ESC Evaluation Services Center

Key Evaluation Results of the CEEMS Project, Year 4

Prepared for

Dr. Anant Kukreti, PI

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Evaluation Services Center
P.O. Box 210175 • Cincinnati, OH • 45221
http://www.uc.edu/evaluationservices

UNIVERSITY OF Cincinnati

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The CEEMS Evaluation has been guided by three primary evaluation questions that map to the project goals. To promote ease in reading, key data and results associated with the project are presented in a concise format with the following headings: Project Goals and Evaluation Questions, Evaluation Instrument/Metric, and Results and Outcomes.

Evaluation Results

The current CEEMS evaluation results for the fourth project year, Academic Year 2014-2015, are summarized in Table 1 by project goal. Overall, the CEEMS project is progressing toward attainment of these goals. Student interest in engineering is increasing, students are learning the engineering design process, and their content knowledge gains are increasing. Teachers are using CEEMS-promoted instructional practices and their usage is increasing the longer they remain in the program.

For project goal 1, the majority of students reported that they learned about the engineering design process (EDP) and that they have an increased interest in engineering following the unit implementation. When asked to draw the EDP with terms provided, approximately half the students connected the terms but did not represent the iterative nature of the process. Encouragingly, 12% were able to draw the process both with its iterative nature and the terms in an accepted order. This is a slight increase relative to last year (9.6%).

For project goal 2, teachers created pre-post assessments for each unit that were analyzed for content knowledge gains. Nearly all (96%) of the units had significant gains in knowledge using a two-tailed paired t-test at a 95% confidence interval with an effect size of 0.56 (Cohen's *d*), indicating a moderate effect size. There were no differences in content knowledge gains between Cohorts 2 and 3. These results were corroborated by teachers, via surveys and focus groups, and students, via surveys, both reporting that they learned from the units.

For project goal 3, changes in teachers' self-reported current instructional practices indicate that all teachers are using the instructional practices promoted by the CEEMS training. Usage of three behaviors increased significantly from pre- to mid-project: 1) Guide students in their refining problems; 2) Allow students to communicate their solution pathways and results to others; and 3) Explicitly connect class content to complex problems or issues with global impact. Additionally, one behavior usage significantly increased from pre- to post-project: Explicitly connect these real-world applications to STEM careers. Teachers reported they were well trained. Consistent with results from past years, teachers also reported the resource team was their most helpful support.

Table 1. CEEMS PROJECT YEAR 4 (2014-15) - Evaluation Instruments/Metrics and Teacher and Student Results and Outcomes

<table>
<tr><td colspan="2">***Project Goal 1. Increase 7-12 student knowledge of engineering design process and STEM careers and increase interest in college study in engineering or other STEM careers.***
Evaluation Question 1a. To what extent have students demonstrated knowledge of the engineering design process?
Evaluation Question 1b. To what extent have students demonstrated interest in STEM-based fields and careers?</td></tr>
<tr><th>Evaluation Instrument/Metric</th><th>Results and Outcomes</th></tr>
<tr><td>Student Feedback Survey
Using CEEMS teacher input and piloting with students, this survey was adapted from the NSF ITEST CincySTEM Urban Initiative project (Grant #0929557) high school student survey.

“I understand how the EDP activity allowed us to solve to use the guiding questions to solve the challenge selected.”
“This unit made me more interested in engineering.”
“I learned about the careers related to this challenge and our solution.”
(Scale: 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree)</td><td>Student Feedback Survey
• 88.2% of students *agreed* or *strongly agreed* that they understood how the EDP activity helped them solve the challenge. (n=3273, mean=3.20, SD=0.68)
• 62.5% of students *agreed* or *strongly agreed* that the unit increased their interest in engineering. (n=3242, mean=2.80, SD=0.93)
• 75.1% of the students *agreed* or *strongly agreed* that they learned about careers related to the challenge. (n=3243, mean=2.95, SD=0.83)</td></tr>
<tr><td>EDP Drawing
Student understanding of the iterative nature and ordering of 9 EDP terms was measured using an adaptation of the “Draw an Engineer” question (Lachapelle et al., 2012) in consultation with the measure developers. The scoring rubric was informed by previous EDP student assessment articles (Achieve, 2013; Schubert, Jacobitz, & Kim, 2012). Two raters scored each drawing (inter-rater reliability 0.94-0.98).

Scoring rubric: 0= no understanding; 1=elements listed but not connected; 2=elements listed and connected but not iteratively; 3=elements listed and connected in an iterative manner but elements are not in one of many acceptable patterns; 4= comprehensive understanding of the process.</td><td>EDP understanding
• Nearly 67% of students understood EDP elements are connected (scores of 2 or higher).
• Nearly 18% of students understood both the EDP elements & iterative nature (scores of 3 or 4).
• 12% of students could correctly draw the entire EDP model (score of 4).
• Nearly 17% had no relevant drawing of the EDP mode (score of 0).

Table 1. Rubric Scores from Students’ EDP Drawings: 2014-2015 Academic Year
<table>
<tr><th></th><th colspan="5">Rubric Score</th></tr>
<tr><th></th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td>All 2014-15 Classes (n=3189)</td><td>529 (16.6%)</td><td>529 (16.6%)</td><td>1567 (49.1%)</td><td>180 (5.6%)</td><td>384 (12.0%)</td></tr>
</table></td></tr>
<tr><td>Teacher Post Unit Survey:
Three surveys were jointly developed by the evaluation and project teams and piloted among four teachers to document important aspects of CEEMS units (CBL, EDP, and student outcomes as reported by teachers) that were successful and inform future modifications.

“Overall engagement of my students increased during this unit compared to non-CBL units.”
(Scale: 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree)</td><td>Teacher Post Unit Survey:
• 98.3% of teachers were in agreement (35.0% *agreed* and 63.3% *strongly agreed*) that their students’ classroom engagement had increased during the unit compared to non-CBL units (n=60, mean=3.62, SD=0.52).
• Teacher quote: “This unit was a huge success. The students were engaged each and every day. Out of the 23 students, there was only one student who did not enjoy the unit.”</td></tr>
</table>

Project Goal 2. Increase 7-12 student knowledge of math and science content when taught using engineering as a context for learning.

Evaluation Question 2. To what extent do student math and science content scores increase as a result of unit implementation?

Evaluation Instrument/Metric	**Results and Outcomes**
Student pre-post assessments of learning *Each teacher created unit-specific pre-post assessments of students' change in math and science content knowledge associated with the unit.*	Student pre-post assessments of learning • 96% (53 out of 55) pre- to post-test assessment scores, measuring math and science content, increased significantly (two-tailed paired t-test; 95% CI; 0.56 effect size using Cohen's *d*). • Students' scores increased 30.5% from pre- to post-test, measuring math and science content, for combined Cohort 2 and 3 teachers. There were no significant differences in student gain scores by teacher cohort at a 95% CI ($F_{(1,2444)}$=0.02, p=0.968).
Student Feedback Survey "I learned a lot." "This unit made me feel more confident about math or science." "I feel using challenges is a more effective way to learn than the way we are usually taught." (Scale: 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree)	Student Feedback Survey • 90.4% of students *agreed* or *strongly agreed* that they "learned a lot" from these units. (n=3287, mean=3.25, SD=0.67) • 68.9% of students *agreed* or *strongly agreed* that the unit made them "feel more confident about math or science." (n=3236, mean=2.87, SD=0.86) • 84.0% of students *agreed* or *strongly agreed* that using challenges was a "more effective way to learn" than how they are usually taught. (n=3249, mean 3.20, SD=0.77)
Teacher Post Unit Survey "Students mastered the expected material." (Scale: 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree)	Teacher Post Unit Survey • 91.7% of teachers *agreed* or *strongly agreed* that their students mastered the expected unit content. (n=60, mean=3.15, SD=0.61)
Teacher End-of-Year Focus Groups *Annual focus groups (90 minutes) were conducted at the end of each implementation year per cohort. Protocol was developed to assess student learning and future program modifications for improvement.*	Teacher End-of-Year Focus Group Quotes • Teachers observed gains in students' skills and content knowledge: ○ *"What this project is teaching is not even measureable on a test, work in a group, follow directions, persevere."* ○ *"Students were able to work through the problems and come up with a solution and work through it again."* ○ *"Atmosphere, last year [my teaching] was not very good and this year I did it with a CEEMS unit. I was not asking the students to redo their test answers … they had a debate … hook was their school's air pollution … the gross filter factor."* ○ *"The concept of music frequency and theory - drew it back to trigonometry."*

Project Goal 3. Develop math and science teacher knowledge of challenge-based learning, engineering, and the engineering design process as instructional strategies through explicit training and classroom implementation support.
Evaluation Question 3a. To what extent and in what ways has teachers' knowledge increased in 1) CBL and 2) EDP?
Evaluation Question 3b. What CEEMS project activities supported these changes?

Evaluation Instrument/Metric | **Results and Outcomes**

Teacher Current Instructional Practices Survey
Teacher challenge based and design based learning instructional practices were assessed via a modified version of a pre-post survey developed by researchers at the Evaluation & Assessment Center for Mathematics and Science Education at Miami University, Oxford, OH, using an EDP-related construct consisting of 6 practices (alpha = 0.84).
Questions asked about the extent to which teachers provide students with opportunities to:

1. Gather information about important problems or issues.
2. Explore multiple solution pathways for problems.
3. Test their solution pathways.
4. Refine and retry a solution pathway.
5. Communicate their solution pathways and results to others.
6. Take responsibility for the decisions they made about the processes used in solving complex problems.

(Item categories: Use Regularly, Use Occasionally, Have Tried It, Never Used)

Teacher Current Instructional Practices Survey:

- 100% of Cohorts 1, 2 and 3 teachers used instructional practices promoted by CEEMS programming to at least some degree after one year of CEEMS (mid-CEEMS).
- Across the three cohorts of teachers (n=48), teachers increased their use of three EDP practices from pre-CEEMS to one year of programming (mid-CEEMS). For Cohort 1 and 2 teachers (n=27), there was an increase in regular use of one EDP practice from pre-CEEMS to two years of programming (post-CEEMS) (chi-square p<0.05 for each).

Table 2: Comparison of Pre-, Mid, and Post-CEEMS EDB Instructional Practices

	% Use Regularly		**% Never Used**	
Instructional Practice (Pre to Mid for Cohorts 1, 2, and 3)	**PRE (n=48)**	**MID (n=48)**	**PRE (n=48)**	**MID (n=48)**
Guide students in their refining problems.	16.7%	68.8%	10.4%	0%
Allow students to communicate their solution pathways and results to others.	8.3%	50.0%	14.6%	0%
Explicitly connect class content to complex problems or issues with global impact.	8.3%	43.8%	6.3%	0%
	% Use Regularly		% Never Used	
Instructional Practice (Pre to Post for Cohorts 1 and 2)	**PRE (n=27)**	**POST (n=27)**	**PRE (n=27)**	**POST (n=27)**
Explicitly connect these real-world applications to STEM careers.	3.6%	29.6%	25.0%	0%

Chi-square indicates significant differences (at 95% CI) from pre- to mid- or post-project distributions for all questions. Results are cumulative across all matched and available data for Cohorts 1, 2, and 3. Cohort 3 does not have post-date in Year 4.

Summer Institute for Teachers (SIT) Evaluation Survey
Teachers rated the usefulness of various SIT interactions and workshops.
(Item categories: 1= very useless, 2= useless, 3=useful, 4 = very useful)

Summer Institute for Teachers (SIT) Evaluation Survey

- 100% of teachers reported overall interactions with resource team were *useful* or *very useful*. (n=32, mean = 3.69, SD = 0.47)

Project Goal 3. Develop math and science teacher knowledge of challenge-based learning, engineering, and the engineering design process as instructional strategies through explicit training and classroom implementation support. *Evaluation Question 3a. To what extent and in what ways has teachers' knowledge increased in 1) CBL and 2) EDP?* *Evaluation Question 3b. What CEEMS project activities supported these changes?*	
Teacher Post Unit Survey "I felt I had enough understanding of the CBL approach to guide my students so they got the most from this experience" "I felt I had enough understanding of the engineering design process (EDP) to guide my students so they got the most from the EDP activity or activities implemented in this unit." (Scale: 4=strongly agree, 3=agree, 2=disagree, 1=strongly disagree)	Teacher Post Unit Survey • 100% of teachers *agreed* or *strongly agreed* that they had enough understanding of CBL to effectively guide their students through the experience. (n=60, mean=3.72, SD=0.45) • 100% of teachers *agreed* or *strongly agreed* that they had enough understanding of the EDP process to effectively guide their students through the EDP activity and unit implementation. (n=60, mean=3.72, SD=0.45)
Resource Team Communication Log Resource Team members tracked communications with CEEMS teachers via a 12 question (9 closed-ended, 3 open-ended) online log.	Resource Team Communication Log • Of 490 entries, the most-mentioned communication topics were related to unit/lesson/ activity implementation (26%), observations (11%), planning school visits (9%), and/or unit/lesson/activity development (8%). The top four topics remained the same as in previous years.
Teacher end-of-year focus groups Annual focus groups (90 minutes) were conducted at the end of each implementation year by cohort. Teachers were asked about project activities and what they learned.	Teacher end-of-year focus groups • All CEEMS teachers learned CBL and EDP within the SIT courses. ○ *"[CEEMS] taught me a new way of teaching as far as how to make my project seem to matter to the students. … They had ownership in it … they had a part in [creating] it."* • Teachers received support during the academic year from the resource team members. ○ *"[My resource team member] was extremely helpful and insightful throughout creating and implementing this unit."* • Teachers reported resource team interactions as the most effective in supporting their content knowledge and pedagogical skills. ○ *"The resource team members [including fellows] gave my students another voice in the classroom … a different person to give them a different perspective."*