

AC 2008-2131: GEARUP: TEACHING ENGINEERING, SCIENCE, AND MATHEMATICS TO JUNIOR HIGH AND HIGH SCHOOL STUDENTS THROUGH THE USE OF K’NEX BRIDGES

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GEAR UP: Teaching Engineering, Science, and Mathematics to Junior High and High School Students through the use of K'Nex Bridges

Abstract

Building Bridges to the Future is a GEAR UP program developed by mathematics, science, engineering, and education faculty from Louisiana Tech University. The primary goal of the project is to expose students from under-performing schools to mathematics, science, engineering, and literacy subject areas. Faculty members from the College of Engineering and Science have teamed up with the College of Education to develop engaging projects aimed at junior high and high school students. These projects utilize K'Nex bridges kits as a means for providing a hands-on learning environment. *Building Bridges to the Future* includes aspects of team and collaborative learning, as well as literacy in the teaching of math, science, and engineering principles.

During the summer of 2007, 41 junior high and 54 high school students, from throughout the state of Louisiana participated in the summer camps. Of this group, the majority of the students were from under-represented groups. Material for the camps centered on building bridges. By designing small-scale K'Nex bridges, the students have to apply the math, science, and engineering they are learning to a real-world problem. During the course of the week, the students continually add to their skill set, and the week culminates with a design competition and a field trip to view bridges in the local area. Experiences indicate that topics which utilize hands-on activities and lead to a design competition will motivate students.

Results of the project include documented pre and post test scores, activities developed, as well as student attitudes toward math, science, and engineering.

Introduction

Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP) is a major focus of the United States Department of Education. It is well documented (National Science Board) that enrollment in science based programs has been declining since the 1980s¹. To ensure competitiveness in a changing global economy, the Board strongly recommends national-level action to provide more graduates in science and engineering based fields. (*The Science and Engineering Workforce: Realizing America's Potential*)².

GEAR UP efforts focus on schools where more than 50% of the student population is eligible for free or reduced lunch under the National School Lunch Act. Students in the selected districts were judged to have above-average needs, based on four criteria: 59% or more of the district's students are eligible for free or reduced lunch; the district's composite ACT score is 19.6 or lower; the percentage of first-time college freshmen is 42.7% or lower; and the percentage of freshmen requiring remedial courses is 45.6% or higher.

A summer camp program was developed by the mathematics, science, engineering, and education faculty. The primary goal of the camp is to expose junior high and high school

students from under-performing schools to mathematics, science, engineering, and literacy subject areas through a series of design activities. The camp utilized K'Nex Bridges as a means for providing a hands-on learning experience.

Project Description

Collaborating across two colleges, two one-week camps entitled *Building Bridges to the Future* were offered during the summer of 2007. 41 junior high and 54 high school students, from throughout the state participated in the two summer camps. Of this group, the majority of the students (93.6%) were from under-represented groups. The curriculum for the camps centered on building bridges. By designing small-scale K'Nex bridges, the students applied math and science to a real-world engineering problem. During the weeklong camp, students continually add to their educational skill set, and the week culminates with a design competition and a field trip to view bridges in the local area.

“There are important differences between tasks and projects that encourage hand-on doing and those that encourage doing with understanding...”³ With this in mind, the authors set off to design a one week program that would provide an engaging academic challenge for students.

Building Bridges to the Future encompasses engineering aspects of bridge design as well as team skills, creative problem solving, and career exploration. Each of the explorations planned for the camp are designed to pique student interest and show the importance and relevance of both mathematics and science. Experiences indicate that topics which utilize hands-on activities and lead to a design competition will motivate students⁴. The bridge-building theme was selected because the design of bridges serves as a good application of algebra and trigonometry, is very hands-on and intuitive, gives an excellent introduction to engineering design, and easily leads to a design competition. In addition to the math and science explorations, students participated in leadership development activities and individualized tutoring sessions based on results of a pre-test administered on arrival to camp. Students were able to experience college life through dorm living, participation in a variety of free-time activities, and planned activities provided by camp staff.

Implementation

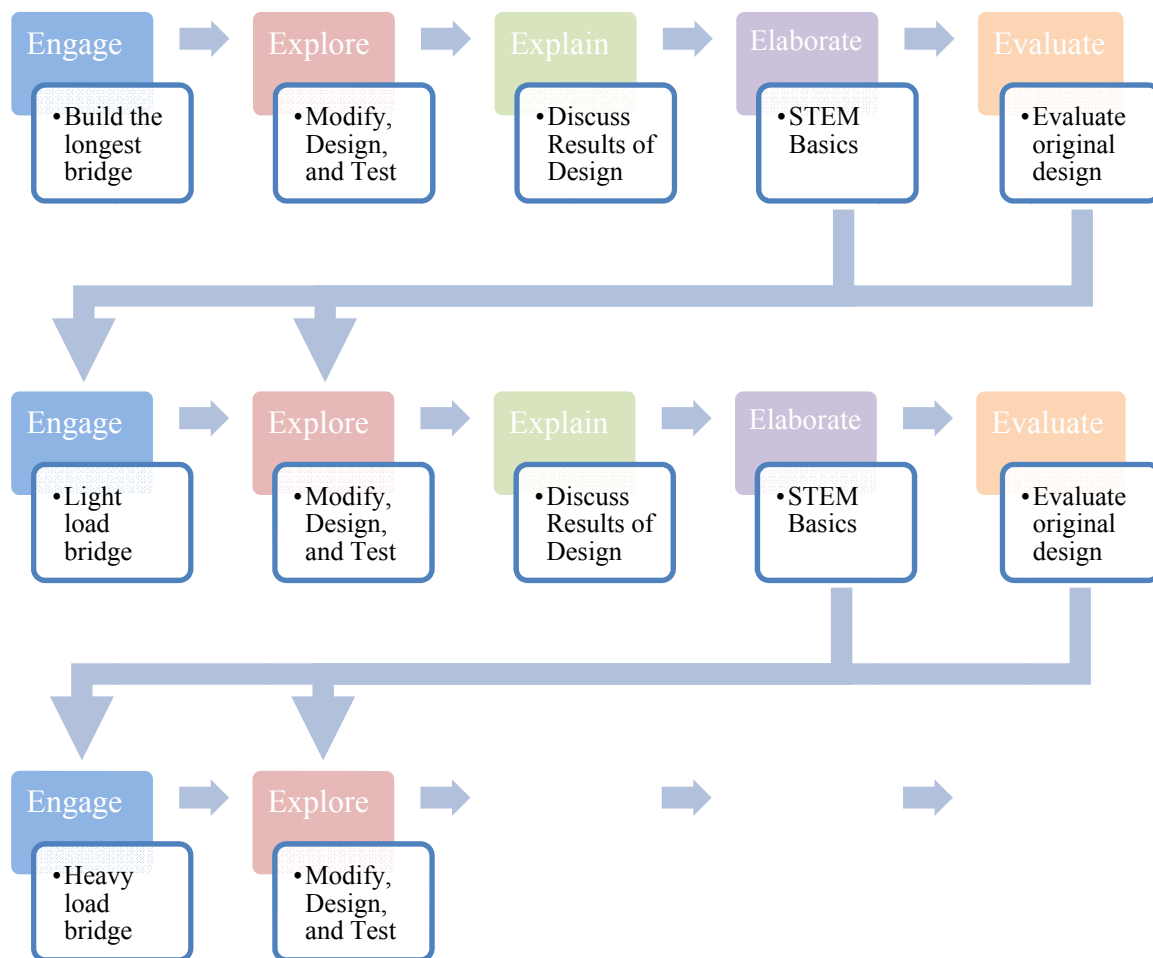
“An alternative to simply progressing through a series of exercises that derive from a scope and sequence chart is to expose students to the major features of a subject domain as they arise naturally in problem situations. Activities can be structured so that students are able to explore,



Figure 1: Students testing K'Nex bridge designs

explain, extend, and evaluate their progress. Ideas are best introduced when students see a need or a reason for their use – this helps them see relevant uses of knowledge to make sense of what they are learning.”⁵

The authors utilized the 5 E Learning Cycle Model of Instruction for use as a guide to curriculum development and day-to-day instructional activities. The Learning Cycle, as developed by Karplus & Thier⁶ and later modified by Roger Bybee, recommends that prior experience and first-hand knowledge gained from new explorations be used when students are learning new concepts, or attempting to connect prior knowledge to higher level understanding . The 5-E model includes five learning experience components: Engage, Explore, Explain, Elaborate, and Evaluate. Each stage builds upon the previous as students construct new understanding and develop new skills. Through *Building Bridges to the Future*, the Evaluation stage was continued the following day by Engaging students in a new hands-on activity that builds upon the previous day.



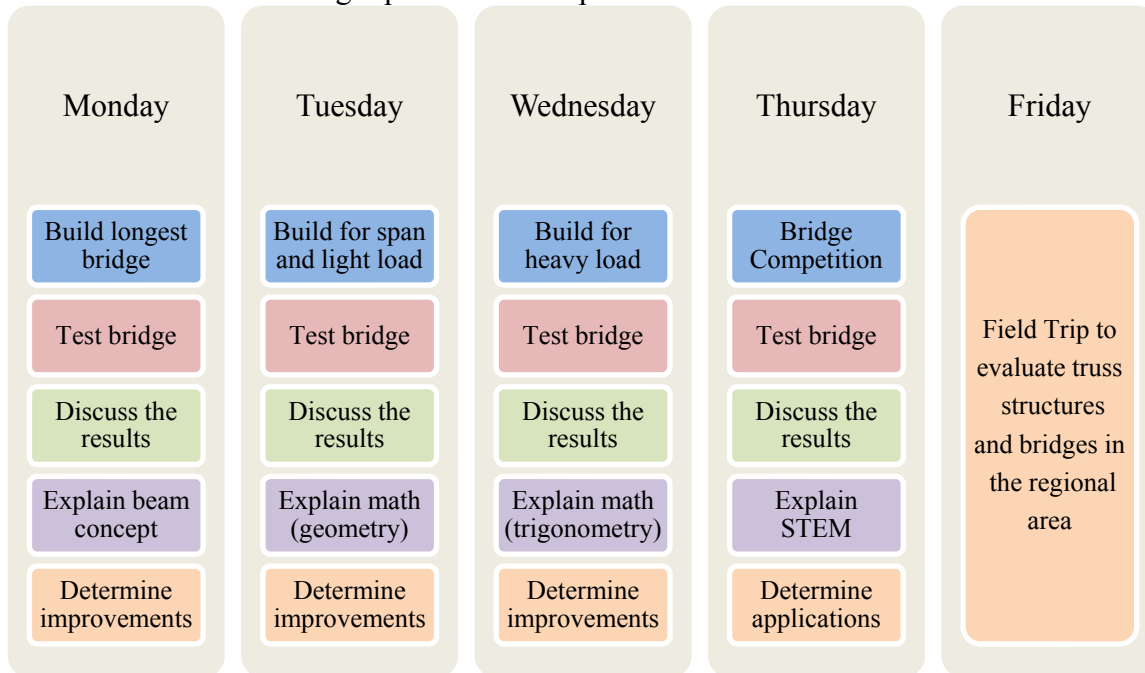
Fundamental to using the 5 E Model while working collaboratively, as well as being essential to scientific inquiry, is the process of brainstorming. Students were introduced to this element by showing a 20 minute video that introduces the IDEO design process. The comments made by the

participants in the video provided a framework to discuss the ground rules for the brainstorming sessions to be implemented during *Building Bridges to the Future*. These guidelines for brainstorming were:

1. No dumb ideas – every idea should be considered
2. No criticizing of other student’s ideas – no idea is better or worse than another
3. Build on other students’ ideas – use previous ideas to springboard new ones
4. Go for quantity over quality – initially formulate as many ideas as possible
5. All ideas are recorded
6. All team members are expected to contribute
7. No long discussions – say your idea and let others contribute also

The students found that in order for the brainstorming session to be successful, the facilitator had to stay neutral, be positive, listen intently, keep the session moving and lively, provide quality prompts and know when to close the discussions.

An outline for the morning topics of the camp is shown below:



Assessment of Student Work - Formative

“To assess students’ conceptual understanding, effective teachers constantly monitor students’ thinking throughout instruction, not just at the end of a unit of study. This ongoing assessment is known as formative assessment”⁷. Understanding that formative, ongoing assessments would be important to the success of the project, the following factors were integrated into the teaching and learning process:

1. The learning outcomes of the activity were clearly stated to the students prior to the start of each activity both orally and in writing.

2. Through purposeful questioning, group communication (brainstorming), and self-evaluation processes, the students became aware of the variance between their initial understanding and the expectations of the activity.
3. Continuous feedback to the students throughout the activity was fundamental as they began to narrow their understanding gap. In addition, the quality and specificity of the feedback was critically important. For example, suggesting that the student “think more about it” was not adequate feedback. Also, the feedback had to be useful to the students. It was important for them to be able to initiate a positive action on the basis of the instructor advice and comments as well as feedback of their team members.

In *Building Bridges to the Future*, it was important to assess the prior knowledge of the participants. This was accomplished through the use of an established assessment tool: ACT’s EXPLORE and PLAN college readiness tests. The results of the science and math components provided diagnostic instruments to ascertain the level of knowledge of the students, as well as determining gaps in their understanding that may be a detriment to their success. Pre-camp testing results are provided below along with the results of the post-camp assessments.

Evaluation of Achievement: *Building Bridges to the Future* Junior High Camp

Results of the *EPAS (Explore test)* pre and post test scores for *Building Bridges to the Future* junior high students showed significant increases in English, Math, Science and overall achievement for the total group (see Table 1). There was a small, but significant decrease in Reading scores. Data collected also shows that 62% of the junior high students significantly improved their achievement score between the pre and post test with an average gain score in achievement of 5 points (11.1%).

Subject	N	# Questions	Pre-test		Post-test	
			Mean	SD	Mean	SD
English	37	10	5.41	2.15	6.08	2.01
Math	37	15	6.62	2.98	8.30	3.59
Reading	37	10	6.03	1.99	4.51	2.45
Science	37	10	5.11	2.11	6.46	2.62
Total Score	37	45	22.97	7.67	25.32	8.94

Evaluation of Achievement: *Building Bridges to the Future* High School Camp

Results of the *EPAS (Plan test)* pre and post test scores for *Building Bridges to the Future* high school students showed no significant increases in Reading, Math, Science or overall achievement for the total group (see Table 2). There was a small, but significant decrease in English scores. Although not statistically significant as a group, it should be noted that 54% of high school students improved their achievement score between the pre and post test with an average gain score in achievement of 3.4 points (7.6 %).

Subject	N	# Questions	Pre-test		Post-test	
			Mean	SD	Mean	SD
English	50	10	5.02	2.42	4.38	1.76
Math	50	15	5.30	2.10	5.90	2.26
Reading	50	10	3.74	2.14	3.84	2.19
Science	50	10	3.96	2.21	3.94	1.97
Total Score	50	45	18.02	6.07	18.04	6.18

Final Camp Evaluation by Students

In order to gain further understanding of the impact of the *Building Bridges to the Future* camps, each student provided feedback to the authors by filling out camp evaluation forms. Students completed a Final *Building Bridges to the Future* Evaluation on the last day of camp. The evaluation contained statements to which campers were asked how much they agreed or disagreed (Likert Scale 1-4). A total of 87 students (37- Junior High; 50 - High School) completed the evaluations. The results of these surveys are presented below in Tables 3 and 4.

Table 3 indicates that Junior High students clearly were satisfied with the overall organization and experience at camp, evening activities, thought the experience would help them in school, and would recommend it to others as indicated by the mean scores of 3.40 or higher and a percentage of agreement of over 90% on 6 of the 8 statements. Slightly lower scores were reported for satisfaction as to learning about self (3.24/89.19%). The lowest response was satisfaction with dorm facilities (2.62/75.68). It should be noted that camper satisfaction was above 89% on 7 of the 8 statements.

Statement	Mean	% Agree Strongly Agree	% Disagree Strongly Disagree
I enjoyed the scheduled evening activities.	3.70	100%	0%
I was satisfied with the Dorm facilities.	2.62	75.68%	24.32%
I was satisfied with the camp meals.	3.76	100%	0%
The Bridges Camp was well organized.	3.60	100%	0%
Bridges Camp will help me do better in school.	3.43	91.89%	8.11%
I learned more about myself.	3.24	89.19%	10.81%
I would come to <i>Building Bridges to the Future</i> Camp next year.	3.54	94.59%	5.41%
I would recommend Bridges Camp to my friends.	3.65	100%	0%

N = 37

Similarly, Table 4 shows that High School students clearly were satisfied with the overall organization and experience at camp, evening activities, dorms, meals, thought they earned about themselves and thought the experience would help them in school as indicated by the mean scores of 3.30 or higher and a percentage of agreement of 90% or more on 6 of the 8 statements. The lowest response rates were for items 7 (come to camp next year: 3.00/70%) and 8 (recommend camp to others: 3.32/82%).

Table 4: Final Camp Evaluations – <i>Building Bridges to the Future High School Students</i>			
Statement	Mean	% Agree Strongly Agree	% Disagree Strongly Disagree
I enjoyed the scheduled evening activities.	3.46	94%	6%
I was satisfied with the Dorm facilities.	3.50	92%	8%
I was satisfied with the camp meals.	3.62	98%	2%
The Bridges Camp was well organized.	3.66	100%	0%
Bridges Camp will help me do better in school.	3.32	90%	10%
I learned more about myself.	3.40	90%	10%
I would come to <i>Building Bridges to the Future</i> Camp next year.	3.00	70%	30%
I would recommend Bridges Camp to my friends.	3.32	82%	18%

N = 50

Students were asked to complete Likert Scale evaluations (1-5) on the engineering content at the completion of each *Building Bridges to the Future* Engineering Camp. Data was analyzed for frequency percentages and mean scores for each item. Results are presented in Tables 5 and 6.

Table 5: Engineering Component – <i>Building Bridges to the Future Junior High Students</i>				
Item	Mean	% Agree Strongly Agree	Neutral	% Disagree Strongly Disagree
The instructors knew their material.	4.70	93.94 %	6.06 %	0 %
The instructors seemed to want to help me learn.	4.79	96.97 %	3.03 %	0 %
The information helped me better understand mathematics	4.61	96.97%	3.03%	0 %
The session was well organized.	4.79	96.97%	3.03 %	0 %
The way the material was presented helped me learn.	4.64	93.94 %	6.06 %	0 %
The activities helped me to better understand mathematics.	4.27	81.82 %	15.15%	3.03%

N = 37

Table 6: Engineering Component – <i>Building Bridges to the Future</i> High School Students				
Item	Mean	% Agree Strongly Agree	Neutral	% Disagree Strongly Disagree
The instructors knew their material.	4.82	96 %	4 %	0 %
The instructors seemed to want to help me learn.	4.82	100 %	0 %	0 %
The information helped me better understand mathematics	4.86	88%	10%	2 %
The session was well organized.	4.66	98%	2 %	0 %
The way the material was presented helped me learn.	4.50	92 %	8 %	0 %
The activities helped me to better understand mathematics.	4.40	88 %	8 %	4 %

N = 50

Observations

The pre and post camp test results provide quantitative analysis that show what the camp facilitators observed. The instructors noticed trends in the *Building Bridges to the Future* camps that are supported by the pre and post test results.

It was commonly observed by the instructors that the junior high students were actively engaged and had a desire to continue evaluating their bridge designs. One example of this is how many of the junior high students did not want to go to scheduled break times. Many students chose to stay in the classroom and continue refining their bridge designs. This suggests that the group was actively engaged, and will perform higher on their post camp test. The test scores reflect this observation. *Building Bridges to the Future* subject areas such as mathematics had an average increase of 1.68 or (11.2%), science had an average increase of 1.35 or (13.5%), and an overall increase of 3.4 or (8.6%). This observation of active engagement of the students is validated by the student's evaluations of *Building Bridges to the Future*. 94.5% of the Junior High students responded that they would attend the camp the following year, whereas 100% responded that they would recommend *Building Bridges to the Future* to a friend.

In comparison, it was observed that the high school students as a whole had a harder time staying engaged. One example of this observation is that the instructors were consistently dealing with outside distractions (like cellular phones, iPod/mp3/CD players). Another example, in contrast to the Junior High students, was during the scheduled breaks. Many High School students chose to take naps instead of continuing to refine their bridge designs. While this was not true of all students, the instructors anticipated that this group would not show as much improvement as a whole. The test scores reveal minimal overall statistical improvement for the High School students, which are consistent with the instructor's observations. *Building Bridges to the Future* subject areas such as mathematics had a minimal increase of 0.6 or (4%), and science had an average decrease that can be considered negligible. The overall scores for the high school

students also showed a negligible change (0.02 increase or 0.2%). This observation of active engagement of the high school students is validated by the student's evaluations of *Building Bridges to the Future*. 70% of the High School students responded that they would attend the camp the following year, and 82% responded that they would recommend *Building Bridges to the Future* to a friend. While these percentages are two of the lowest responses for all evaluations, the majority of students felt they benefitted from the camp.

Conclusion

Results and observations show that if the students are actively engaged, there is potential for increased knowledge and understanding based on test performance. *Building Bridges to the Future* provided the opportunity for 95 students to be further exposed to science and mathematics in the context of an engineering design program. While the authors believe that the program can be improved, the feedback from students shows that the *Building Bridges to the Future* had significant impact both on performance and student opinion about science, technology, engineering and mathematics.

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