120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #6169

# Correlation Analysis of Scaffolding Creative Problem Solving Through Question Prompts with Process and Outcomes of Project-Based Service Learning

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## Abstract

This paper is intended to present on-going efforts on scaffolding for Creative Problem Solving (CPS) through question-prompts for freshmen's Project-Based Community Service Learning, and to reveal the correlation of scaffolding creative problem solving through question prompts with students' process and outcomes of their self-regulated learning and creative problem-solving in their problem-based community service learning projects. The presented results were based on the available data from the current investigation conducted in the course of one semester. Student participants were freshmen who were involved in the required community service learning projects. Participating students were assigned to the community service learning sites, required to provide innovative solutions to the problems they identified on the sites, and facilitated with the designed interventions of question prompts on self-regulated learning and creative problem solving, which included metacognitive prompts, procedural prompts, elaboration prompts, and reflective prompts, as well as prompts for creative problem solving strategies. The presented results were based on analysis of data collected through students' process journals and project reports. The students' utilization of question prompts, and self-regulated learning and creative problem process and outcomes were quantified first by employing the specific rubrics. Correlation analyses of question prompts with both process and outcomes of students' project-based service learning were conducted. The analysis reveals that question prompts are positively related with important components of self-regulated learning process and creative problem solving outcomes. It implies that scaffolding through question prompts could play an important role in the process and outcomes of self-regulated learning and creative problem solving. The limitations of current findings and suggestions for future research are also discussed.

## 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 demand 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 to lack of engineers.[2] To maintain our nation's global competitiveness, educational institutions have to address two imperative needs: one is to attract/retain diverse excellent students in science, technology, engineering, and mathematics (STEM) fields; and the other is to provide learning environment that fosters self-regulated learning and creative problem solving skills of STEM students.[3]

In general, however, current engineering education has been criticized for lack of characteristics necessary for developing creative problem solving skills, and often may stifle the development of these higher-order skills.[4] Such examples were identified by Magee et al. including: (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 the development of 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 be less effective than they might expect.

This paper intends to present the current efforts for exploring the effects of scaffolding creative problem solving through question prompts for community service learning projects in which underserved minority students learn and practice CPS techniques. It contends that the engineering design process can promote students' demands for cognitive and metacognitive strategies of self-regulated learning and creative problem solving, and the scaffolding through question prompts based on cognitive research findings can facilitate and promote the development of students' creative problem solving skills.

## Theoretical Basis and Methodological Background

### *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 to awareness of and reflection upon how one learns knowledge and how to use information to achieve a goal[7], 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. [8] Researchers have distinguished two main components of metacognition: metacognitive knowledge (acquired knowledge about cognitive processes and strategies that can be used to control cognitive processes and metacognitive experience) and metacognitive experiences (activities that control one's thinking and learning and involve the use of metacognitive strategies and metacognitive regulation). [9] 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 that metacognitive training, in addition to task-based training, can considerably improve performance.[10] Students with poor metacognition can benefit more from metacognitive training for improving their metacognition and academic performance.[11]

Creativity involves the introduction of new variables, significant leaps, and novel connections;[12] and deals with a "process" which results in a "novel product."[13]The most accepted frameworks on creativity can be categorized with Amablie's model. [14] 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 (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).[15] De Bono made a similar distinction between lateral thinking and vertical thinking. [16]Torrance 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. [17]

*Creative Problem Solving through Engineering Design*

Engineering design is an approach to identify and solve 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 and open to the idea that a problem may have many possible solutions, and provides a meaningful context for learning STEM concepts and a stimulus to system thinking. It requires actively 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 is typically 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 into core engineering courses.[18] Ocon adopted issue-based learning to introduce creativity and creative techniques.[19] 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.[20] Cropley 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, and concluded that the students in intervention group were more innovative in the machine design, whereas the control group was simply less inhibited.[21]

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.[22] 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. Though many claimed beneficial outcomes from students, there is limited research to support the claims. McCormick et al. have conducted experimental studies by using 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 participate in PBSL (N=33). The results indicated that the students with PBSL experience had a higher skill level than those who had not have a PBSL.[23]

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 through Question Prompts*

Rosenshine & Meister examined a variety of scaffolding that supported students' learning.[24] 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 undergraduates' 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 could prompt students to make meaningful and intentional efforts to identify relevant factors; help them organize information and plan the solution process; assist them in articulating their solution process; evaluate the selected solutions, and compare alternatives for the most variable solutions. [25]

Davis and Linn also found that reflective prompts supported knowledge integration and encouraged reflection at a level that students did not generally consider. [26] Reflection helps to connect metacognitive knowledge and metacognitive control. [27] 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 the 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.[28]

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 educational communities provide methodological basis for engineering educational 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.

## Method and Implementation Procedures

### *Participants, Objectives, and Requirement of Community Service Learning Project*

The participants of this research were freshmen who involved in the required community service learning project. The goals and requirements of the community service learning were presented to students at the beginning of the semester by the service learning facilitator through course lectures and handouts. The overall goal of this community service leaning project is to learn and practice self-regulated learning and creative problem-solving skills through experiential learning. The objectives of this community service leaning project is to provide a unique opportunity for students

- to learn, practice, and reflect on strategies for self-regulated learning and creative problem solving;
- to identify and define a real-world problem;
- to propose innovative solutions to the identified problems by using engineering design approach and
- to collaborate with others with different background and share learning experience.

Requirements and grade percentages of community service learning activity for students were composed of the following:

- Participation in self-evaluation survey (10%)
- Learning and tests on strategies of self-regulated learning and creativity (10%)
- Service learning journal (40%)
- Final project presentation (40%)

Once students were introduced to the community service learning sites, they needed to identity the problems that the community faces and define the problem that they would solve during their community service. They were required to work with their team members and make a plan to learn the related knowledge and strategies for creatively solving the problem through self-regulated learning, and to design innovative solution to the problem through creative problem solving process. Rather than just providing one solution to the problem, they were required to propose innovative solutions and consider the multiple alternatives by using engineering design approach.

During the community service learning process, students were required to learn the strategies for creative problem solving, and participate in self-evaluation surveys and mini-tests to evaluate their knowledge on the introduced strategies and their performance in applying the knowledge. They were also required to write community service project journals to record their thinking and reflection on the process of identifying problems, obtaining relevant knowledge, and creating innovative solutions. Finally, they were required to present and report their projects. At the end of the community service, they were required to submit their journals and final project reports.

Requirements and grading criterion of community service learning journal were given to students at the beginning of the semester. Students were required to have at least two journal entries per week. The journals will focus on cognitive (learning) and metacognitive (thinking, planning, and decision-making) processes in problem solving and learning, which included following aspects:

- establishment of your motivation and interest;
- problem identification;
- time planning and effort management;
- selection and application of relevant strategies introduced to them;
- idea-generation, self-monitoring, and self-evaluation;
- seeking help and resource;
- evaluation of usefulness of collections of creative thinking strategies; and
- identification of the effective question prompts on the above processes

Requirement and grading criteria of community service learning project reports were also given to students at the beginning of the semester, which included the following aspects:

- Proper presentation format;
- Problem description;
- State of previous work or solution by others;
- Innovative solution and how it is built on the previous works;
- How many alternative solutions and how many different approaches have been considered;
- How the innovation is initiated or what strategies are utilized for your innovative solution;
- References cited;

*Self-Regulated Learning and Creative Problem Solving Model*

To facilitate students' learning and problem solving in their community service learning projects, the components and processes of self-regulated learning and creative problem solving were presented to students through the course handouts, which were intended to provide students with conceptual understanding of effective learning and problem solving approaches. The presented components were developed based on self-regulated leaning model and includes components of self-monitoring and self-correction of the following three aspects in self-regulated learning and creative problem solving process.

- Motivation: including mastery goal for self-actualization (i.e., personal pursuit of well-being and passion); self-efficacy for maintaining optimal emotion and overcoming frustration due to failure; and persistency in valuable task until achieving goals;
- Metacognitive knowledge: including awareness of one's beliefs regarding learning and creativity, and metacognitive knowledge of the following interrelated parts: (a) knowledge of one's own cognitive and creative process; (b) conceptual knowledge about the specific cognitive and creative strategies that might be used for various learning and creativity tasks; and (c) procedural knowledge of when and where to use the acquired strategies; and
- Metacognitive action: planning; identifying resources and priority; implementing and monitoring; evaluating, reflecting, and taking proper action (e.g. control motivation and learning beliefs).

The general motivation model proposed by Pintrich was presented to students, which includes three components of motivation: (1) task value, which is an individual's perception of importance of a task, personal interest in the task, and perception of the utility value of the task for future goals; (2) goal orientation, which refers to a learner's concern with learning and mastering the task for self-improvement using self-set standards; and (3) self-efficacy, which is an individual's belief and confidence in their ability to accomplish goals they set[29]. The cognitive strategies are characterized by certain types of cognitive actions that actively promote the comprehension and retention of knowledge and information for solving problems. The metacognitive strategies could help students to formulate plans and goals, reflect critically on the proper selection of cognitive strategies, employ different cognitive strategies where necessary, and monitor progress while engaged in learning and problem solving processes. Creative problem solving strategies can help and guide students to think out of the box and generate innovative ideas for solutions. The question prompts corresponding to cognitive and metacognitve strategies, and creative problem solving strategies as described in the following section were also provided to students for guiding and prompting them to take proper actions.

The processes of engineering design as mentioned in the previous section and processes of self-regulated learning were presented to students as the process model for the community service learning through assigned reading materials. The self-regulated learning (SRL) process model includes four cyclic phases: (1) planning and designing, (2) identifying priorities and allocating resources, (3) self-monitoring, and (4) evaluating and controlling [30]. The proposed self-regulated learning model is actually repeated cycles of the four phases towards learning goals as shown in Fig. 1 and is similar to the processes of engineering design. Thus, presentation of the two processes together are expected to provide a unified conceptual process model for self-regulated learning and creative problem solving for guiding students' community service learning projects.

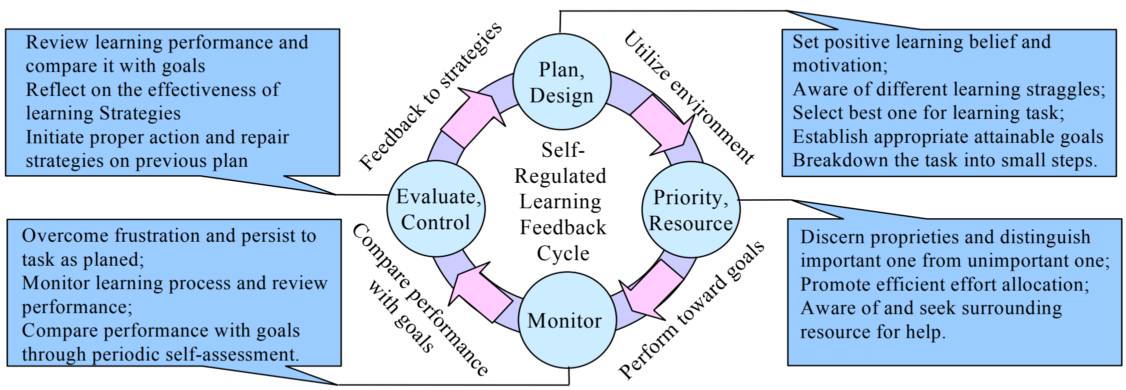


Fig. 1 SRL four-phase implementing feedback cycle model

*Scaffolding Creative Problem Solving with Question Prompts*

To guide students' creative problem solving 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 and creative thinking prompts based on cognitive research findings as follows [20,25] :

- 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, 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 articulate and elaborate 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 the exploration of more idea or solutions;
- Reflective prompts are intended to serve as cues to provoke students’ reflections and elicit self-evaluation on what happened in the past, such as “What did I do 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 I avoid this type of mistake in the future?”
- Creative problem solving prompts are provided to guide students generate creative design or solution to the problem they face, such as “What would happen if I put two solutions for other problems together for the problem I try to solution?”

*Implementation Procedures*

Student participants were provided with reading materials and a list of question prompts as described in the proceeding section after they started their creative problem solving in their community service learning project. Students were required to write down which question prompts were helpful for them to learn relevant knowledge and might help to develop their innovative solutions. To help students focus on some important aspects of the problem solving, instructors reminded them regularly through e-mails besides the list of question prompts. The students’ community service learning and embedded research included the following phases:

- Phase 1-Training: Seminars on creative problem solving skills were provided to students before they go to the community learning sites. Students were required to learn the materials to master how to solve a problem facing them in their service. The pre-test survey was administrated in this phase.
- Phase 2-On-site: Students were introduced to their community partners or mentors and started their service learning project for about two month period. Assisted by their project mentors, the students were introduced with the problems that the community faces and selected the project topics that fit into their learning interest and capability.
- Phase 3-Question prompts: Mentors or Instructors working as facilitators provided students’ prompt questions based on their progress by reminding students to use the question prompts and sending randomly-selected question prompts to students though e-mails regularly.
- Phase 4-Evaluation and report: Students wrote and submitted their process and reflection journals, and the project reports based on the provided requirements. The post-test survey was administrated in this phase.

Table 1 Rubric for Assessing Students' Process of Self-regulated Learning in Project-Based Service Learning Project

| Dimension Full description | Dimension Abbreviation | 1 Below Expectation | 2 Basic | 3 Average | 4 Outstanding |
|---|---|---|---|---|---|
| **Motivation and Interest** | Motivation and interest | No reasons for participating in project could be found; or little interest could be found. | One or two reasons for participating in project could be found, but low motivation. | Some reasons for participating in project could be found. | Some reasons for participating in project could be found clearly and definitely, showing strong motivation and interest.. |
| **Problem Identification** | Problem identification | Very incomplete or incorrect problem identification. | Problems are identified, but incomplete, some important information is missing. | Problems are identified basically, but incomplete, only minor improvements are needed. | Problems are identified completely and clearly. |
| **Time Planning and Effort Management** | Time planning | No time planning and effort management; or, time planning is irrational. | There is time planning and effort management, but not so clearly. | There is a clear time planning and effort management. | There is a clear and efficient time planning and effort management. |
| **Selection and Application of Relevant Strategies** | Selection Strategies | There is no selection and application of relevant strategies; or, strategies are irrational. | There is a selection and application of relevant strategies but not so clearly illustrated. | There is a good selection and application of relevant strategies. | There is an excellent selection and application of relevant strategies |
| **Idea-generation** | Idea-generation | There is no idea-generation in the completing of the program; or, idea is not clearly. | There is evidence for idea-generation in the completing of the program, but not so clearly illustrated, some important information is missing. | There is evidence for idea-generation, which can help the completion of the program and be stated clearly. | There is evidence for idea-generation, which played an important role in the completion of the program and is stated clearly. |
| **Self-monitoring** | Self-monitoring | No cue of self-monitoring can be found during the process. | A little cue of self-monitoring can be found during the process, but not clearly stated.. | Some cues of self-monitoring can be found during the process, but minor information should be added. | Some cues of self-monitoring can be found during the process clearly and definitely, which help the student complete the program successfully. |
| **Self-evaluation** | Self-evaluation | No cue of self-monitoring can be found; or self-evaluation is inaccurate and unclear. | A little cue of self-monitoring can be found, but, some self-evaluation is inaccurate and unclear. | Some cues of self-monitoring can be found, but, part self-evaluation is unclear. | Some cues of self-monitoring can be found accurate and clear, which are realized by the student to play an important role in program completion. |
| **Seeking Help and Resource** | Seeking help | There is no help seeking or resource processing. | Seeking help and resource processing once. | Seeking help and resource processing two or three times. | Seeking help and resource processing more than three times. |
| **Evaluation of Usefulness of Collections of Creative Thinking Strategies** | Creative thinking | No evaluation of usefulness of collections of creative thinking strategies. | Evaluate usefulness of collections of creative thinking strategies, and can use one in the creative problem solving. | Evaluate usefulness of collections of creative thinking strategies, and can use two of them in the creative problem solving. | Evaluate usefulness of collections of creative thinking strategies, and can use three of them in the creative problem solving. |
| **Identification of the Effective Question Prompts on the Above Processes** | Question prompts | No identification of the effective question prompts and indication of using them. | Identify effective question prompts, and state how to use one of them in the learning and problem solving | Identify effective question prompts, and state how to use two of them in the learning and problem solving | Identify and illustrate effective question prompts, and clearly state how to use at least three of them in the learning and problem solving. |

Table 2 Rubric for Assessing Students' Outcomes of Creative Problem Solving in Project-Based Service Learning Project

| Dimension<br>Full description | Dimension<br>Abbreviation | 1<br>Below expectation | 2<br>Basic | 3<br>Average | 4<br>Outstanding |
|---|---|---|---|---|---|
| **Proper presentation format** | Proper presentation | Sections out of order, sloppy formatting; or, some sections are missing. | Sections in order, formatting are rough but readable. | All sections in order, formatting generally well but could still be improved. | All sections in order, well-formatted, very readable |
| **Problem description** | Problem description | No problem description; or, missing several important details. | Still missing some important details. | Important details are covered, some minor details missing | All details are covered in a logical way. |
| **State of previous work or solution by others** | Previous work | There is no state of previous work or solution by others. | There is a state of previous work or solution by others, but not so clearly. | There is a state of previous work or solution by others, and some reviews on them. | There is a state of previous work or solution by others, and some excellent reviews on them. |
| **Innovative solution and how it is built on the previous works** | Innovative solution | There is no solution | There is a solution, but no clear description on how this solution is innovative in comparison to existing solutions or others' works. | There is a solution and description on how this solution is different from existing solutions or other's works in a slightly different way. | There is a solution, and clear description on how this solution is innovative and different from existing solutions or others' works in a significantly different way. |
| **How many alternative and different approaches have been considered** | Alternative solutions | There is no alternative solution in the program. | There is an alternative solution in the program, but no detail description about it. | There is an alternative solution in the program, with detail description about it. | There is an alternative solution in the program, with detail and excellent description about it. |
| **How the innovation is initiated or what strategies are utilized for your innovative solution** | strategies utilized | There is no description about how the innovation is initiated or what strategies are utilized for your innovative solution. | There is a description about how the innovation is initiated or what strategies are utilized for your innovative solution, but not so clearly. | There is a description about how the innovation is initiated or what strategies are utilized for your innovative solution, with detail description about it. | There is a description about how the innovation is initiated or what strategies are utilized for your innovative solution, with detail and excellent description about it. |
| **Reference cited** | Reference cited | There is no reference cited. | There is a reference cited, but not based on the norm. | There is a reference cited, based on the norm, but less than three citations. | There is a reference cited, based on the norm, and more than three citations. |

Table 3 Assessment of students' process and outcomes of self-regulated learni
and creative problem solving

| Variables | Dimension | Level (score) distribution * | | | | Mean | Standard Deviation | % of students with 3 or 4 |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | | | |
| stion prompts | Question prompts | 4 | 9 | 5 | 3 | 2.33 | 0.97 | 38.1 |
| rning cess | Motivation and interest | 0 | 0 | 4 | 17 | 3.81 | 0.40 | 100 |
| | Problem identification | 0 | 1 | 6 | 14 | 3.62 | 0.59 | 95.2 |
| | Time planning | 1 | 2 | 7 | 11 | 3.33 | 0.86 | 85.7 |
| | Selection of strategies | 0 | 3 | 8 | 10 | 3.33 | 0.73 | 85.7 |
| | Idea-generation | 2 | 2 | 10 | 7 | 3.05 | 0.92 | 80.5 |
| | Self-monitoring | 1 | 4 | 9 | 7 | 3.05 | 0.86 | 76.2 |
| | Self-evaluation | 2 | 2 | 12 | 5 | 2.95 | 0.86 | 80.5 |
| | Seeking help | 3 | 1 | 13 | 4 | 2.86 | 0.91 | 80.9 |
| | Creative thinking | 3 | 1 | 13 | 4 | 2.86 | 0.91 | 80.9 |
| | Total (all process dimensions) | 12 | 16 | 82 | 79 | 28.33 | 5.80 | |
| rning comes | Proper presentation | 0 | 1 | 7 | 13 | 3.57 | 0.60 | 95.2 |
| | Problem description | 0 | 2 | 9 | 10 | 3.38 | 0.67 | 90.5 |
| | Previous work | 0 | 2 | 10 | 9 | 3.33 | 0.66 | 90.5 |
| | Innovative solution | 0 | 3 | 14 | 4 | 3.05 | 0.59 | 85.7 |
| | Alternative solutions | 7 | 5 | 7 | 2 | 2.19 | 1.03 | 42.8 |
| | Strategies utilized | 14 | 3 | 2 | 2 | 1.62 | 1.02 | 19.0 |
| | References cited | 20 | 0 | 0 | 1 | 1.14 | 0.65 | 4.8 |
| | Total(all outcome dimensions) | 41 | 16 | 49 | 41 | 18.29 | 3.87 | |

Note: * numbers of students with different levels for each dimension or variable

Table 4 Correlations among students’ process of learning, those in their learning outcomes in design project and question prompts

| Variables | Dimension | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Learning Process | 1.Motivation and interest | 1 | | | | | | | | | | | | | | | |
| | 2.Problem identification | .629** | 1 | | | | | | | | | | | | | | |
| | 3.Time planning | .522* | .462* | 1 | | | | | | | | | | | | | |
| | 4.Selection strategies | .567** | .693** | .774** | 1 | | | | | | | | | | | | |
| | 5.Idea-generation | .566** | .803** | .588** | .868** | 1 | | | | | | | | | | | |
| | 6.Self-monitoring | .547* | .765** | .551** | .818** | .945** | 1 | | | | | | | | | | |
| | 7.Self-evaluation | .746** | .720** | .626** | .845** | .876** | .873** | 1 | | | | | | | | | |
| | 8.Seeking help | .171 | .403 | 0234 | .331 | .431 | .499* | .399 | 1 | | | | | | | | |
| | 9.Creative thinking | .195 | .449* | 0.359 | .677** | .724** | .753** | .644** | .682** | 1 | | | | | | | |
| | 10.Total process | .629** | .813** | .669** | .895** | .944** | .942** | .915** | .614** | .797** | 1 | | | | | | |
| Learning outcomes | 11.Proper presentation | .333 | .548* | .125 | .310 | .517* | .572** | .438* | .435* | .404 | .525* | 1 | | | | | |
| | 12.Problem description | .462* | .660** | .630** | .774** | .825** | .887** | .780** | .673** | .759** | .903** | .643** | 1 | | | | |
| | 13.Innovative solution | .267 | .586** | .365 | .573** | .766** | .733** | .525* | .260 | .525* | .650** | .302 | .628** | 1 | | | |
| | 14.Alternative solutions | .469* | .553** | .767** | .648** | .781** | .724** | .659** | .335 | .422 | .727** | .397 | .712** | .679** | 1 | | |
| | 15.Strategies utilized | .440* | .591** | .730** | .693** | .798** | .732** | .673** | .288 | .417 | .730** | .491* | .730** | .635** | .946** | 1 | |
| | 16.Total outcomes | .454* | .663** | .553** | .671** | .809** | .825** | .742** | .561** | .636** | .827** | .775** | .913** | .639** | .785** | .823** | 1 |
| Question prompts | 17.Question prompts | .195 | .385 | .266 | .602** | .665** | .690** | .581** | .569** | .940** | .711** | .350 | .665** | .525* | .340 | .334 | .551** |

Note: ** < 0.01, * < 0.05; the number in the table refers to the correlation coefficient. Previous work and reference cited

*Data Collection and Analyses*

The data on students' process and outcomes of community service learning under the scaffolding for creative problem solving were collected from students' process and reflection journals, and their final project reports. Those processes and outcomes were quantified prior to statistics analysis. Students learning and problem solving process were divided into 10 dimensions. The rubrics in Table 1 were developed for coding each dimension of the process of self-regulated learning and creative problem solving. Students learning and problem solving outcomes were divided into 7 dimensions. The rubrics in Table 2 were developed for coding each dimension of the outcomes of self-regulated learning and creative problem solving.

The students' journals and project reports were read and evaluated by one research assistant and one research associate. A list of emergent themes related to dimensions in the learning process and outcomes, particularly for those related to students' utilization of question prompts, dimensions in the process related to self-regulated learning, and dimensions in the outcomes related to creative problem solving, were identified. Based on these identified themes, these journals and reports were then coded and quantified in according to the rubrics mentioned in the above. Pearson product-moment correlation analysis was performed by using software SPSS to explore the correlation between question prompts with self-regulated learning in the process, and the correlation between question prompts with creative problem solving in the outcomes.

**Results from Data Analysis**

The total 21 pairs of students' learning and reflection journals and final project reports were available from the research implementation during the fall semester of 2011. Results from quantifying those journals and reports based on rubrics in Table 1 and 2 are shown in Table 3 in terms of utilization of question prompts, learning and problem solving process, and learning and problem solving outcomes. Results from the correlation analysis among question prompts, learning process, and learning outcomes performed by using software SPSS are tabulated in Table 4.

The correlation between two variables or dimensions are examined and expressed in terms of the correlation coefficient r and p-value. The correlation coefficient r ranges from −1 to 1. The lager the absolute value of r is, the stronger the correlation between two variables will be. The p-value here is referred to as the probability that the assumption that there is no correlation between two variables as hypothesized is actually correct. When the p-value is less than the predetermined significance level, which is often 0.05 or 0.01, it indicates that the observed correlation can be statistically acceptable with confidence.

The results from correlation analysis in Table xxx shows that question prompts was related with learning process ($r = 0.711$, $p < 0.01$). And it was closely related with three components of self-regulated learning involving "Selection strategy"($r = 0.602$, $p < 0.001$),"self-monitoring" ($r = 0.690$, $p < 0.001$), "self evaluation"($r = 0.581$, $p < 0.001$). This indicates that question prompts are correlated with self-regulated learning. Additionally, question prompts was closely correlation with other components in learning process, such as "Idea generation"($r = 665$, $p < 0.01$), "Seek help"($r = 569$, $p < 0.05$).

Further, the results correlation analysis was also conducted to examine the relationship between question prompts with creative problem solving outcomes. Question prompts was related with "creative thinking"($r = 0.940$, $p < 0.01$), "innovative solution"($r = 0.525$, $p < 0.05$), "problem description"($r = 0.665$, $p < 0.01$) in the outcomes. The correlation coefficient between question prompts with learning outcomes was also significant ($r = 0.551$, $p < 0.01$). It means that question prompts are related with the enhancement of students' learning outcomes.

The current study also showed that the correlation between learning process and learning outcomes was positive and the coefficient was significant ($r = 0.827$, $p < 0.01$). The relation between each dimension in learning process and learning outcomes were significant positive correlation ($0.454 \leq r \leq 0.825$, $p < 0.05$), and the relation between each dimension in learning outcomes and learning process were significant positive correlation ($0.525 \leq r \leq 0.903$, $p < 0.05$). This implies that the better scores of the process of community service learning, the better the learning outcomes is.

**Discussion**

The results from correlation analyses indicate question prompts were positively related with different components of self-regulated learning in the learning and problem solving process, as well as with components of creative problem solving in the learning and problem solving outcomes. This indicates that scaffolding creative problem solving through question prompts indeed has closely relation with self-regulated learning and creative problem solving skills. The more intensively the question prompts are utilized, the better the self-regulated learning process and creative problem solving outcomes are. This implies that the question prompts could lead to better self-regulated learning process and creative problem solving outcomes.

The current study is based on data collected from limited numbers of paired process journal and outcome reports. The analysis of those data only reveals the correlation of question prompts with self-regulated learning in the process, as well as creative problem solving in the outcomes. However, it can not precisely confirm what effects question prompts could have on the self-regulated learning and creative problem solving skills. In further research, several structure models should be explored and constructed to conduct confirmatory factor analyses and confirm the effects of scaffolding through question prompts on self-regulated learning and creative problem solving skill development. The further efforts should also be made to collect and accumulate more valid students' journal and reports. Besides, the data collected from the instrument particularly measured creative problem solving skills and creativity should be also included in the model to more precisely reveal the effects of scaffolding through question prompts in the project-based service learning on students' higher-order skill development.

**Conclusion**

This paper describes on-going efforts for investigating effects of scaffolding creative problem solving through question prompts on students' self-regulated learning and creative problem solving skill development. The results from correlation analysis of available data reveal that question prompts were positively related with major components of self-regulated learning process, such as "selection strategy", "self-monitoring", and "self-evaluation", question prompts were also positively related with important components of creative problem solving outcomes, such as "problem description", "creative thinking", and "innovative solution". It indicates that scaffolding through question prompts could play an important role in self-regulated learning process and creative problem solving outcomes. Further research should explore structure models by using confirmatory factor analyses to confirm effects of the scaffolding through question prompts on self-regulated learning and creative problem solving skill development. The further efforts should also include collecting and accumulating more valid data from students' self-regulated learning process and creative problem solving outcomes.

**Acknowledgements**

The authors gratefully acknowledge the support of the Division of Undergraduate Education of the National Science Foundation under the grant HRD-#1036328. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

## References


[1] Harvey, L., Moon, S., & Geall, D. V.. "Graduates' Work: Organizational Change and Student Attributes". Centre for Research into Quality, Birmingham, UK. 1997.

[2] National Science Board (NSB). "Moving Forward to Improve Engineering Education" 2007. Retrieved from http://www.nsf.gov/pubs/2007/nsb07122/nsb07122.pdf.

[3] Baillie, C. "Enhancing Creativity in Engineering Students". *Engineering Science and Education Journal, 11* (5), (2002): 185 – 192.

[4] Tobin, K., & Gallagher, J. J. "What Happens in High School Science Classrooms?" *Journal of Curriculum Studies, 19*, (1987): 549–560.

[5] Magee, C. L. et al. (2003). Advancing Inventive Creativity through Education, the report of the Lemelson-MIT Workshop on Advancing Inventive Creativity through Education, retrieved in 2003, http://web.mit.edu/invent/n-pressreleases/downloads/education.pdf.

[6] Barak, M. & Goffer, N. "Fostering Systematic Innovative Thinking and Problem Solving: Lessons Education Can Learn from Industry". *International Journal of Technology and Design Education, 12* (3), (2002)：227-247.

[7] Flavell, J. H. "Cognitive Monitoring". In W. P. Dickson (Ed.), *Children's Oral Communication Skills.* New York: Academic Press (1981).

[8] Dunslosky, J., & Thiede, K. W. "What Makes People Study More? An Evaluation of Factors that Affect Self-paced Study". *Acta Psychologica, 98*, (1998): 37–56.

[9] Brown, A. L. "Metacognition, Executive Control, Self Regulation and other More Mysterious Mechanisms." In F. E. Weiner & R. H. Kluwe (Eds.), *Metacognition, Motivation, and Understanding.* Hillsdale, NJ: Erlbaum (1987).

[10] Nietfeld, J. L., & Schraw, G. The Effect of Knowledge and Strategy Explanation on Monitoring Accuracy. *Journal of Educational Research, 95*, (2002):131–142.

[11] White, B. Y., & Frederiksen, J. R. "Inquiry, Modeling, and Metacognition: Making Science Accessible to All Students". *Cognition & Instruction, 16* (1998): 3–118.

[12] Schunn, C. D., Paulus ,P. B., Cagan, J., and Wood, K. "The Scientific Basis of Individual and Team Innovation and Discovery". Final report from the NSF innovation and discovery workshop (2006). Retrieved from http://www.nsf.gov/pubs/2007/nsf0725/nsf0725.pdf.

[13] Burleson, W. "Developing Creativity, Motivation, and Self-actualization with Learning Systems". *International Journal of Human-Computer Studies, 63* (2005.) : 4-5.

[14] Amabile, T. "The Social Psychology of Creativity: A Componential Conceptualization". *Journal of Personality and Social Psychology 45* (2), (1983): 357–376; Amabile, T. M. "How to Kill Creativity". *Harvard Business Review, 76* (5), (1998):76-87.

[15] Guilford, J. P. *The Nature of Human Intelligence.* New York: McGraw-Hill (1967).

[16] De Bono, E. *Lateral Thinking.* Ward Lock Educational, London (1990). ; De Bono, E. *Serious Creativity.* Harper Collins Publications, New York (1992).

[17] Torrance, E.P. Rewarding Creative Behavior: Experiments in Classroom Creativity. Englewood Cliffs, NJ: Prentice-Hall, Inc. (1965).

[18] Ogot, M. and Okudan, G. E. "Integrating Systematic Creativity into First-year Engineering Design Curriculum". *International Journal of Engineering Education, 21*(2005).

[19] Ocon,.R. "Teaching Creative Thinking to Engineering and Technology Students". Proceeding of 9th International Conference on Engineering Education (2006).

[20] Yashin-Shaw, I "The effectiveness of the StrateGEE model for creative problem-solving as a tool for facilitating creative thinking", in Enriching learning cultures: proceedings of the 11th annual international conference on post-compulsory education and training: volume 3., ed. G University Faculty of Education Centre for Learning Research, Australian Academic Press, Brisbane( 2003), pp.190-197.

[21] Cropley, D. "Engineering Creativity: A Systems Concept of Functional Creativity". In Kaufman, James C. & Baer, John (Eds). *Creativity Across Domains: Faces of the Muse.* Mahwah, NJ: Lawrence Erlbaum Associates Publishers (2005): 169-185.

[22] National Science Board (NSB). "Moving Forward to Improve Engineering Education" 2007. Retrieved from http://www.nsf.gov/pubs/2007/nsb07122/nsb07122.pdf.

[23] McCormick, M., Swan, C., Matson, D., Gute., Durant, J. (2008). Enhancing Engineering Education: Learning to solve problems through service-learning projects. Proceedings of 115th Annual American Society of Engineering Education Conference, Pittsburgh, PA

[24] Rosenshine, B., & Meister, C. "The Use of Scaffolds for Teaching Higher-level Cognitive Strategies". *Educational Leadership, 49* (7), (1992): 26-33.

[25] Ge, X., & Land, S. M. "Scaffolding Students' Problem-solving Processes in an Ill-structured Task Using Question Prompts and Peer Interactions". *Educational Technology, Research and Development, 51*(1), (2003): 21-38.

[26] Davis, E. A., Linn, M. C. "Scaffolding Students' Knowledge Integration: Prompts for Reflection in KIE". *International Journal of Science Education, 22* (8), (2000): 819-37.

[27] Ermer, P. A., Newby, T. J. "The Expert Learner: Strategic, Self-regulated, and Reflective". *Instructional Science, 24* (1), (1996): 1-24.

[28] Malloy, C. E., & Jones, M. G. "An Investigation of African American Students' Mathematical Problem Solving". *Journal for Research in Mathematics Education, 29* (2), (1998): 143-163.

[29] Pintrich, P.R. 1999. "The role of motivation in promoting and sustaining self-regulated learning." International Journal of Educational Research 31(1999) 459-470

[30] Zheng, W., Yin, J., Skelton, G., Shih, H., Pei, T. & Yin, J. (2012). "Implementing Self-Regulated

Learning Process Model and Assessment for Facilitating Civil Engineering Students to Master Engineering Concepts," Proceedings of 2012 ASEE Annual Conference, June 10 - 13, 2012, San Antonio, Texas