increased their test score mean from 8.84 (58.9%) at pre-test to 9.81 (65.4%) at post-test. Some of the levels within the game showed statistically significant relationships with the gain scores ($r = .34$, level 3; $r = .33$, level 4, and $r = .41$, level 6). These relationships would appear to indicate that more persistence at these levels was related to subsequent increases in the post-test score.

Results for the Cell Divide game show an increase in the post-test score mean from 5.62 (28.1%) at pre-test to 6.88 (34.4%) at post-test. A statistically significant

correlation was found between the gain score and time spent playing the game for the first session ($r = .41$, $p = .045$), and some correlations approached statistical significance, such as gain score and highest level reached during game play ($r = .38$, $p = .064$) and gain score and time spent playing the game during the second session ($r = -.39$, $p = .055$). The maximum level reached during game play was in a positive direction, but not statistically significant ($\beta = .29$, $p = .13$). These results would suggest that more time spent on the initial game coupled by less time on subsequent games produced higher gains on the post-test.

These results above are promising and indicate specific areas where future research must address. As with empirical research in a new field, we are left with more questions such as:

1. Were the game characteristics relevant to the three games above similar enough to have a potential relationship to student learning outcomes?
2. If the classroom teacher were to have included the SLP games as part of a comprehensive unit, how would this have changed how the students perceived the game and subsequent learning outcomes?
3. In the taxonomy of computer games, is there a better fit between certain types of games in a school context vs. at home or other settings?

In addition of the above accomplishments, the following are some of the other outcomes of SLP project.

Teachers Development:

The five teachers, one chemistry, two math, one biology, one physics indicated that how working with researchers and development teams (OSD and BSU) helped them in their teaching, learning, and digital content development at their schools. These five teachers gained adequate knowledge which enable them to train and advice other teachers in digital content development and usage of it in teaching and learning.

The researchers established a framework for each module and asked teachers to follow the frame work in selection of subjects and development of content for the games. The researchers and the developers worked together with teachers on the team to create a development method for all the games. One of the teachers wrote “When the conception

of the game was developed the fun really began. It was interesting to see how the game evolved over time." Another teacher wrote "It was pretty neat to see how my observations and critiques were utilized with the game development to improve the over all quality."

Students Development:

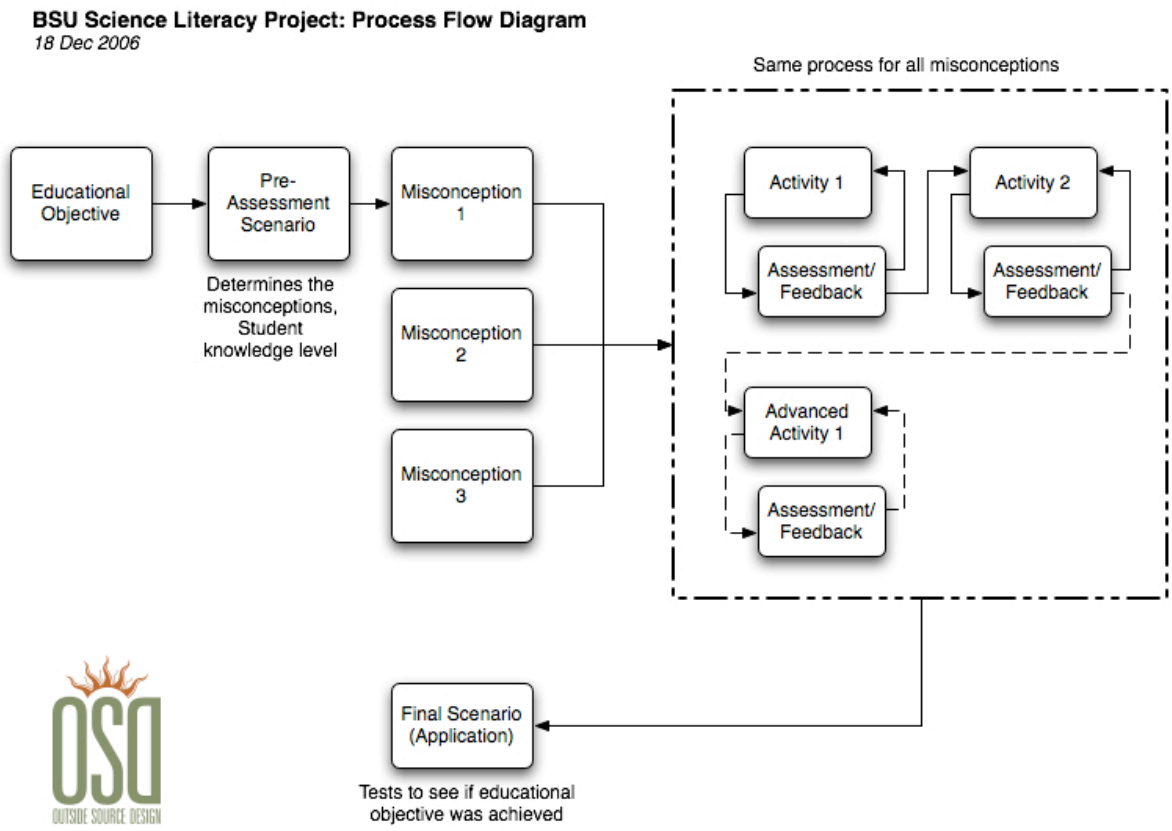
The SLP project provided an excellent immersive learning opportunity for the student developers on the team who participated in the design, development, and research activities.

The students were from the disciplines of education, computer science, graphic design and music. The enormous advantage of having a team of such diverse areas became evident in the design and development phases. During these phases, the constant flow of artistic-oriented ideas combined with rational and analytical thoughts created a perfect balance of highly creative and highly educational final products.

The student developers gained extensive experience in state-of-the-art technologies that were used to create the games. These technologies include Macromedia/Adobe Flash/Action Script 8.0 and 9.0, Adobe Photoshop, Adobe Illustrator, Microsoft ASP.NET and HTML for web-based user interface development, Microsoft SQL Server Database for data tracking and retrieval, and digital music creator software. The constant interaction among the development team, researchers and teachers was a key contributing factor to the success of the project. This interaction enhanced the entire team's software development experience and expertise since it paralleled what students are likely to encounter in real-life business settings. Additionally, the interaction of the team members with experts in education, mathematics and science created a perfect environment to develop and put into practice leadership and teamwork skills.

Methodology & Design:

After 6 months of discussions, evaluations, and assessment the project team (teachers, developers, researchers) developed the following development model for all the eight games. Based on this model the development activities and processes were clear to all the different teams and made it easy to focus on the outcome oriented development. The model is available for other to use it.



The first draft of each game was tested by all the members of the SLP team, and the input helped the initial improvement of the games. In order to assess the playability of the games developed prior to final testing a usability study was completed during May and September, 2007. The focus of this portion of the study was on the implementation of the game; in other words, did the students find the module fun and game-like, and were the instructions and user controls understandable? With the exception of one game, the 55 students in May and 277 students in September (total n=332) were very positive in their feedback of the modules. For 7 of the 8 modules, over 80% of the students indicated they would like to play the game again. The most common description of the modules was "fun," while many students also provided positive descriptions of the educational aspects of the modules. For the one module that was not favored by the students, the main difficulty with that module was lack of clear introductory instructions that left almost all the students confused when attempting to play that module. For the other modules, some

students would provide suggestions to help improve game-play. Where feasible and if not distracting from the educational objective, the suggestions provided by the students were included in revisions of the 8 games.
By December 2007, the development of the all the 8 games completed.

Publications and Presentations:

"Can Video Games Change Students Scientific Misconceptions?" has been accepted for presentation at the 2009 Hawaii International Conference on Education, January 4-7, Honolulu, Hawaii.
"Software Development of SLP Games", Department of Computer Science Showcase, Ball State University, April 2007.

Future Opportunity:

If the United States is to remain competitive in the global economy, our citizens must not only be scientifically literate but also innovative. American society is increasingly dependent upon sophisticated technologies. However, only a small fraction of our citizens actually understand those technologies. Improvements to science education will help move the economy to the next level, where average citizens have an understanding of scientific and technical principles. The development of new media in science education will help pull us toward that goal. The entertainment industry has taken the concept of "gaming" from the checkerboard to the rich, interactive gaming media that children enjoy today. The same approach can be applied to science education. The same rich, interactive media can be used to pull American youth into fascination with science and scientific discovery. The following research stats from National Assessment of Educational Progress clearly indicates a great need to do what is possible to redefine our science education in K-12 school system. Our children are the best to play recreational games and if we be able to provide them game-based science and math learning opportunity, our K-12 school students might learn all needed basic of science and math which can help them to succeed in higher education and provide society needed scientists that can compete with the best in the world and help to preserve America's place as the center of innovation and creation in the world.

Trend in Science Achievement Levels according to National Assessment Of Educational Progress (NAEP)

4th Grade Science Students Achievement Level (by percentage)

Assessment Year	Below Basic Level	At or Above Basic Level	At or Above Proficient Level	At Advanced Level
1996	37%	63%	28%	3%
2000	37%	63%	27%	3%
2005	32%	68%	29%	3%

8th Grade Science Students Achievement Level (by percentage)

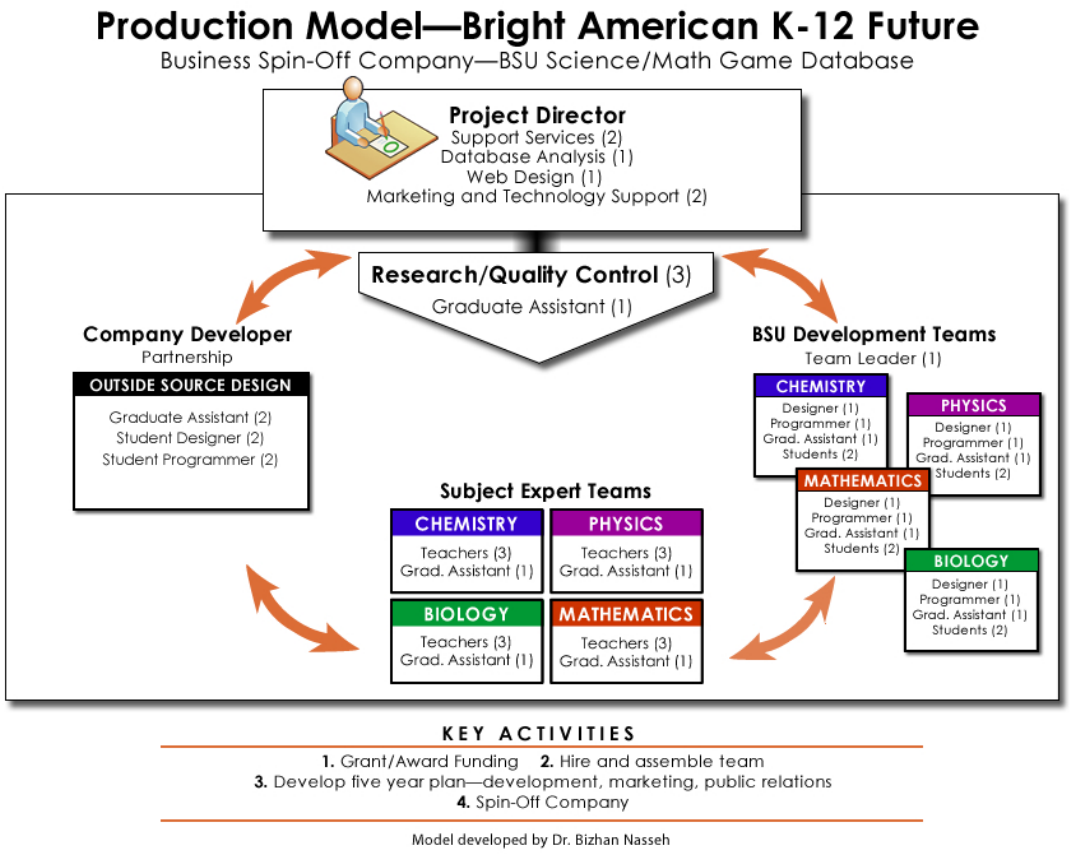
Assessment Year	Below Basic Level	At or Above Basic Level	At or Above Proficient Level	At Advanced Level
1996	40%	60%	29%	3%
2000	41%	59%	30%	4%
2005	41%	59%	29%	3%

12th Grade Science Students Achievement Level (by percentage)

Assessment Year	Below Basic Level	At or Above Basic Level	At or Above Proficient Level	At Advanced Level
1996	43%	57%	21%	3%
2000	48%	52%	18%	2%
2005	46%	54%	18%	2%

Innovative Development Model

The following is an innovative and unique development model which is results of last 2 years experiences of the team members. The project team members have adequate experiences to implement this model. Anybody who has plan to use the following production model should receive written permission from designer Dr. Bizhan Nasseh (bnasseh@bsu.edu).



The model of the practice is innovative and unique, which can be a future model for similar developments. In recent publications of Educause, the Holy Grail model of game-based educational content development was described as a combination of the team of expert teachers and developers. In comparison, the Science Literacy Project at Ball State created a new model which includes expert teachers, researchers, developers, faculty advisors and project directors. This variety of experience and expertise will surpass the suggested model by Educause in its recent publication (Educause Review, March/April 2006 "Digital Game-Based Learning" by Richard Van Eck). Based on the gained experiences, and collective knowledge of the teams members, the team developed a comprehensive 5 years plan to develop over 500 games in Chemistry, Biology, Physics, and Math. This innovative production model can help tremendously the advancement of the K-12 in science and math. The model has potential to be a spin-off business.

The key elements of this innovative development model are:

- Divide the development team to 4 groups, each group will focus on one subject.
- Divide subject expert team to 4 teacher groups, each group will work with related development team.
- Each teacher group has a teacher from elementary, middle, and high school.
- Research tam will control quality and game to satisfy learning objectives.
- BSU development team and OSD development teams share new ideas and designs.
- Students will participate in design, development, and research.