AC 2012-5454: ENHANCING STUDENTS' HIGHER-ORDER SKILLS THROUGH COMMUNITY SERVICE LEARNING USING SCAFFOLDING FOR CREATIVE PROBLEM SOLVING

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Enhancing Students' Higher-Order Skills through Community Service Learning Using Scaffolding for Creative Problem Solving

Abstract

This paper is intended to build up an implemental framework that integrates the educational research findings with engineering education practice for developing effective instructional scaffolding of Creative Problem Solving (CPS); and to communicate the potential impact of this scaffolding on underserved minority students' higher-order skill development through Project-Based Service Learning (PBSL). It contends that adoption of engineering design process in experiential learning could promote students' demands for cognitive and metacognitive strategies of Self-Regulated Learning (SRL) and Creative Problem Solving (CPS), and scaffolding with question prompts based on cognitive research findings could better facilitate SRL and CPS process of underserved minority students, and lead to their enriched metacognitive experience, meaningful accomplishment, and improvement of self-efficacy and higher-order skills. The overall goal of the presented scaffolding instruction is to develop students' higher-order skills and their identity as engineers and innovators, especially for African-American students. The instruction is based on the hypothesis: PBSL incorporating with engineering design pedagogy could promote students' awareness of and demands for metacognitive knowledge and strategies in creativity and self-regulated learning. Scaffolding Creative Problem Solving through PBSL could lead to under-served minority students' meaningful accomplishment and enhance their self-confidence and creativity. This could help students to form their identity as engineers and innovators and prompt them to choose engineering and scientific research as careers. Meanwhile, the development of creativity could improve students' metacognitive skills in learning and creative problem solving in their engineering education. This will help students to enhance their academic performance and pursue engineering studies as their career goals. The outcomes from the prior implementation are outlined through students' responses and reflections on their learning experience. It is expected that the presented scaffolding could have positive impact on students' self-efficacy and higher-order skill development, and further experimental research is needed to validate this conclusion.

Introduction

In today's global knowledge-driven economy, technological innovation and creative transformation of new knowledge into products and services are critical to a nation's competitiveness. Companies now demands engineers to possess higher-order skills, such as an ability to adapt to rapidly-developed technologies and an ability to innovate.[1] U.S. engineers have long led the world in innovation and this leadership is essential to U.S. prosperity and security. However, this great national resource now seems to be at serious risk due of lack of engineers.[2] To maintain nation's global competitiveness, educational institutions have to address two imperative needs: one is to attract/retain diverse excellent students in engineering fields; and the other is to provide learning environment that foster self-regulated learning and creative problem solving skills of engineering students.[3]

In general, however, current engineering education has been criticized for lack of characteristics necessary for developing creative problem solving skill, and often may stifle the development of these higher-order skills.[4] Such examples identified by Magee et al. include: (1) overemphasis on memorization of knowledge and procedures, rather than higher-order skills; (2) a rapid pace of learning that undermines the self-reflection and self-assessment; (3) highly structured learning formats that constrain the expression of ideas; and (4) inadequate balance between building a body of knowledge and creative use of the knowledge. [5]Most students have not received explicit holistic instruction based on cognitive science findings, which emphasizes the students' metacognition and reflection on the processes and strategies of CPS they undertake.[6] Even though many engineering faculty members have recognized that CPS skills are important for students, most of them have not been trained as teaching professionals and are not fully aware of developments from cognitive science on how people learn and how creativity proceeds. As a result, engineering faculty members are often unable to integrate cognitive theoretical frameworks into their instruction in engineering education. Their efforts to help their students develop these higher-order skills may consequently be less effective than they might expect.

Currently African-American students enrolled in engineering makes up only 6-7% of engineering undergraduates, as compared to their 14% of share of the US population of 18-24 year olds. [7] National Science Board (NSB) has identified that students at historically black colleges and universities may see engineering as unfriendly, unaffordable, and requiring extra preparation. They do not see a direct benefit to their community and often believe they would have to leave their community to succeed in engineering; others leave because their poor academic performance in engineering-related courses[8]. Based on the experience of teaching African-American students, the authors believed that one of major causes for low retention of African-American in engineering include lack of divergent thinking and motivation in learning engineering, besides the poor preparation in their early schooling. When facing with problems, those students who have lower performance usually fail in establishing the connection between the problems and their prior knowledge and solution procedures that have been discussed in the classes, and lack cognitive and metacognitive strategies for guiding their thinking and searching solutions in every possible direction. There is an imperative need for engineering faculty to adopt effective instructional strategies to inspire and guide students' thinking and acting in the processes of learning and problem solving.

Experiential learning refers to a process of making meaning from direct experiences.[9] Its application in the form of Project/Problem-Based learning through community service project or co-curricular design project has been widely used in current educational practices, in which students will have opportunities to select learning topics for solving real world problems. It provides the most suitable learning environment for students to develop higher-order skills in learning and problem solving. According to Kolb and Fry, to gain genuine knowledge from experiential learning, the learner must (1) be willing to be actively involved in the experience; (2) able to reflect on the experience; (3) possess and use analytical skills to conceptualize the experience; and (4) possess decision making and problem solving skills in order to use the new ideas gained from the experience.[10] Well-designed scaffolding of cognitive and metacognitive strategies for SRL and CPS for the experiential learning could help students to maximize the beneficial impact of experiential learning.

This paper intends to illustrate an experiential learning with community service learning project in which underserved minority students learn CPS techniques. It contends that the engineering design process could promote students' demands for cognitive and metacognitive strategies of CPS, and scaffolding with question prompts based on cognitive research findings could facilitate students' CPS development. Further experimental research is needed to validate the experiential learning effect.

Literature Review

Metacognition and Creativity

The research development on how people learn emphasizes the importance of "metacognitive" approach to instruction in helping students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them. Metacognition refers as awareness of and reflection upon how one learns knowledge and how to use information to achieve a goal[11], and is higher-order self-regulated mental processes that include making plans for learning, using appropriate strategies to acquire information, solve a problem and evaluate performance.[12] Researchers have distinguished between two main components of metacognition: metacognitive knowledge, which refers to acquired knowledge about cognitive processes and strategies that can be used to control cognitive processes and metacognitive experience; and Metacognitive experiences, which refers to activities that control one's thinking and learning and involve the use of metacognitive strategies and metacognitive regulation.[13] The most effective approaches to metacognitive instruction are to provide the learner with not only metacognitive knowledge and strategies, but also metacognitive experience (or practice). The previous studies have confirmed Metacognitive training, in addition to task-based training, can considerably improve performance.[14] Students with poor metacognition can benefit more from metacognitive training for improving their metacognition and academic performance.[15]

Creativity involves the introduction of new variables, significant leaps, and novel connections,[16] and deals with a ''process'' which results in a ''novel product.''[17] The most accepted frameworks on creativity can be categorized with Amablie's model.[18] This model includes three components within the individual: intrinsic motivation, domain knowledge, and creative skills, as well as a fourth component from environment, e.g. external setting, extrinsic motivation, rewards, social interactions, and time pressure. Guilford pointed out two main thinking in the creative process: divergent thinking is concerned with the review of ideas and solutions with maximal openness and the avoidance of premature judgment; and convergent thinking uses mainly knowledge, analysis and judgment to find the most suitable solution.[19] De Bono made a similar distinction between lateral thinking and vertical thinking. [20]Torrance has characterized three aspects of creativity: originality (i.e., how one idea can advance existing ones); Idea Fluency (i.e., how many ideas have been generated); and Flexibility (i.e. how many different approaches have been considered), and advocated that *every person should realize he can do some sort of original work. If this realization were cultivated early, there would not be so many adults who sense futility about doing something original.* [21]

Armbruster discussed the function of metacognition in the process of creativity and believed that metacognition is linked to creativity and plays a very important role in creativity. [22] Bruch has proposed the concept of metacreativity, which is viewed as an approach to examining what to do and how to do it in creative processing, including selection of creative strategies and reflection on what happens during the creative process.[23] Although metacreativity differs from metacognition, they have similar characters. Metacreativity can be regarded as metacognition related to the creative process. Pesut presented a model of creative thinking as a metacognitive process, in which creativity technologies are reframed as metacognitive strategies; and creativity itself is viewed as a self-regulatory process of metacognitive knowledge, self-evaluation, and self-monitoring. [24]

As a well accepted theory of learning, constructivism emphasizes that learning is an active knowledge construction process through experience, particularly creating and experimenting experience, which involves establishing the connection between learners' new knowledge and their own existing knowledge, and imagining applications of new knowledge in different situations.[25] Kay advocated that learners should innovatively question the 'facts' and believed that the creative ways of thinking can enormously expand students' understanding and learning.[26] Creativity and creative thinking could benefit learning in the process of creating connections and imagining applications during knowledge building and application in the three aspects: originality (i.e., new connections and imaginations); fluency (i.e., many connections and immigrations), and flexibility (i.e., different types of connections and imaginations).

A wealth of creative thinking strategies has been developed for guiding creative thinking. Dieter described the various creative strategies.[27] Yashin-Shaw has developed a comprehensive model that includes various creative problem solving strategies. Altshuller studied thousands of patents and the way in which the innovation had taken place, and established Theory of Inventive Problem Solving (TRIZ, a Russian acronym). As students are equipped with multiple thinking strategies and engage in creativity to use these tools and strategies, they can develop the capacity to apply the various modes of thinking and solutions to the problems, where most appropriate. In this sense, students' metacognitive processes can be triggered.[28] Thus, there is a potential to use creativity education to not only enhance students' creative thinking and problem solving skills, but also develop student's metacognition and self-regulated learning skills.

Creative Problem Solving through Engineering Design

Engineering design is an approach to identifying and solving problems innovatively. The process of engineering design essentially could be defined as repeated cycles of a multiple-phase model. A five-phase model includes the following five phases: (1) Define the problem; (2) Gather pertinent information; (3) Generate multiple solutions; (4) Analyze and select a solution; and (5) Test and implement the solution. It is a process that is highly iterative; open to the idea that a problem may have many possible solutions; a meaningful context for learning STEM concepts; and a stimulus to systems thinking. It requires active learning knowledge for solving the problem, and needs idea generation or creativity. Engineering "habits of mind" align with essential skills for citizens in the 21st century. This "habits of mind" could essentially benefit the problem solving skills of all people for reaching innovative solutions to various challenges.

Engineering design process is mostly taught to engineering students during their senior year capstone design course after students have acquired relevant knowledge for the design. Thus, the phase of gathering knowledge is mostly carried out in a passive instructor-centered learning model. Most creativity education in engineering typically is associated with product design in the senior design course through introducing idea-generation techniques. For example, Ogot and Okudan, as well as Shields, have introduced Theory of Inventive Problem Solving (TRIZ, a Russian acronym) into core engineering courses.[29] Ocon adopted issued-based learning to introduce creativity and creative techniques.[30] Yashin-Shaw proposed a heuristic creative process model, including various creative strategies and metacognitive strategies to scaffold the thinking process of innovative problem solving for creative endeavors. She found that students believed that the model worked for them, but felt that some terminology was a little difficult to interpret and grasp. In response to the later results, a sets of simple 'prompt questions' associated with each procedures and skills within the model has been developed for use in the further research.[31] Cropley has compared creativity of the undergraduates who received three lectures on creativity (N=37) with those who did not through pre-test and post-test (N=21) during the six week period. He concluded that the students in intervention group were more innovative in the machine design, whereas the control group was simply less inhibited.[32]

To improve retention of engineering students, National Science Board (NSB) has identified many approaches, including: introducing students to the excitement and relevance of engineering early in the educational experience; making extra resources available to students who need help; and placing engineering in a social or business context.[33] Project-based learning (PBL) has become an emergent opportunity to address the above needs. PBL is a form of active learning where students work on projects that benefit a real community and obtain a rich learning experience. Many universities have included PBSL in their first year courses. Even though many claimed beneficial outcomes from students, there is limited research to support the claims. McCormick et al. (2008) have conducted experimental studies used four-open-ended questions to evaluate the analytical skills, practical skills, creative skills of students who participated in PBSL (N=11) and those who did not participated in PBSL (N=33). The results indicate that students with PBSL experience have a higher skills level than those who have not had a PBSL.[34] However, this study calls for further evaluation on a larger sample with more diverse groups of students, and a more flexible curricular scaffolding to support the appropriate learning in PBSL.

Scaffolding though Question Prompts

Rosenshine & Meister examined a variety of scaffolding that support student learning.[35] The overall findings have consistently pointed to the advantages of the use of question prompts in directing students' attention to important aspects of the problem, activating their schema, eliciting their explanations, and prompting them for self-monitoring and self-reflection. For example, Ge and Land have investigated the problem using a combination of different types of question prompts to scaffold undergraduate students' problem solving. They found that the students who received question prompts during problem solving performed significantly better than those who did not receive question prompts, because question prompts can prompt students to make meaningful and intentional efforts to identify relevant factors; help them to organize information and plan for the solution process; assist them in articulating their solution process; evaluate the selected solutions, and compare alternatives for the most viable solutions. [36]

Davis and Linn also found that reflective prompts supported knowledge integration and encouraged reflection at a level that students did not generally consider. [37] Reflection helps to make the connection between metacognitive knowledge and metacognitive control.[38] Reflection prompts helped students to self-monitor and study strategically. It is expected that reflection prompts may play an important role in helping students to self-monitor their problem-solving processes and consider various perspectives and values regarding their selected solutions. In a study of problem solving process of African American 8th-grade students, Malloy and Jones found that students' problem-solving actions matched previously reported characteristics of good mathematical problem solvers: successful use of strategies, flexibility in approach, use of verification actions, and ability to deal with irrelevant detail. Success was highly correlated with strategy selection and application and moderately correlated with verification actions.[39]

Unfortunately, most research on the students' problem solving process and effective scaffolding for facilitating these processes comes from science and math education communities. Efforts among engineering education community have been limited in using cognitive findings to facilitate engineering students' learning and problem solving, particularly for underrepresented minority students in engineering. However, the research and practice development in other education communities provide methodological basis for engineering education community to address these important issues. Through collaboration with educators from education and psychology, the proposed education research project will strive to make contributions to this knowledge basis for engineering education.

Scaffolding and Implementation Procedures

Community Service Learning Project Sites

For the current study, scaffolding creative problem solving was carried out through students' community service learning projects. Four community service sites were selected for facilitating students to carry out their community service through creative problem solving by using engineering design approach. The projects for each site are introduced below:

- **PROJECT #1**- Community & Economic Development- Booker Street Community House: Students will collect, identify, propose essential ways and means for turning an abandoned house into a neighborhood community house (center). They will focus on issues, such as the design of water recycling system for sustainable garden and landscaping; the adoption and development of the innovative flooring, windows, duct, walls, and roof for energy efficiency heating and cooling systems, as well as the proposals of operational functions, maintaining procedures, and safety measurement of the community house for creating a model community home.

- **PROJECT #2** - Homelessness & Hunger Assistance Project: Students can assist the Jackson Homeless Assistance Coordinator by identifying effective ways and means to decrease Homelessness in the City of Jackson through the Stewpots Homeless Advocacy Project. They will use creative problem solving through using engineering design approach to identify a problem and propose innovative solutions for decreasing homelessness throughout the metro area.

- **PROJECT#3**: Education/Literacy Program: Students can assist the academic enhancement of school-age children and work directly with parents, teachers, school administrators to prevent at-risk children and youth from dropping out. Students can involve in community activists and provide effective instructions for keeping students in school and reducing the school dropout rate through defining problem and providing innovative solutions.

- **PROJECT#4**: Poverty Reduction (Bridge out of Poverty): The students are assigned to Stewpot Community Services Center where they can assist the community to reduce and prevent poverty through defining problem and providing innovative solutions. Students can examine the causes for poverty; define resources that are necessary for a high duality of life, and improve community actions & policies that can enhance resources.

Scaffolding Creative Problem Solving with Question Prompts

To guide students' CPS processes in their community service learning and promote their reflection on the processes, the scaffolding will be provided to students in the form of question prompts that can be categorized into procedural, elaborative, and reflective prompts as follows:

- Metacognitive prompts are used to prompt students to make plans for the next steps, such as "If what I'm doing at the moment isn't working or if I'm stuck or if I simply want some fresh ideas - what else can I do?"
- Procedural prompts are characterized by directing students' efforts to complete a specific cognitive task, such as "Can I think of something really similar and then something really different that in some ways can be connected with my current idea or solution?" for guiding the generation of new solutions or ideas for generation of ideas ;
- Elaboration prompts are designed to activate strategies and help students elaborate and articulate their thinking and reasoning process, such as "How can I develop and expand this idea by both using my existing knowledge and understanding or researching more information?" for exploration of more idea or solutions; and
- Reflective prompts are intended to serve as cues to provoke students' reflections and elicit self-evaluation on what happen in the past, such as "What did I leads me successfully to the right solution and how can I apply this into other similar situation?" or "What I did was a mistake and how can avoid this type of mistake in the future"?

Samples of such question prompts that correspond to the cognitive and metacognitive strategies for creative problem solving have been developed by Yashin-Shaw (see Table 1).[40] The research team further develops more suitable question promotes from both literatures and inputs and data collected from students' problem solving process. Particularly, students are encouraged to provide most suitable question prompts based on their own successful experiences and reflections in their creative problem solving processes.

Implementation Procedures

The students were provided with a list of question prompts after they start their creative problem solving in their PBSL project. These question prompts correspond to the process model and strategies, which are categorized into procedural, elaborative, and reflective prompts. Students were required to write down what question prompts were helpful for them to learn relevant knowledge and may help develop their innovative solutions. To help students focus attention to some important aspects of the problem solving, participants received question prompts regularly as reminding through e-mails setups in online software platform Blackboard besides the lists of question prompts provided to them before they start their own projects. The students' community service learning included the following phases:

Phase 1: Training. Seminars or on-line materials on creative problem solving skills are provided to students before they go to the community learning sites. Students will learn the materials to master how to solve a problem facing them in their service.

Phase 2: On-site: Students are introduced to their community partners or mentors and start their service learning project for about two month period. Assisted by their mentors, the students will be introduced with the problems that the community faces and will select the project topics that fit into their learning interest and ability levels.

Phase 3: Question prompts: Mentors or Instructors working as facilitators provide students' prompt questions based on their progress.

Phase 4: Evaluation: Students are required to report service learning project based on following criterions: (1) Proper presentation format (10 points);(2) Problem description (10 points); (3) State of previous work or solution by others (10 points);(4) Innovative solution and how it is built on the previous works (20 points);(5)How many alternative solutions and how many different approaches have been considered (20 points); (6) How the innovation is initiated or inspired or what strategies are utilized for your innovative solution (20 points); and (7) Reference cited (10 points).

Table 1 Question Prompts on Cognitive and Metacognitive Strategies

<table>
<tr><td colspan="3">MANAGING THINKING (Strategic Thinking/ Executive control)
▪When I'm finished what do I want this outcome to achieve? (Goal setting)
▪If what I'm doing at the moment isn't working or of I'm stuck or if I simply want some fresh ideas - what else can I do? (Switching)
▪What questions should I ask myself at the moment to help me decide whether or not I'm generally happy with the way things are going? (Cognitive awareness)
▪Is what I'm doing at the moment going to help me achieve the aim of the project? (Goal monitoring)
▪Is what I'm doing at the moment taking me in the general direction of where I think I want to go even if I'm not sure about where that is exactly? (Strategy formulation)</td></tr>
<tr><th>GENERATION</th><th>EXPLORATION</th><th>EVALUATION</th></tr>
<tr><td>Are there any other ideas I can come up with if I dig a little deeper into my mental database or think more broadly about the problem? (Search)</td><td>How can I develop and expand this idea by both using my existing knowledge and understanding or researching more information? (Knowledge Application)</td><td>What are the strengths and weaknesses of this solution? (Analysis)</td></tr>
<tr><td>What are the things I already know that I can easily call up into working memory to help me get started with this project or problem? (Retrieval)</td><td>Does anything interesting happen if I fold this/cut it in half/ bend the edge/ curl it up/ change the shape etc.?(Experimentation)</td><td>Am I ready to make some definite decisions about whether this idea is a good one? (Assessment)</td></tr>
<tr><td>Can I think of something really similar and then something really different that in some ways can be connected with my current idea? (Association)</td><td>If I put this idea or thing into a completely different place or time what would happen to it? (Context shifting)</td><td>What's good about the things I've decided to keep in so far? (Verification)</td></tr>
<tr><td>What is the opposite of this and what would happen if I put it together with what I'm thinking about right now? (Contrast)</td><td>What are some of the patterns, trends or features that I can see coming out in the project? (Attribute finding)</td><td>If I 'test drive' this does it work? (Trialing)</td></tr>
<tr><td>What would happen if I blended two or more ideas together to come up with something different but that still had some of the features of the original ideas? (synthesis)</td><td>What could be some of the problems I might have to think about? (Acknowledging limitations)</td><td>Does this solution do (or look like it will eventually do) everything it is supposed to? (Criteria fulfillment)</td></tr>
<tr><td rowspan="2">If I had to make a drawing or a basic model of this idea or concept and folded it or manipulated it in different ways does it begin to look like something else that is interesting? (Transformation)</td><td rowspan="2"></td><td>Does this idea, or some part of it, need to be taken out because it is just not useful for this particular project? (Elimination)</td></tr>
<tr><td>Some ideas or parts of them may have to go but what is definitely staying? (Selection)</td></tr>
<tr><td>Are there any particular features of this idea that resemble any particular aspects of other really different things? (Analogical transfer)</td><td></td><td>Why is this outcome better or worse than another one? (Comparison)</td></tr>
</table>

Outcomes of Implementation

Data analysis from students' journal

Data were collected from the students' process and reflection journals and analyzed them by using a verbal protocol analysis.[41] Eight themes were revealed as below.

1. Self-Efficacy (confidence): Most students indicated that they can positively contribute to community through their community service projects. They placed more emphasis on their actions and activities, through which they are able to provide a specific service to the community. They did not state whether they were able to provide the innovative solutions to a specific problem that is identified and defined by them, even though the project assignment sheet clearly indicates the requirement for defining problem and finding innovative solutions.

2. External Resource Use: All students realized the importance of seeking external assistance and indicated that they would like to obtain the help and assistance from other people, e.g. instructors, knowledgeable persons, or professionals. Few students indicated they would like to think harder by themselves, or change problems. However, they did describe the actual action that they take or the process that they experience in seeking the external assistance and did not indicate any outcomes specifically from this assistance.

3. Team work and Collaboration: All students realized the importance of team work and collaboration. Some students thought that working as a group could bring different perspectives on the issues being discussed, and allow them to come up with the multiple solutions. Some felt that working as a team tended to be more productive and innovative and get more accomplished. Some think that it also have fun which in turn makes more people willing to contribute, and more than one opinion on a matter is always better. They did not describe any actual benefit or specific contribution from the team work or collaboration for their projects. This could indicate that students may well perceive the benefit of the team work or collaboration, but may not come up with a way to realize this benefit during their community service learning process.

4. Originality (i.e., how their design can advance existing approach) and strategy use: If students got stuck with the method you are using at the moment, they demonstrated that they have alternative strategies for solving the existing problems. Some students mentioned that they would look at how other model leaders and other communities are solving their problems and issues. Even though they did not explicitly mention what strategies they used, it appears that they adopted Association Strategy (i.e., the mental connection of either unrelated or related ideas, free from their normal contexts), and Analogical Transfer Strategy (i.e., A correspondence and mapping between similar features of concepts and principles that are otherwise dissimilar). Some students indicated that they could not think of or did not know the strategies that can help them come up with alternative solutions.

5. Idea Fluency (i.e., how many ideas have been generated and considered for their design) and strategy use: Students worked out some solutions that look similar and yet are somehow different from what they are currently using. Most students suggest they can come up with other solutions that are different from their current one. A fewer students indicate they were not able to come up with other solutions. Students typically tended to propose multiple solutions for different issues in a general conceptual sense, rather than define a specific problem that can draw their interest and efforts to develop an innovative solution in a deep sense. They did not describe any process in which they have used specific strategies to come up with the multiple innovative solutions. It appears that students tend to use diverging thinking over different issues or problems, rather than use diverging thinking for different perspectives of a specific problem. They also did not mention any evaluation of alternative solutions. This may be the important process that is missing in their service learning projects, or an indication that they might not reflect on and report the strategies that they have used to generate, even though it is required to reflect and report this process in the service leaning project assignments.

6. Flexibility (i.e., how many different approaches to the design have been considered) and strategy use: Some students indicated the processes that can help them come up with the new

idea include the evaluation of current solutions and synthesis of everybody's ideas to come up with new idea; writing down own ideas and showing them to others and seeking others' help; or looking at and learning from previous mistakes. Some student reported that using previous experiences could make it easier to come up with a solution that could work for the current problem. Even though they did not explicitly mention what strategies they have used, it appears that they have adopted Synthesis strategy (i.e., a combination or blending of two or more ideas or concepts. It is a more advanced amalgamation of ideas and concepts than the associative process), Association Strategy (i.e., the mental connection of either unrelated or related ideas, free from their normal contexts), and Analogical Transfer Strategy (i.e., a correspondence and mapping between similar features of concepts and principles that are otherwise dissimilar).

7. Dealing with mistakes and fails: Most students indicated positive attitude towards the mistake and failures, and are able to find their own ways to deal with their mistakes and learn from their failure experiences, e.g. thinking about what part is good and what part may have caused failures and trying to fix it; identifying errors and thinking of alternative ways to handle them and meantime seeking external help; asking questions on what happened and see what does and doesn't work so he doesn't waste time with errors; reflecting the experience by documenting what he has tried along the way so he or someone else would spend time doing the same thing while he or she can look for a better solution; stopping and asking if his course of action is the proper one and use past mistake to help; or looking at the failure experience as a trial-and error situation and so that brainstorming a litter more and changing their strategies. However, students did not indicate they have generalized the specific types of error or mistake in a broader sense so that they can really learn from this and avoid similar mistakes in other contexts.

8. Evaluation and Reflection: Most students indicated their reflection on the cause that makes them feel successful. They attribute their successes to those actions or strategies, such as taking time to study the nature of the problem and its cause before making efforts for formulating solutions; stopping to think of all the possible outcomes and choosing the best action; using their personal experience when he was a child to teach other children; raising standards and expectations from the local level to the national level; spending more time at the service sites; adopting a positive attitude throughout the process; having motivation for making changes; looking at the problem from various perspectives; or getting connected with the right people. Based on those data, their reflections related to the application of creative problem solving apparently includes the diverging thinking, Association strategy, or Analogical Transfer strategy. However, they seem lack of generalization of their success experiences and did not come up with the reflection on how to extend their successful experiences into other similar situations.

Data Analysis from Students' projects

The data analysis of the students' service leaning project reports was conducted using the case study. It is intended to supplement the findings obtained from students' process and reflection journals by further revealing the students' creative problem solving processes and the outcomes from these processes.

In one of the selected cases, for example, the student works on the project for turning an abandoned house into a Community Center at Booker Street Community nearby the Jackson State University main campus. The student first determined the basic function of the community center as recreation and further clarified the recreation by looking at its definition: “Recreation - noun definition: (1) refreshment - the refreshment of the mind and body after work, especially by engaging in enjoyable activities; (2) amusement - an activity that a person takes part in for pleasure or relaxation rather than as work.” Then, the student attempted to define the problems through posing questions: “What is the best location to set up a Recreation/Community Center? Will it help to enrich the community? Will the center serve the needs of the people? How will Jackson State maintain security in the area? Will the center become self sufficient or will there be a constant need for funds to thrown into the upkeep and daily operations? Who will oversee the day to day operations?”

With the closely related research questions in mind, the student looked around and presented the photos of the public facilities near the proposed community center: “Picture of the Tennis Court, Picture of the Rest area/Eating space, Picture of the Play ground, and Picture of the park Grounds”. The student seems to use the proposed community center to enrich the recreation of the community. Then, the student appeared to use diverging thinking to come up with various ideas on how to use new technology to remodel the old house and turn it into a community center: “Add solar light to the outside of the center. Solar panels on the roof (White tin Top). Make sure that there are timers on the water heaters and throughout the building. Secure the building windows. Talk to the business in the area and ask for help.” “Speed bump should be added in the area. The community should be asked to come up with a beautification campaign. There is a need for a community garden. The swings and slides (Playground) should have a cover to shield the equipment from the weather. There is a need for a secure walking track.” The student concluded the report with more thoughts: “The things at the parks around JSU that are not really being used to their fullest are the very same items that are needed. The more you talk about what you want to do on Booker Street, the more likely it will never get done. The daycare owner would like to see a place that any child can go to and feel safe. Computer learning center for aging citizen by morning and youth after school (can be added). A banquet area (can be added) that would lend to aid the facility to generate funds to help maintain the daily upkeep. A revolving door should be considered and installed for keeping JSU students as volunteers in the community. So let’s get busy and start working.”

In this case, the student appeared to go through the process of defining the problem, gathering pertinent information, and generating multiple solutions, but did not reach, even in the conceptual sense, the process of analyzing and selecting a solution, and testing and implementing the solution, which are the other two important problem solving processes of engineering design approach. Furthermore, the student did not focus on identifying a specific problem that the student would like to create an innovative solution through her efforts in learning and problem solving. Instead, the student came up with various ideas using new technologies that have been developed. This indicates the student went through self-regulated learning processes to learn these technologies and their applications. However, the student did not clarify whether he/she has developed any new ideas based on these applications and did not report whether the he/she has unitized any creative problem strategies for doing so. This project report indicates that the student’s cognitive and metacognitive processes for developing the project included Observing, Predicting, Questions/hypotheses, Visualizing, Communicating, and Managing, and may also include Creating in some extent, but did not include Designing, Experimenting, Modeling, Testing, Measuring, Computing, Analyzing and Interpreting data. Among these missed metal process, Designing, Computing, Testing, and Analyzing are critical components for innovative problem solving and requires times and persistent efforts. The student seems to use diverging thinking to generate multiple ideas for different perspectives, but not multiple solutions to a specific problem. It is not clear about what creative problem solving strategies have been used by the student.

In another selected case, the student worked on the same the project as mentioned above. The student may be aware that there was an urgent need for identify problems or issues for the community center, but did not clearly define a specific problem. Instead, the student thought that "the ideas for the community house and the relevant issues with its reconstruction should be decided by the community. Issues such as programs, classes, and the rebuilding process should be discusses and voted on by the people of the community who will be in charge and using the facility." Then, the student proposed several ideas for the function or utilization of the community center, such as "A boy scout troop would be a great thing to have at the community house." "A mentoring program could also be offered at the community house. Volunteers could spend time with children, help them with schoolwork and homework, and provide another positive example of role models." "After school programs could be offered for children whose parents are still at work when school is out." "A class on financial planning would be a great thing to offer to the adults of the community." "Contact the specialists of air conditioning and heating to find out most energy efficient way for house that is cost effective and get estimates." and "Research different landscaping ideas and pick an appropriate one for the house. Can call property manages and ask for their landscaping recommendations. It may be cheaper to have the landscaping done by volunteers for the community."

In this case, the student did not go through a process of defining a specific problem that he intended to come up with innovative solution. The student used diverging thinking to come up with multiple different conceptual ideas for creating a community center that could better serve the community needs.

Discussion of Outcomes

The outcomes have revealed some characteristic disposition of the students' cognitive and metacgnitive processes when they are faced with real world problems in their community service endeavors. The students showed their confidence for making contribution to the community through their service learning projects. They fully understood the importance and value of the team work, collaboration, and external help. They possessed a positive attitude towards mistakes or failures and were able to think of strategies to deal with their mistakes and learn from their failures. They were able to take the diverging thinking to look at the different issues of phenomena and proposed multiple ideas from different perspectives for these issues. The typical strategies that the students tended to adopt for their creative problem solving includes Diverging Thinking strategy, Synthesis strategy, Association Strategy (i.e., the mental connection of either unrelated or related ideas, free from their normal contexts), and Analogical Transfer Strategy (i.e., a correspondence and mapping between similar features of concepts and principles that are otherwise dissimilar). In their service learning projects, the students typically tended to focus on more broad issues and propose multiple solutions to different issues in a general conceptual sense.

However, the students did not seem to be able to define a specific problem that can draw their interest and efforts to develop innovative solutions in a deep sense. They were weak in metacognitive processes making a plan and motivating their efforts for looking at the problem, learning specific knowledge, and using varieties of creative problem solving strategies to generate the innovative solutions to the problems. Although they appeared to have gone through the procedures of defining the problem, gathering pertinent information, and generating multiple solutions, they did not take other two critical engineering design procedures, i.e., analyzing and evaluating a solution, and testing and implementing the solution, even in the conceptual sense. Their cognitive processes during their development of the service learning project have not included some critical mental processes in implementing engineering design approach: i.e., designing, computing, analyzing, and testing. Their reflections on their experience did not focus on the generalization of what they have learned from both successes and failure experiences. This may limit their abilities or skills for extending what they have learned into other contexts for their subsequent study and future careers.

Better understanding why students behave in such way as observed will provide insights into developing effective instruction for guiding students to become skillful in creative problem solving, and require the subsequent full implementation of the designed research in a larger scale as designed and the further follow-up studies, such as using constructed interviews. Eventually, the findings from the research can lead to identifying what process variables, as well as the relevant strategies and their corresponding question prompts, are significantly associated with positive student's project outcomes, as well as understanding what is the magnitude of their effects associated with those outcomes, and how these efforts are motivated. At the current phase, it is too early to have significant findings as expected in the proposal. However, the data collected from the pilot implementation revealed the characteristics of students' cognitive and metacognitive processes, and indicated some critical processes and strategies missed from their problem solving process. These findings provide the project team with insights into how to improve instructions through question prompts, and also indicate the potential for the project team to achieve the expected project outcomes. For improvements in the next full implementation, more efforts will be placed on guiding students to go through the missed important procedures and critical metal processes identified from the pilot implementation, and refining the question prompts corresponding to these processes and relevant strategies. Particularly, the project team will place more emphasis on clarifying the significance of the conducting service learning as required to motivate students' efforts, and also place more emphasis on guiding student to identify and define a specific problem, make a plan to obtain knowledge on the problems, design innovative solutions to the problem, and motivate their efforts and persistence.

Conclusion

In this paper, the authors described an experiential learning procedure to develop students' creative Problem Solving capability. The students' learning outcomes revealed their disposition to handle questions and challenges during their involvement in this course. Our goal is to communicate the potential impact of scaffolding CPS with question prompts through community service learning on underserved minority students' higher order skills. Meanwhile, we intended to address issues regarding the enhancement of engineering students' creativity, which has becoming high demands in the current data-supported and knowledge-driven economy. Based on our implementation experience, we discussed the details of scaffolding with question prompts for community service learning and implementation procedures. The research integrated in the implementation is also presented to evaluate students' learning outcomes and validate the presented scaffolding with question prompts. It is expected experimental research will be conducted in the future to confirm the hypothesis that students' CPS capability significantly improves with their guided and committed participation in the project.

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