AC 2009-1201: NURTURE MOTIVATED, CONFIDENT, AND STRATEGIC LEARNERS IN ENGINEERING THROUGH COGNITIVE AND PSYCHOLOGICAL INSTRUCTION FOR AN ENTRY-LEVEL COURSE

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Nurture Motivated, Confident, and Strategic Learners in Engineering through Cognitive and Psychological Instructions for an Entry-Level Course

Abstract

There is a disconnection between teaching specific domain contents and developing effective cognitive skills for students in current engineering education. This disconnection makes it difficult for students to apply effective cognitive strategies for their learning in specific engineering domain. Students who failed in their engineering studies may attribute their failures to lack of ability in learning engineering rather than a lack of effective use of cognitive strategies. They may decide to quit from engineering programs due to frustrations from their setbacks in learning. As students from minority groups are interested in learning engineering, the challenge is to nurture their interest, maintain their efforts, and strengthen their confidence that they can succeed. Thus, there is an imperative need for engineering faculty to adapt new instructional strategies that can help students to effectively regulate their learning motivation, strategies, and efforts, particularly at their early learning stages.

Self-Regulated Learning (SRL) has been research subject and educational practice in the context of Educational Psychology. SRL involves self-monitoring and self-correction of three components of learning: motivation, behavior, and cognition. It refers to active learning guided by three important aspects of learning: (1) motivation to learn; (2) metacognition (awareness of one's knowledge and beliefs); and (3) strategic action (planning, evaluating, and acting). One important aspect in SRL is to regulate the learners' motivation. Psychological instruction model of Expandable Intelligence (EI) is established based on new psychological findings that learners' belief on their intelligence has a profound influence on their motivation to learn. With the belief that intelligence can be expanded (as opposed to the view of fixed intelligence), learners are able to attribute their successes or failures to factors within their control (e.g. effective use of strategies, or effort on a task) rather than lack of ability. They can be motivated to use learning strategies and persist in their learning efforts for expanding their intelligence.

This paper presents relevant development and findings from cognitive science and education practice on motivation and self-regulated learning, and proposes a new instructional strategy and its implementation plan for a freshmen entry-level course. It includes Direct Instruction that presents the EI and SRL model, as well as related strategies, to students as stand-along learning contents; and Immersion Instruction that merges the instruction based on EI and SRL as salient cues and scaffold into Problem/Project-Based Learning (PBL) process through a co-curricular design project. The course project requires freshmen to identify a problem and provide innovative technological solutions that could impact and improve students' studies and lives around campus. Students will be given sufficient time and autonomy to identify problems, learn required knowledge through SRL, and formulate innovative solutions in a way that not only engages them but also is relevant to their particular learning level and interest. The outcomes from pilot implementation indicated that the proposed instruction strategies could improve students' perception on self-regulated learning and innovative-problem solving through Problem/Project-Based Learning pedagogy, and promote students to seek and practice the learning strategies. The proposed instruction strategies could be transferable for other courses to facilitate students to become motivated, confident, and strategic learners in engineering.

Introduction

Lower retention rate of students in engineering can be attributed to lack of interest and confidence in studying engineering. As students from minority groups are interested in learning engineering, the challenge is to nurture their interest, maintain their efforts, and strengthen their confidence that they can succeed. One of major objectives of an entry-level course is to help freshmen make a smooth transition to university life and maximize their academic potential. Most efforts in such a course have typically focused on teaching a variety of learning strategies and problem solving skills. However, these strategies and skills may be taught without appropriate excises or practice on specific learning tasks. Students often can not fully understand these strategies and effectively apply them in their subsequent studies. Furthermore, the instructions in these courses has usually less focus on addressing students' motivation, confidence, and reflection in learning, which are critical for students to effectively implement learning strategies and persist in their learning efforts. Students who failed in their engineering studies may often attribute their failures to lack of ability in learning engineering rather than lack of effective use of learning strategies. They may eventually decide to quit from engineering programs. Thus, there is an imperative need for engineering faculty to adapt new instructional strategies that can help students to effectively regulate their learning motivation, strategies, and efforts, particularly at their early learning stages.

Self-Regulated Learning (SRL) has become a research subject and educational practice in the context of Educational Psychology. It involves self-monitoring and self-correction of three components of learning: self-regulation of motivation, behavior, and cognition[1], and refers to active learning that is guided by motivation to learn[2,3], metacognition (awareness of one's knowledge and beliefs), and strategic action (planning, monitoring, and evaluating personal progress, and taking proper action). One important aspect in SRL is to regulate the learners' motivation. Psychological instruction model of Expandable Intelligence (EI) is established based on new psychological findings that learners' belief on their intelligence has a profound influence on their motivation to learn. With the belief that intelligence can be expanded (as opposed to the view of fixed intelligence), learners are able to attribute their successes or failures to factors within their control (e.g. effort on a task, or effective use of strategies) rather than their ability. They can be motivated to use learning strategies and persist in their learning efforts for expanding their intelligence[4].

A wealth of research has supported that optimal academic performance is strongly tied to the extent to which the learner uses SRL [1,3]. SRL training, even if administered for a short time in addition to task-based training, can improve performance considerably more than students who do not receive SRL training [5,6,7,8]. Even more encouraging is that academically weak students are found to benefit more from SRL training[9]. Equipping students with SRL abilities not only contributes to success in formal education, but also prepares them for lifelong learning[10]. Nonetheless, SRL is not well known and utilized by the Engineering education community for facilitating student learning in Engineering.

This paper presents relevant development and findings from cognitive science and education practice on motivation and self-regulated learning, and proposes a new instructional strategy and its implementation plan, which integrate EI and SRL model through two instructional strategies:

Direct Instruction and Immersion Instruction into an entry-level course for freshmen. The proposed new instruction strategies are built on the framework of cognitive science and authors' engineering education practice in the pilot implementation. The outcomes of the pilot implementation are provided and discussed. The presented instruction strategies and their implementation plan is the part of an ongoing CCLI-Phase I project supported by the Course, Curriculum, and Lab Improvement (CCLI) Program in National Science Foundation.

Objectives of Proposed New Course Modules and Expected Outcomes

Collaborative efforts have been initiated among faculty members from multiple engineering departments and the Division of Undergraduates Studies at Jackson State University to implement new instructional strategies that properly integrate the cognitive instruction model of SRL and psychological instruction model of EI with Problem/Project-Based Learning for freshmen in an entry-level course. The ultimate goal of implementation of these new instructional strategies for a freshmen level course is to improve retention rate of students in the School of Engineering at their early learning stages.

The objectives of instructional strategies are:

- to enhance freshmen's learning motivation, confidence, and strategies through introducing SRL and EI for them to persist and succeed in their subsequent engineering studies
- to facilitate freshmen to understand and use Self-Regulated Learning (SRL) and foster their SRL skills through co-curricular active Problem/Project-Based Learning activities

The expected educational outcomes are:

- to improve students conceptual understanding of basic concepts of SRL,
- to improve students' perception on their intelligence through imposing Expandable Intelligence belief,
- to increase students' motivation, confidence, and willingness to put efforts and take challenge in their studies,
- to enhance students' academic performance through effective use of learning strategies,
- to increase student retention rate in engineering.

Rationale for Development and Implementation of New Course Modules

According to national statistics, the bachelor-degree holders from Engineering and Technology (E&T) declined by 5 % over last decade. Only 5.6 % of the bachelor-degree awardees were from E&T in 2004[11]. African-American students enrolled in engineering were only 6-7% of engineering undergraduates during the last decade, as compared to their 14% of share of the US population of 18-24 year olds [12]. About 60% of students who enter engineering majors obtain a degree within 6 years. Attribution is substantial in engineering, particularly in the first year of college.

This national trend is also reflected in Jackson State University (JSU). JSU is located in the state's capital and largest metropolitan area, and is the only urban university that offers engineering programs in Mississippi. Over 8000 students now are enrolled in JSU and over 95%

of them are African-Americans. As one of largest Historical Black Universities and Colleges, JSU ranks high among universities in educating African-Americans. For example, JSU is No. 1 in its production of African Americans with baccalaureates in education, No. 2 in biological and biomedical sciences, and No. 3 in English by Diverse Issues in Higher Education Magazine in 2006. Each year about 1100 freshmen students are enrolled at JSU. However, only about 5% of them declare engineering as their major. The first year retention rate for civil engineering is 50% (2005-2006). The graduation rate for computer engineering is 25% for the period of 2000-2005. Thus, one of challenge for engineering education is to retain those students who are initially attracted to engineering.

Based on the experience of working with students at risk or those who quit from the engineering programs, the discussion among faculty members in the School of Engineering (SOE) at JSU has revealed that most of these students possess the ability for achieving the required performance in engineering education, and specific reasons that resulted their failing or dropping out of engineering are: (1) lack of motivation and interest in learning engineering; (2) lack of good learning habits or strategies, and efforts in their studies; and (3) lack of association with other engineering students and faculty for seeking support when they needed.

To help all freshmen maximize their potential for academic success, a general entry-level course is required for all freshmen at JSU. This course covers a variety of academic/non-academic skills, such as note-taking, test-taking, critical thinking skills, success seminars and relationship building. The authors of this paper have served as freshmen advisors, instructor for the general entry-level course, and administrator of the First Year Experience program. It is the authors' perception that the series of learning skills in the entry-level course are taught abstractly without appropriate practice on specific cognitive tasks in technical domain. Students may not have opportunity to exercise these learning skills and obtain feedback on how they use these strategies. They often can not fully understand these strategies and effectively apply these skills in their subsequent engineering studies. Reviews of similar interventions also indicated that such programs do not sufficiently help students attain their academic goals [13,14].

Furthermore, possessing learning motivation and self-confidence is a critical prerequisite for students to apply effective cognitive strategies, persist in their effort, and eventually succeed in their engineering studies. Thus, there is an imperative need for engineering faculty to adapt and develop new instructional strategies that integrate cognitive skill development and engineering learning, and help students to effectively regulate their learning motivation, efforts, and strategies at all stages, particularly at students' early learning stages.

National Engineering Education Trend and Paradigms

To address the challenge in engineering education, the National Committee for Educating the Engineer in 2020 presents a suite of recommendations, including: (1) introducing the "essence" of engineering early; (2) introducing interdisciplinary learning to undergraduates; and (3) improving public understanding of E&T literacy[15]. The leading engineering schools have exhibited success with a variety of curricular and non-curricular programs designed to attract and retain students, including out-of-classroom experience; assignments to multidisciplinary project teams; hands-on and integrative experience in the first year; and emphasis on social relevance, service learning, and collaboration[16].

For example, the Colorado School of Mines allows freshmen to discover important connections among multi-disciplines, and to acquire a deeper appreciation of the importance of their Engineering studies and their interrelation with upper-level courses, their careers and life. It includes extensive use of active and cooperative learning strategies for interdisciplinary topics through student peer study group[17]. The evaluation of the program indicates that the intervention improve students' academic performance. Interactions with faculty and peers were the most positive aspect of students' experience. Turf University has formed a multiple-disciplinary learning community, in which senior students from different disciplines work together and achieve hands-on learning in multiple-disciplinary robotic projects[18]. Students regard this experience as the best thing they do in their four years at college. Some students have chosen to continue onto graduate studies, or have started careers related to their experience. In Bucknell University, upper-level students participate in designing a lab for a freshmen-level course and served as TAs, and learn how to create a lab experiment and how to present the information, while the freshmen have the opportunity to contact with upper-level students and obtain hands-on experience [19].

To make STEM more meaningful and inspire high school students, the University of Pittsburgh has developed Design-Based Learning (DBL) units. DBL provides challenge and opportunity for student to make decision on what projects and solutions should be followed. This gives students ownership of their projects, and makes them more deeply engaged in learning. Once the design process starts, students receive well-designed course materials to guide their design[20]. The results suggest that DBL for teaching STEM concepts has superior performance in terms of knowledge gain, engagement, and retention, and is most helpful to minority students [21].

Current Research and Practice Related to Self-Regulated Learning (SRL)

The people's learning belief is a critical motivational component that is very important in Self-Regulated Learning. The latest research from Educational Psychology has revealed that a student’s self-perception on intelligence has a profound influence on their motivation to learn[22]. Students who hold a "fixed" intelligence theory believe that their failure signals lack of intelligence rather than lack of using strategies and making efforts. As a result, they avoid challenges or decrease their efforts after a setback, placing their academic performance in a downward trend. In contrast, students who believe in an "expandable" intelligence belief want to challenge themselves to increase their abilities or intelligence even through they fail at first, because they are motivated and energized by the belief that their intelligence can be expandable by their learning efforts. In that research, students in the intervention group were taught not only with study skills, but also how they could learn to be smart by describing the brain as a muscle that can become stronger as it was used more. A control group also learned study skills but was not taught expandable intelligence concepts. In just two months, the students from the intervention group showed remarkable improvement in learning habits and grades as compared to the control group.

To turn Self-Regulated Learning theory into practice and promote students to develop their Self-Regulated Learning skill, Paris & Winograd suggested that Self-Regulated Learning can be taught with various tactics, including indirect modeling and activities that entail reflective analyses of learning [23]. Somuncuoglu and Yildirim recommend that metacognitive strategies in Self-Regulated Learning can be specifically emphasized by incorporating self-regulated course activities that raise the students' awareness of planning (set learning goals), monitoring (self-testing), and regulating (determine best way to learn) [24]. Celuch and Slama have given students assignments based on the above recommendations to stimulate students' self-regulated learning in marketing education [25]. The learning benefits of these assignments have been favorably assessed with student surveys and feedback. Young evaluated motivational effects of classroom environment in facilitating Self-Regulated Learning in his marketing education. His findings suggest that active application-oriented experiences delivered by enthusiastic faculty, who provide high interaction, supportive feedback, and clear goals that emphasize learning over grades, will increase students' motivation and their use of SRL[26].

Nonetheless, SRL has just started drawing attention among engineering and technology education community. Blank et al. developed a SRL Assessment System through the self-assessment-for-learning approach in their two-year technology program[27]. Within this framework, students learn to track and assess more effectively their academic learning and self-regulation skills through a series of self-assessment questionnaires associated with class quizzes. These questionnaires simulate a three-phase SRL model in series of self-directed feedback cycles. Each of cycles includes planning, practice and evaluation. Through deliberate practice with Self-Regulated Learning assessment, students become more skilled at using both metacognitive and external feedback to continuously adjust and improve their learning efforts.

Step One of Proposed Instructional Strategy -Enhance Students' Motivation

Presenting cognitive strategies to students does not guarantee their achievement, because implementation of these strategies is not an easily task and needs persistent effort. Students must have motivation to use the strategies and regulate their learning efforts. Thus, students must be motivated to learn SRL concepts, acquire SRL strategies, and practice these strategies through self-directed active learning. In order to effectively motivate students' effort, students' motivation for pursuing SRL will be conceptualized using a theoretical framework of the general motivation model by Pintrich[28]. Step one of proposed instructional strategy will utilize expandable intelligent model to address the three motivational components from Pintrich's model for promoting use of SRL, and is developed into new learning materials delivered to students through class lecture with following principles:

- Enhancing Self-efficacy: Self-efficacy is an individual's belief and confidence in their ability to accomplish goals. The expandable intelligence concept will be introduced to students with. It is expected to help students establish learning confidence and belief that their learning efforts can improve their intelligence or ability, and they can succeed if they make effort and use effective strategies.

- Increasing Task Value: Task value 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. Expandable intelligence theory can help students perceive that challenge in learning engineering through SRL can provide intellectual stimulation for enhancing their own intelligence or ability.

- Setting Goal Orientation: Goal orientation includes mastery goal orientation referring to concern with learning and mastering the task using self-set standards and self-improvement; extrinsic goal orientation focusing on getting good grades and pleasing others may be attained without much in-depth self-regulated learning; and relative ability orientation concern with comparing their performance with others. The instructors will instruct students to shift their focus from comparing their performance to peer to self-comparison toward mastery goal orientation. The mastery goal orientation can be reinforced by an expandable intelligence concept through linking their mastery of learning to students' own intelligence or ability development and improvement.

Step Two of Proposed Instructional Strategy - Promote Self-Regulated Learning

To promote students to development self-regulated learning skills, the conceptual SRL model and its strategies have to explicitly be introduced to students in the class room and integrated into their learning activities. Step two of proposed instructional strategy is to implement two types of instruction strategies for promoting SRL in incorporation with classroom lecture learning and effective problem-based learning as followings.

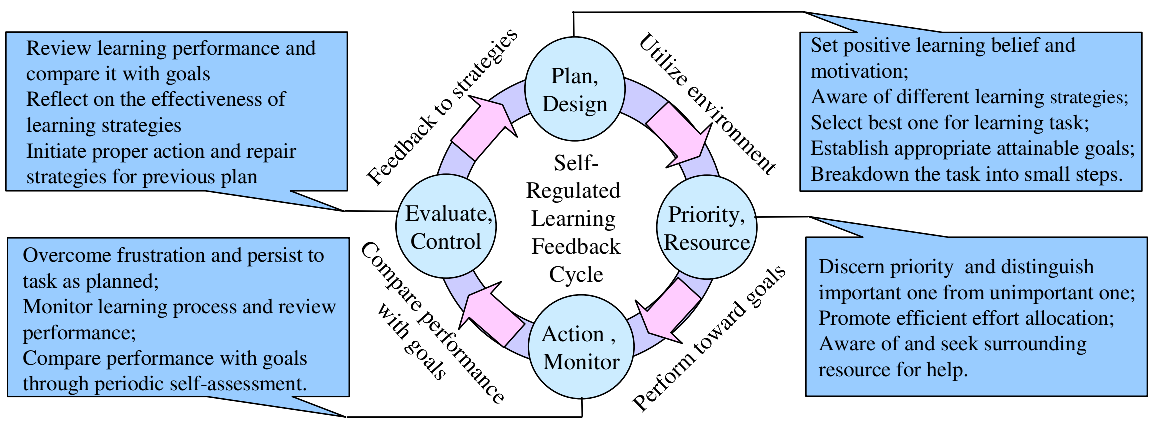

Fig. 1 Self-Regulated Learning Four-Phase Implementing Feedback Cycle Model

Direct Instruction strategy – The learning materials that cover a set of the SRL concept, model, and related strategies are presented to students as stand-along learning contents for one or two class period. These SRL strategies will focus on three aspects as outlined in following:

- Personal: these strategies usually involve how one organizes and interprets information; goal setting and planning; keeping records and monitoring; and rehearsing and memorizing
- Behavioral: these strategies involve actions that the student takes, e.g. self-evaluating or regulating (checking quality or progress); and self-motivation and self-reinforcement
- Environmental: these strategies involve seeking assistance and structuring of the physical study environment, e.g. seeking information (library, Internet); environmental structuring (selecting or arranging the physical setting, minimizing distractions, breaking up study

periods and spreading them over time); emulating exemplary models; and seeking social assistance (from peers or instructors)

The model of Self-Regulated Learning process is partitioned into four phases in its one cycle: (1) planning and designing; (2) identifying priorities and allocating resources; (3) self-monitoring; and (4) evaluating and controlling. This model is based on the three-phase model [27] by Blank et al. However, the identification of priority and allocation of resource is particularly separated from learning strategies as one of important phases in SRL. This is because it is critical for students to organize information and knowledge based on their priority and seeks help from their environment as suggested by Paris & Winograd [23]. It will be emphasized to students that SRL is repeated cycles of these four phases towards learning goals as shown in Fig. 1 above.

Immersion Instruction strategy – The request of higher level learning and thinking only can emerge when students are motivated and make their own plan and take control in their learning. The immersion instruction strategy is developed to meet the student's autonomous request. It incorporates authors' prior experience and successful Problem-Based Learning (PBL) Model [29,30] into the framework of SRL Assessment System and Learning Academy Model. It will be implemented in students' course project to promote SRL. Particularly, the development of PBL projects follows the same cyclic model as SRL implementation (Fig.1). Thus, instruction for SRL implementation can be naturally merged into the development of the course project through students' inquiry-based active learning. The course project is assigned early and allows students have more than two months to plan, conduct, evaluate, revise, and finish the project. Three to four students can form a project team with clearly defined responsibilities. Students will make their own decision about how to select subject and accomplish learning activities.

SRL instructional scaffolds are provided to guide students' cognitive skill development as salient cues for each SRL phase, and are in the form of the plan sheet, e.g. Goal-Setting Questions, Time Management and Organization, Study Time, Strategies, as well as the self-assessment questionnaire similar to these in SRL Assessment System. Student teams are required to meet instructors at least four times in accordance with the four phases in SRL cycle to seek feedbacks. This will be planned by students in the project plan in alignment with project's development schedule. For the project technical aspect, the instructor and student TAs present related learning materials and examples, demonstrate models, and provide technical assistance as students need.

To help students shift their learning regulation away from the instructors to their own, instructors will adopt systematic instructional approaches based on the SRL Learning Academy Model, which are exemplified in following:

- Emphasize on tutoring and coaching during actual performance efforts, help students focus on behavior; provide peer modeling and direct social feedback for performance efforts;
- Guide students' self-beliefs, goal setting, and expectations, help students frame new information or feedback in a positive rather than a negative manner
- Promote reflective dialogue, encourage student practice with reflective dialogue group discussions to think through problems, provide modeling of reflective practices through instructor own teachings

- Provide timely corrective feedback that are positive about the learning task and use of strategy, not about the learners, and provide performance goals that are clear and perceived as attainable

Detailed Plan for Integration of Proposed Instruction into the Entry-Level Course

The proposed direct instruction strategy and immersion instruction strategies will be planned to be implemented in the entry-level course UNIV100 at Jackson State University. The Direct Instruction is implemented through class lectures and introducing the knowledge and strategies of Self-Regulated Learning and Expandable Intelligence models to students. This is expected to motivate students' effort for their learning and pursuing knowledge and strategies for self-regulated learning. The immersion instruction strategies are implemented through students' course project- innovative problem-solving as stated in following.

The Immersion Instruction will be implemented through student course project. The course project requires students to identify a problem and provide innovative technological solutions that can impact and improve their studies and lives around campus. It is assigned to students at the beginning of the course, which allows students to have sufficient time to identify the problem and subject for their self-directed learning and innovative problem-solving. Example problems are given to students. Students may try to provide innovative solution to the example problems, or use their autonomy to identify problems by themselves. Students are challenged through Problem/Project-Based Learning to learn required knowledge and formulate solutions in a way that not only engages them but also is relevant to their particular learning level and style. Students are encouraged to search literature to seek the information and knowledge.

Following the course project assignment, various strategies for self-regulated learning and problem solving will be introduced to students from classroom lecture through the direct instruction. In addition to self-regulated learning model, a well known Wallis Model of the Creative Process developed by psychologist and engineer Graham Wallis will be also introduced to students. In his model, Wallis set down a description of what happens as people approach problems with the objective of coming up with creative solutions [31]. He described his four-stage process as follows:

- Preparation: One defines the problem, need, or desire, and gathers any information on the solution or responses that need to encompass, then sets up criteria for verifying the solution's acceptability
- Incubation: One steps back from the problem and lets his minds contemplate and work it through
- Illumination: Ideas arise from the mind to provide the basis of a creative response. These ideas can be pieces of the whole or the whole itself. That is, seeing the entire concept or entity all at once
- Verification: one carries out activities to demonstrate whether or not what emerged in illumination satisfies the need and the criteria defined in the preparation stage

Besides, samples of technology invention are provided to students to exemplify innovation strategies and their application, such as *innovation through synthesis*, in which combination of different material or function is utilized to create new material or functions, and *innovation* *through transformation,* in which one begins with an already existing object or idea, and searches for ways it can be altered to provide possible solutions to a new problem. It is expected that the strategies for problem-solving could help students to foster the origination of new ideas and obtain inspiration for innovatively solving problem they identify for their project.

The project is required to include the description on how the solution and creativity proceeded, how students regulate their efforts and confidence in learning process, such as overcoming frustration and utilizing strategies to formulate solutions, as well as their reflection on what strategies can work successfully or not effectively, as well as how to extend their SRL experience into other context. Students are required to submit followings in their final projects:

- Final project report is required to include technical writing, graphic illustration of design, and how the ideas for problem-solving and creativity are conducted.
- Poster presentation is also required for exchanging the ideas of design and solution in the project will be exchanged through within students.

The student course projects are graded based on following grading criterion:

- Presentation format (10 points)
- Problem description (20 points)
- State of Previous work or solution by others (10 points)
- Innovative solution and how it is built on the previous works (see following particular criterion) (30 points)
- How the solution utilizes and relates to nanotechnology (10 points)
- How the innovation is initiated or inspired or the strategies for your innovation (10 points)
- Reference cited (10 points)

Particular Criterion for evaluating innovation of students' solution is based on following three aspects:

- Originality-students are required to describe how their design can advance existing design.
- Fluency- students are required to describe how many ideas have been generated for their design or Idea
- Flexibility-students are required to describe how many different approaches to the design have been considered.

As the course proceeds, students are presented with new course modules on problem solving and instructed to review the course materials and references. Students also were encouraged to do their own literature search. They were required to communicate with instructors periodically for feedbacks in the each phase of SRL. The early assignment allows students to have 2-1/2 months to develop their self-directed process, i.e. planning, identifying recourse, monitoring, and evaluating as guided by a Self-Regulated Learning model. The students are also required to present and share their final design project with their peers.

Outcomes from Pilot Implementation

The proposed model is based on the cognitive theoretical framework of self-regulated learning and built on authors' engineering education practice. It is extended from the pilot implementation of the instruction model that integrates Problem/Project-Based Learning and cognitive instruction strategies into a co-curricular student course project. It is intended to apply this instructional model into the freshmen entry-level course. The pilot implementation started in the Fall semester of 2007 and has been integrated into the courses in the Department of Civil Engineering and the Department of Technology at JSU. The implementation and its outcomes are described below.

In the pilot implementation, authors have worked with their collaborators to develop and integrate new course modules on emerging Nanotechnology for civil infrastructures into existing curricula. New course modules include not only nanotechnology-enabled sensing and multi-functional materials and intelligent structure technologies, but also strategies for innovation and creativity. The objective of the new course modules is to convey a new vision of civil engineering with nanotechnology and create diverse learning opportunities for students, including Problem/Project-Based Learning for a co-curricular design project through innovative problem-solving and self-directed learning.

One new course module is the Creativity Strategies and Problem/Project-Based Learning for Innovative Design through a co-curricular design project. This module started at the beginning of the course with the assignment of the course design project - Innovative Design of Civil Infrastructures. The course project required students to innovatively solve civil engineering problems by using emerging nanotechnology. Students were given autonomy to choose their own project subject, identify problems, and formulate solutions. The course design project is intended to engage students in Problem/Project-Based Learning for new technology application, practice strategies for innovation, and foster their creativity.

The early assignment and the autonomous selection of the subject for the course design project allowed students to develop their plan and control over their efforts in their learning and design process over 2-1/2 months. This provides students an opportunity to take ownership and a more interactive relationship with their learning subject and to generate rather than simply to receive knowledge through active Problem-Based Learning.

The instructors facilitated students' self-directed learning activities for their project by providing inspiration and supportive feedback. For example, students were provided with more learning materials and references that were not covered in the course lectures for their self-directed learning in addition to new course modules presented through the course lectures. The examples of the innovative application of nanotechnology for civil infrastructures were presented through course lectures. These selected examples of innovation exemplify strategies for innovation, e.g. Innovation through Synthesis and Creativity through Transformation. Besides, the classic model of creativity strategies - the Wallis Model of the Creative Process (Juan, 2003) was presented to students during the course lecture. The references to Disney's creative cycle and other strategies for innovation were also provided. Students were encouraged to do their own literature search for learning knowledge and creativity strategies needed for their course projects. They were also encouraged to communicate with instructors periodically for feedbacks on their design subject and process during their Problem/Project-Based Learning process.

To assess students' satisfaction level of the clarity, delivery, and content of the module and their related learning experience, a post-test survey was administrated for each new course module after the new course module was completed. Students were asks to give the score based on 1 to 5 scales to five questions and provide their comments for their satisfaction level of their learning experience and quality of proposed instruction model. The higher score indicates more positive merit. The average score from available student participants in a class is used as a composite score for the class. The genetic questionnaires for each new course module are tabulated with score scales in Table 1, and concern about the interesting aspect, practical aspect, clarity, delivery, and content of the course module. In addition, students' comments and instructors' judgment on students' learning experience were used to supplement the above assessment.

Table 1 Genetic questionnaire on each new course module implementation

Q1. The topic of Module subject is (1) not interesting at all (2) interesting to a little extent (3) interesting (4) very interesting (5) greatly interesting	**Q2.** Do you think that the topic of Module subject is (1) not practical at all (2) practical to a little extent (3) practical (4) very practical (5) greatly practical
Q3. The course materials for Module subject are organized (1) not effectively at all (2) effectively to a little extent (3) effectively (4) very effectively (5) greatly effectively	**Q4.** The basic concept and application on Module subject are presented (1) not clearly at all (2) clearly to a little extent (3) clearly (4) very clearly (5) greatly clearly
Q5. The in-depth of the course material for the topic of Module subject is presented (1) not sufficiently at all (2) sufficiently to a little extent (3) sufficiently (4) very sufficiently (5) greatly sufficiently	**Q6.** Please give your comments or suggestions for course materials on the topic of Module subject

Table 2a The Post-Test Survey Results From Student Participants From Jackson State University 2008

Module	Module of Creativity Strategies and Problem/Project-Based Learning for Innovative Design																								
Question	Q 1					Q 2					Q3					Q 4					Q5				
Score	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Student #	1	2	1	3	2	0	0	5	3	1	0	0	7	1	0	0	2	4	3	0	0	1	2	3	3
Ave. Score	3.33					3.56					3.13					3.11					3.89				

Table 2b The Post-Test Survey Results From Student Participants From Jackson State University 2007

Module	Module of Creativity Strategies and Problem/Project-Based Learning for Innovative Design																								
Question	Q 1					Q 2					Q3					Q 4					Q5				
Score	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Student #	0	1	4	2	3	1	1	6	1	1	0	3	5	1	1	0	3	6	1	0	0	2	7	1	0
Ave. Score	3.70					3.00					3.00					2.80					2.90				

During the first year implementation, the Self-Directed Learning and Expandable Intelligence model had not been developed and presented to students for their Problem/Project-Based learning process. Outcomes of the first year implementation indicated that all students participated in the active learning and completed their project. Students had presented a variety of subjects and innovative solutions in their projects, which were beyond the scope of learning materials provided in class lectures. Most of students were seemingly engaged in their active learning and motivated by the appeal of innovation and the intellectual challenge in the course project.

For the course module of Creativity Strategies and Problem/Project-Based Learning for Innovative Design, the post-test survey results for the first year implementation shown that students gave a score of 3.7/5.0 for the interesting aspect of this module (see Table 2b). This score is also higher than scores for other four aspects of this module, and indicated students' interest at this module. This is consistent with the extent of their participation in the active Problem/Project-Based learning. Students gave positive comments on the project experience, such as "My knowledge about it is unknown; we need to brush-up on it"; "Include practical applications to aid creativity"; "I think this gave the students a chance to think outside the box and allows each person to be free".

However, the lower scores for remainder aspects revealed students' lower perception on the practical aspect of this module and lower satisfaction level for clarity, delivery, and content of the module instruction (see Table 2b). The first year post-test survey results promoted authors' efforts for improving the course modules of Creativity Strategies and Problem/Project-Based Learning for Innovative Design.

Table 3 Suggested four phases for Problem/Project-Based Learning in re-cyclic process

Phase	Students Activities in Course Design Project and Learning Specific Topics
Plan & Design	Establish the objective of design project and learning goal for acquiring new in-depth knowledge: Students have to identified a problem needed to be solved; learn and select creativity strategies and related nanotechnology from new course modules and self-directed learning to formulate innovation; identify specific aspect of nanotechnology that would be applied for the design project; break down objective and task into several small steps with timelines for accomplishing these objectives and tasks.
Priority & Recourse	Identify priorities of learning topics and learning strategies and resources: Students needed to focus their efforts on the topic that were related to the subject they chose for the design project; identify resources to acquire the knowledge and information from lectures, course materials or reference provided by instructors, or further literature search through their own efforts; or seek the advice and suggestion from instructors or peer students.
Monitor & Conduct	Carry out the plan for learning task and design project: Students performed learning tasks through attending course lecture, self-directed learning of supplemented course materials or literature reviewing; and conducted design process through describing problems and illustrating its innovative solution through nanotechnology; monitor the progress of the learning tasks and project design and see if they meet the goals and timeline as planned.
Evaluate & Control	Evaluate learning results and final design project, and seek feedback for improvement or alternation: Students evaluate if they have achieved the objectives; seek the feedback or suggestion from themselves, instructors, or their peers on their project subject or the final innovative solution. Based on evaluation and feedbacks, students could enter the next cycle of the four phases to improve their design through acquiring additional learning; or adjust or alternate the original plan, learning tasks, or even the design subject if there is no desired progress was made. Finally, innovative design and solutions in students' design project were exchanged through final project presentations among students. Further evaluation and feedbacks can be obtained through peer comments and suggestions

Through literature search, the Self-Regulated Learning (SRL) and Expandable Intelligence (EI) model was developed and integrated in the instruction for the problem/project-based learning. In the second year implementation, the SRL and EI concepts and models were presented to new students for the same course through proposed Direct Instruction Strategies. Expandable Intelligence instruction was utilized to address the three motivation components as presented in the previous section and help students perceive importance of pursing innovative design and creativity through active learning, i.e., expanding the personal intelligence or learning and problem-solving skills. To facilitate students follow SRL for their Problem/Project-Based Learning, a similar four-phase SRL implementation process conceptual model (see Fig.1) was presented to students with the course project assignment. The four phases of SRL was further detailed in Table 3 for guiding student project activities and also included in the course project assignment.

For the second year implementation, the post-test survey results from indicated the students' overall satisfaction level of this course module has been improved. The score on practical aspect of the module topic is increased to 3.56/5.0 and score for the in-depth of the content of the module to 3.89/5.0. Students perceived that the practical aspect of this module exceeds the interesting aspect of this module.

This pilot implementation suggested that an early-assigned open-end course project, which contains appropriate challenges that can match students' capability, requires some innovations, and allows students to have autonomy in selecting subject, can be a suitable way for involving students in inquiry-based active learning process and promoting use of cognitive skills. The proposed instruction strategies can improve students' perception and motivation on pursuing self-directed learning and innovative problem solving through Problem/Project-Based learning. They can guide the action through self-regulation and reflection and have the potential to leading to enhancement of students' creativity and self-regulated learning skills.

Summary and Further Implementation

This paper addresses the urgent needs for developing new instructional strategies for developing students' cognitive skills in engineering education and retarding the trend of declines in future engineering workforce. It examines the current shortcomings in instructional practice for improving students' academic learning skills and introduces the context of Self-Regulated Learning (SRL) and Expandable Intelligence (EI) from Cognitive Science literatures. New instruction strategies are proposed to integrate SRL and EI model and instruction into Problem/Project-Based Learning Pedagogy. It can potentially facilitate students to improve their learning confidence and strategies, which is essential for intellectual development and academic success of all students. The outcomes from pilot implementation indicated that all students have participated in the problem/project-based learning process and presented a variety of subjects and innovative solutions beyond the scope of learning materials presented in the course lectures. The proposed instruction strategies can improve students' perception and motivation on pursuing self-directed learning and innovative problem solving through Problem/Project-Based learning.

Based on instructors' assessment from pilot implementation, students' awareness of and involvement in each of the four phases in the self-directed feedback cycle of SRL varies. Thus, the repeated cycles for improvement or adjustment based on the evaluation and reflection may not well perceived and proceed by students. In the future implementation, the efforts need to be given to the encouragement for seeking feedback from the evaluation by students, their peers, and instructors. In addition, rigorous self-assessment instrument needs to be developed to facilitate engineering students' self-reflection and recording their SRL process for evaluation and analysis. Other types of student assignment suitable for engineering courses needs be explored and incorporated with students' self-assessment instrument.

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