AC 2007-2201: SELF-MANAGEMENT OF COGNITION IN A TEAM-BASED ENGINEERING DESIGN PROJECT: A CASE STUDY

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Despite little direct guidance and instruction received from their professors, working on an open-ended task such as designing an engineering artifact is expected to be a rich learning experience for students. In order to be successful on such a task, students need to set reasonable goals for themselves and adopt intrinsic standards for success so that they will be able to solve problems strategically. Many studies [3, 7] have found that students’ cognitive and metacognitive skills (i.e., monitor and control one’s own cognitive processes) play an essential role in problem solving processes.

The application of one’s metacognitive skills can be observed through what that particular person does for a particular given task. Brown [2] identifies metacognition through activities such as planning, monitoring, and revising. Paris and Winograd [11] offer a more comprehensive view where metacognition can be observed through two essential features of metacognition; (a) cognitive self-appraisal and (b) cognitive self-management. These two metacognitive features involve cognitive and motivational issues such as skill and will, which are interwoven with one another [4], are shareable among people [11], and are influenced greatly by the social aspects of the situation [5]. These aspects include affective and motivational characteristics of thinking that often lead to situations where students are less likely to invoke complex cognitive and metacognitive routines to improve learning.

Self-appraisal in learning refers to learner’s personal judgment about his or her own ability to meet a cognitive goal. When a student is asked to calculate the volume of a triangular-shaped birthday cake, he or she may immediately wonder if he or she had enough knowledge (i.e., declarative, procedural, and conditional knowledge) to answer such a question. Self-appraisal is about “judgments about one’s personal cognitive abilities, task factors that influence cognitive difficulty or cognitive strategies that may facilitate or impede performance” [11, p. 17].

In contrast, self-management refers to maintaining executive control that will indicate “how metacognition helps to orchestrate cognitive aspects of problem solving” [11, p. 18]. This self-management issue relates to processes that involve evaluation, planning, and regulation. Self-management skill refers to students’ abilities to plan before they handle a task and make necessary adjustments and revisions during their work, which consequently has direct implications for students’ performance. Three skills are commonly used to indicate the presence of students’ self-management: (a) their ability to plan, (b) to regulate, and (c) to evaluate their learning. Planning involves activities such as setting goals, analyzing tasks, and selecting strategies to achieve specific goals. Regulating refers to the fine-tuning and continuous adjustment of learners’ cognitive activities. Evaluation refers to assessing learners’ current knowledge state, which occurs continuously: before, during, and after a task.
Since most professional design engineers work in a team-based environment, the success of projects very much depends on the effectiveness of their team management. Professional engineers know that engaging in a design project in a team often requires engineers to manage more than just their own individual technical expertise. They need to manage their organization and team work skills as well. To do so, they are often required to create a working environment that facilitates collaborative activities so they can build and monitor their teamwork. Although the intention of doing team-based activities in an academic setting is to promote richer learning experiences for students, Dunbar [5] argues that several studies find that it is not always the case. As a team, students are expected to be able to use their knowledge, skills, time, and other available resources effectively so their work objectives can be accomplished. This study attempts to further our understanding of the use of metacognitive skills by students who engage in an open-ended team-based design project.

This study explores how a group of engineering students exercised their self-management of cognition, through the way these students planned, evaluated, and regulated their cognitive activities, during the design process to build an engineering artifact. Using Paris and Winograd’s lens of self-management of cognition, two research questions were constructed to guide this instrumental case study. They were:

1. How did individual members of the team execute their meta-cognitive ability as reflected in the way they plan, regulate, and evaluate any task they encounter throughout the project time?
2. How did the way they plan, regulate, and evaluate any encountered task fit together as the team evolved their design?

Method

The purpose of this study was to examine learners’ self-management of cognition by observing a group of four undergraduate engineering students (i.e., the Orange Team) exercising their executive control over behavior during their work on their senior design project class (MIE 470). MIE 470 is one of the major capstone design courses prescribed by the mechanical engineering department’s curriculum at one of the large Midwestern University.

Design Task and Context. This team’s task was to design and build a hydraulic bicycle. Unlike a regular bicycle, a hydraulic bike replaces a mechanical drive system with a hydraulic transmission and therefore, there is no direct connection between the chain-wheel and the free-wheel cogs. This project was funded by an external organization referred to in the document as PHC, which is a leading diversified manufacturer of motion and control technologies and systems. As part of the funding agreement, this team, and other teams from different universities that also received this hydraulic bike funding, had to participate in a hydraulic bike race competition upon completion of the project. A teaching professor was assigned to this team and functioned as both the project adviser and project evaluator.

Participants. A team of four students (i.e., the Orange team) were selected for this study. These students had voluntarily agreed to work on this funded project as their senior design project. This particular team consisted of four senior mechanical engineering students, three males (i.e., Brian, John, and Alex) and one female (i.e., Linda). All names are pseudonyms. This team was one of
33 other teams who participated in MIE 470 in the spring semester. While taking MIE 470, these students were also taking several other courses (i.e., three or four other classes) to fulfill their mechanical engineering degree requirements. Prior to this project, no team member knew all of the other individuals in the team. However, some of them knew individual teammates from past classes.

There were two reasons why this team was selected for participation in the study. First, the project this team was working on was funded by PHC. Since the project was funded by an external party, students were expected to be more accountable for their work and the hydraulic bike they would produce. Second, according to the team’s co-advising professor, who has extensive experience in advising engineering teams, the Orange Team consisted of students who had good academic performance (i.e., Cumulative GPA ≥ 3.00) and moreover, these students had off-campus work experience through internship programs during their college year. It was expected that good academic standing students with some off-campus work experience would have adequate knowledge and skills to engage in an engineering design project collaboratively in a team-based environment.

*) Procedure. This study was an instrumental case study [13] that examined the design process in a work team through careful observation of each team member’s ability to exercise his or her executive control over behavior during the project. This study employed a naturalistic design in that these students were observed through their individual and group activities. It was expected that this approach would reveal how engineering students exercise their metacognition abilities while engaging in a team-based project.

Data Collection. Several sources of information were accessed to gain a better understanding of the student design activity and processes. Throughout the design process, interviews were conducted with each member of the team, observations were made at the team’s working laboratory, team communications were accessed (i.e., emails and shared Netfiles), and individual logbooks were read. For anonymity, interviewee names were coded using his or her pseudonym. The purpose of the interviews was to obtain information on how students, individually and as a team, evaluate, plan, and regulate their cognitive activities. The gathered information from interviewing and other resources, such as shared electronic files that were posted in the university Netfiles system, student-student emails, student-professor emails, logbook, status reports, presentations, and meetings, were categorically aggregated and directly interpreted [13]. In other words, interpretations were made through individual instances as well as through aggregation of instances until a clearer picture of understanding emerged about the Orange Team’s hydraulic bike design process.

Instrumentation. Four control-of-self skills were quantitatively measured in this case study through motivation scales of the Motivated Strategies for Learning Questionnaire (MSLQ) designed by Pintrich, Smith, Garcia, and McKeachie [12]. The internal reliability coefficients for each motivational component are high: Intrinsic Goal Orientation (i.e., $\alpha = .74$), Task Value (i.e., $\alpha = .90$), Control of Learning Beliefs (i.e., $\alpha = .68$), and Self-Efficacy for Learning and Performance (i.e., $\alpha = .93$) The scale correlations with the final grade of this test instrument are statistically significant (i.e., Cronbach’s alphas of .52 to .93), which demonstrate predictive validity.
The motivation aspects measured through MSLQ were students’ intrinsic goal orientation (4 questions), students’ task value (6 questions), students’ control beliefs (4 questions), and students’ self-efficacy for learning and performance (8 questions). These four motivation components were purposely selected because they represent the value and expectancy components of student’s motivation [12]. The intrinsic goal orientation and task value are two value components of motivation, while control beliefs and self-efficacy for learning and performance are the expectancy components of motivation. These questions were only parts of the MSLQ instrument and they were asked in the same order as its original complete version. The instrument uses a seven point Likert scale from “not at all true of me” (i.e., scale of 1) to “very true of me” (i.e., scale of 7). Four scores of those motivational components were then averaged and assigned to each team’s member as his or her motivational score.

Data Analysis. Two types of data collected in this study were analyzed differently, statistical and qualitative interpretations. The MSLQ data, scores from each motivational components item (i.e., intrinsic goal orientation, task value, control beliefs, and self-efficacy for learning and performance) for each team member were averaged. To interpret these averaged MSLQ data, Pintrich, Smith, Garcia, and McKeachie (1991) suggest that students should be considered doing well if their scores are above 3. Since MSLQ was not used as the primary data source, these students’ averaged scores were only used to compliment the data analyses from interviews, email messages, team’s final project report, and observations. Data from recorded interviews, email messages, team’s final project report, and notes from observations were qualitatively analyzed to find the common themes that indicated the students’ self-management of cognition activities (i.e., planning, evaluating, and regulating). To minimize error in interpreting these qualitative data, data from one source was often triangulated with other relevant data sources.

Findings

After being with these four students for 14 weeks, conducting more than 10 hours of field observation, two individual interview sessions with each of them, reading four individual journals, and reading 45 email messages, a clear picture about the process and the dynamics of this team in designing and building an hydraulic bike could be drawn. There was sufficient evidence that these students had applied their self-management of cognition skills various intensities. To see the different intensities of metacognitive applications, the findings of this study are organized into two categories of tasks: Team Management and Design Processes. Team Management tasks include activities such as organizing and managing team-members, and administrative tasks. Design processes focus on technical design-related tasks.

The Motivational Aspect of the Students

All team members had above 3.00 in all four motivational scores (i.e., intrinsic goal orientation, task value, control beliefs, and self-efficacy for learning and performance) measured by the Motivated Strategies for Learning Questionnaire (MSLQ) instrument. According to the MSLQ manual, if a student has an average score of 3.00 or above in all motivational components that particular student could be considered as having adequate motivation [12]. Using this guideline, all team members had “adequate” to “high” motivation for this MIE 470 project. However, when
comparing these four averaged scores for all four motivational components, Linda had the lowest score in the team. She was relatively low on the intrinsic goal orientation and the task value. Her averaged score was 3.96 and it was below the average of the team’s averaged score (i.e., 5.18).

Team Management

This study found that most of the tasks were conducted with the spirit of colleagues where no one had more authorizing power than others. This made the working environment less structured, informal and more egalitarian in nature. Although no line of authority existed in this team, specific responsibilities of each individual member were stated in the project proposal. These students considered the inclusion of these specific individual’ roles for each team-member was simply to fulfill the course requirement. However, as the project was progressing, each individual’s role became present for several specific tasks. Linda’s low MSLQ score, which reflected her pessimism about her knowledge on hydraulics and her skills in building a bike, brought her to take the lead in documentation and reporting tasks. Alex, John, and Brian were comfortable with the design process and building the bike. Although they had not had any experience with hydraulics, building a bike was just a routine activity, especially for Alex and John. Assembling parts to construct a bike was less challenging for them.

During the first three weeks of the project this absence of work coordination and lack of clear individual work roles created some confusion for the team. It began from the situation where no one in the team made an effort to follow up on any of the team’s resolutions to the situation where no work monitoring was conducted because everybody in the team was busy and had been intensively involved in one particular task. It seemed to be difficult for this team to select the proper strategy to organize the team. This difficulty might be due to the unfamiliarity of the complexity of the project and the tasks associated with it. The lack of the team’s task monitoring system had made this team’s performance less optimal.

Linda conveyed her thoughts on this issue by saying, “…after we discussed the process, we kind of just let it go…so it was the execution of the activities according to the timeline that was not going smooth.” She further argued that if the project needed to be managed from the outside, it should be done by people who were not involved in the design and testing because “people who are involved in the design and testing knew what was going on so they would not constantly manage the process in the managerial way, but rather more like a colleague-type of way.” Besides Linda, John also expressed his concern on this team management issue. Both of them seemed to have some sort of procedural knowledge of how they, as a team, should have functioned but they individually failed to operationalize it.

Despite the lack of implementation on some of the managerial tasks, these students, individually, monitored the progress that their team made. This fact was apparent in their email communication. Eighty five percent of the email messages exchanged among these four students were evaluative in nature and few of them contained suggestions and instructions. In one instance, for example, Brian addressed his concern about the need for his team to document all files in more structured and organized manner in one of his email messages to his teammates. As each member worked on the same task individually, standard method of file archiving was necessary. Consider a portion of his email message below:
Hello all,
This should have been done awhile ago, but we need to get some basic organization details out of the way. We need to store ALL of our files in one place, and this should be the ONLY place these files are located. This will be very important as we amass more important files. This way we do not have 5 copies of the different revision levels of the same file floating about. This will mean that you should download the file before you start working on it and re-upload and over write it as soon as you finish working on it. Do not store any files that others will need on your computer always keep them in netfiles. I have seen the hassle that this can save especially when we get to modeling and drawings. .......

Because this team was more focused on the efforts of getting all the design tasks (i.e., building a working hydraulic bike) completed, no immediate corrective action was taken in regard to this team organizational issue. Perhaps, this working condition refers to what Flavell [8] argued about the misalignment between team’s metacognitive knowledge and metacognitive experience. The fact is that knowing a strategy does not necessarily manifest itself into actions.

Design Process

Like other engineers, these students initiated their working journey by first constructing a design strategy that consisted of six steps. Constructing a design strategy that guides the design process is common, not only among expert engineers, but also among novices [6]. This six-phase design strategy was constructed and evaluated through analyzing the functional role of their thoughts and feelings about their own thinking activities [11], and this strategy was used as a design roadmap that reflected the six major tasks this team had to accomplish.

This team divided their design activities into six major phases reflecting six big and distinct types of tasks (Figure 1). They were: (1) research and literature review, (2) preliminary computational analysis, (3) component selection and evaluation, (4) final circuit design, (5) prototype construction, and (6) testing and modification. This team constructed its design strategy based upon each team-member’s understanding of the problem and their strategy to solve it. Building a design strategy (e.g., the six major design phases), which reflected their mental model of both the problem and the solution, are common among engineers. Dividing this relatively big project into several smaller pieces was a strategy for finding well-structured tasks within it [9].

A typical design process model [6] consists of ten steps which includes a set of finer steps such as (1) clarify objectives, (2) establish requirements, (3) identify constrains, (4) establish functions, (5) establish specifications, (6) generate alternatives, (7) analyze design, (8) test and evaluate, (9) refine and optimize, and (10) document design. Although it was possible to identify most of these refined steps in this team’s six-phase design strategy, it was interesting to learn that this team did not explicitly include steps like generating design alternatives and document design in the team’s design strategy. These students argued that their design strategy reflected their approach to produce a working hydraulic bicycle according to their understanding of the problem. Those six steps were logical and they made perfect sense to them. They seemed to view the design project more from the hardware producing aspect than from the engineering design...
process. Those steps would help them bring the design task from its abstractive state closer to its concrete end objective. Each design phase had become the transitioning phase for the next phase and it led this team to focus themselves from their initial abstract and conceptual state of understanding to a more concrete object. The abstract and qualitative understanding of the project had eventually become manifested into real physical components before they were finally able to produce the end product, a working hydraulic bicycle.

In order to gain a better understanding of these students’ self management of cognition during the design processes, each of the design phases will be explored in detail. To simplify the discussion, the prototype construction phase and the testing and modification phase are combined.

**Research and Literature Review.** The research and literature review were conducted in order to gain a firm grasp on the main concepts of hydraulics, bicycles, and previous hydraulic bicycle designs. The team believed that because they had a good understanding of these three concepts, they had a clear idea on the complexity of the design tasks. Moreover, they also believed that by having some understanding of these three main concepts, it had given them some level of self-confidence in completing the project. Understanding these technical issues did not only provide this team with some insights about the technical aspects of building a hydraulic bike, but it also offered a common metacognitive tool [11] so these students could achieve self-appraisal and self-management of their own thinking.

During this phase, these students acquired some declarative knowledge about the project by first identifying the components (e.g., hydraulic pumps and motors), design parameters, and relationship among those components that might affect the performance of their hydraulic bike. As Linda put it, “During this phase, we focused on the *what* thing rather than the *how* thing.” Special attention was given to learn about these components as each component has its own working characteristics that have direct impact on the performance of the bike. Lessons learned from studying the historical aspect of the hydraulic bike were also integrated in this team’s future design.
Preliminary computational analysis. After having a more qualitative analysis of the project from the previous phase, this team proceeded with a quantitative analysis through numerous computer simulations. In this second phase these students tried to gain an understanding of the project from the operational side of the hydraulic system. One of the major tasks in this phase was finding the causal relationship between the input and output of a hydraulic circuit through identifying various factors that may influence the bike’s performance. This quantitative analysis (e.g., efficiency of the hydraulic system) helped them make a more engineering sound decision for component selection.

It was apparent that this team had explored all possible options to improve the hydraulic design and tested them through a series of computer simulations. Although considering alternative designs was not included in the earlier stage of the design process (i.e., during the construction of six-phase design strategy), thinking about alternative designs was incorporated into this phase. The alternatives were considered through the help of computer analysis. The computer analysis gave these students valuable information that had helped them, select the hydraulic model they wanted to incorporate in their bike, and select appropriate components that could support the model. These computer simulations had indeed helped this team bring the design process a step closer to the functionality of a physical hydraulic bike.

Component selection and evaluation. These students argued that their biggest concern in this design phase was getting the highest possible efficiency together with the lightweight hydraulic components and circuit. Each component and the overall hydraulic circuit had to function within the desired operating range. There were two components that this team was concerned with the most: the hydraulic components and the bicycle frame. Selecting a bicycle frame was not a major issue for this team, especially for Alex and John, since they both had enough experience in constructing new bikes; however, selecting the right pump for the bike was a big challenge for this team.

Final Circuit design. After deciding on the types of components used for the bike, the students had to start designing and building the complete hydraulic system of the bike. There were two major activities during this phase: (1) designing and building the supporting parts to connect the selected major components and (2) completing the engineering drawings. These engineering drawings were needed for building the supporting parts and project documentation.

It was interesting to learn that although the project had almost come to its completion, the team considered working on another alternative model, a chainless hydraulic bike. Brian and Alex took the initiative to start working on this new model while John and Linda continued completing the earlier model. This chain-less model was once brought out into the team’s discussion at the very early stage of the design but it was not followed up in the following phases. Perhaps, the team had realized that building a chainless hydraulic bike was much more complex, advanced, and challenging, although it would increase the quality of the design (i.e., improve energy efficiency).

These two sub-groups of students worked in parallel. Branching off into two sub-teams to work on two different tasks was done for the purpose of meeting the project timeline. After having worked on both designs for two weeks, Alex and Brian finally decided to discontinue work on
their chainless system and join their other teammates, Linda and John, to complete the existing hydraulic system (i.e., with-chain hydraulic bike system). This decision was made because Alex and Brian realized that their design was very complex and they knew that the chain-less hydraulic bike system could not be completed on time. They made a well-reasoned decision to help Linda and Brian complete their original design.

Prototype construction and testing and modification. This phase involved the integration of the parts and testing of the bike. This phase had drastically changed the nature of the project-from its abstract realm into a concrete engineering artifact. For these students, this phase was their moment of truth. They were all eager to see if all of their ideas and work previously discussed and conducted would form a working hydraulic bike.

After putting all the basic components on the bike’s frame, everybody focused on the installation of the hydraulic parts (see Figure 2). Lots of effort was put into fitting the pumps together and installing them on the bike frame. The pump and motor were mounted to a small, sturdy aluminum plate, allowing the gears of the pump and the bike crank to maintain proper alignment. A final change to the bike was made to improve the bike’s aesthetics.

Discussion

The findings of this study enhance and support pre-existing assumptions on how typical engineering students engage in a team-based project. In regard to these findings, this discussion will focus on three issues: (1) forms of cognitive engagement, (2) the work categories that reflect all mental and physical activities during the project; and (3) the important knowledge to metacognition during the project.

Forms of Cognitive Engagement. Although engaging in a project like this bike design is considered self-directed learning, Corno and Mandinach (1983) argued that a student may display a form of cognitive engagement that is qualitatively different than self-regulated learning. While solving a problem, a student may engage in both information acquisition and information transformation processes [1]. Four cognitive engagement variations are suggested from these two classes of information processing (see Table 1). The acquisition processes can be viewed as “metacognitive to the extent that they regulate the transformation processes” [4, p. 94]. These processes include self-regulating action such as being alert while receiving incoming
stimuli, or gathering information and monitoring the stimuli and transformation. The transformation processes are cognitive and metacognitive activities such as selecting incoming information, connecting familiar knowledge to incoming information, and planning or organizing a task approach sequence.

In regards to organizational-related issues, it appears that this team was generally engaging in a resource management style as they activated relatively more acquisition than transformation processes. Some of the team-members may display more recipience style as they cared less for resolving any problem associated with their team management. Exceptional use of information acquisition permitted these students to rely on each other’s voluntary and spontaneous initiative to remedy any organizational issues. This fact may not be well aligned with the learning objective that required these students to work together in a team format. In contrast, in the design processes, there is a strong indication that this team had equally activated their transformation and acquisition processes. Hence, it indicates that this team has made use of their self-regulated learning strategies. Although in some instances, a team member may display more task focus-like attitude than others, in general these students have adequately displayed their use of both transformation and acquisition processes throughout the design process.

Table 1
Four Forms of Cognitive Engagement
Adopted from Corno & Mandinach (1983)

<table>
<thead>
<tr>
<th>Use of Transformation Process</th>
<th>High</th>
<th>Low</th>
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<tbody>
<tr>
<td>Task Focus</td>
<td>Self-Regulated Learning</td>
<td>Recipience</td>
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<table>
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<tr>
<th>Use of Acquisition Process</th>
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<td>Low</td>
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<tr>
<td>Resource Management</td>
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Work of Consolidation, Engagement, and Appreciation. Looking from the natures of the effort, all of these students’ activities can be classified into three work categories: work of consolidation, work of engagement (or doing), and work of appreciation (see Figure 3). Within each work category, these students might have engaged in a certain degree of planning, evaluating, and regulating activities according to the context of task they encountered. Marzano, et al. [10] argued that declarative, procedural, and conditional knowledge are important to metacognition. Each work category may require students to apply one, two, or all three types of knowledge.

Despite being an ongoing activity, students’ self-management of cognition appeared to be exercised in unequal intensity. These three work categories were both the starting and ending points, which means that consolidation, engagement, and appreciation occurred at any time.
throughout the progression of the project. As it was a fluid process, often students needed to go back and forth between those three work categories.

During consolidation stage, these four students inventoried and recollected all the resources (i.e., persons, knowledge, and skills) they had. For illustration, two instances reflect this stage: (1) this team assessed each member’s current knowledge and the existing hydraulic bike design and patents during phase 1 of the design process and, (2) Brian’s email message in regards to the idea of having a more structured document filing system. This work of consolidation was a phase where these students exercised their self-appraisal of cognition and evaluated what they had (and had not) known such as working coordination, the existing hydraulic bike design, and patents.

After successfully identifying all their resources, these students were entering the central part of the project, which is engagement in organizational and bike design tasks. During this work of engagement, these students engaged in activities such as creating one common electronics filing system for all team’s documents, selecting a six-phase design strategy, and completing all tasks within each design phase. Although these students had expressed their intention to better manage their team, however little effort was expended to operationalize it. In contrast, adequate team monitoring was apparent in many instances during the actual engineering work. These students managed to plan, regulate, and evaluate their thinking quite well during this stage. These students’ six-phase design strategy shows their preference in viewing the project from the outcome perspective over the process. This interpretation seems to be in agreeing with the fact that they did not well monitor their peers’ performance in resolving many of the organizational-related tasks.

Once a particular design task was completed, an evaluation process was made and these students were valuing their efforts, work accomplishments, and outcomes. The group valued their thoughts, successes, failures, and experiences from all the labor or non-labor activities throughout the project. This work of appreciation was a phase where the students exercised both their self-appraisal and self-management of cognition.

**Figure 3. Work Categories**

Once a particular design task was completed, an evaluation process was made and these students were valuing their efforts, work accomplishments, and outcomes. The group valued their thoughts, successes, failures, and experiences from all the labor or non-labor activities throughout the project. This work of appreciation was a phase where the students exercised both their self-appraisal and self-management of cognition.

**Important Knowledge to Metacognition.** In each work category, it was easy to find the application of declarative, procedural, and conditional knowledge throughout the design activities. Declarative knowledge is factual. It is knowledge about who, what, when, and where. Procedural knowledge is about knowing the how part. Conditional knowledge is about what
strategy works, when, and why. Marzano et al. [10] argued that declarative and conditional knowledge are primarily used during the planning processes. When these students were constructing their six-phase design strategy, they knew what they needed to build and how to build it. In this study, it was found that these students’ understanding of the project was heavily focused on the physical design outcome, and not on the detailed process. This finding supports the finding in one of Chi’s [3] studies about the way novices and experts differ in solving problems. She claimed that novices focus on the problem’s surface attributes. In this study, it was also found that the team’s six-phase design strategy did not include the finer steps or processes that are typically listed in the literature [6].

During evaluation and regulation processes, it was also found that these students were exercising all of their declarative, procedural, and conditional knowledge. When Linda was evaluating the fact that work could be accomplished efficiently if somebody who was not involved in a particular task monitored the work progress, she was exercising her understanding that objective monitoring could be established by the outsider. When Brian was suggesting a better filing system to document and access the individual member’s work progress, he was exercising his declarative (i.e., unorganized filing system was confusing and could yield to accessing invalid data), procedural (i.e., downloading files and then uploading them back in the Netfiles), and conditional (i.e., knowing that this revision should be done at the early stage of the project) knowledge.

As this study is a single instrumental case study, the findings are not intended to draw conclusions that are generalizable to other cases of engineering students working in any kind of design task. However, this study has provided a case that reflects a typical work environment that illustrates the use of the metacognitive model introduced by Paris and Winograd [11] and an in-classroom motivated learning model by Carno and Mandinach [4].

These students’ execution of self-management of cognition, which was manifested in their planning, evaluating, and regulating activities, has given us better understanding of team work dynamics that is often not in line with the intended teaching objectives. To avoid that misalignment, engineering educators may be suggested to include peer monitoring and equally value their students’ project management and design performance in the course grading system.

Conclusions

From the findings and earlier discussion, it is clear that for different type of task, this group of students exercised different intensity of self-management of cognition. Having good team management seemed to be inadequately considered in their priority list. As this was a funded and graded project, having the bike built had become the major concern of these students.

When it comes to managing their peers, these individual members of the team did not seem to use their self-management of cognition skills optimally. Perhaps, this phenomenon was caused by their team management style where these students did not operationalize their individual planning, evaluation, and transformation processes on certain organizational issues. In contrast, these students were good planners, evaluators, and implementers for their engineering design
activities. They individually seemed to be good self-directed learners in solving such an open-ended project.

Despite the uniqueness of these students’ individual working characteristics, as a team, they had managed to resolve many tasks they encountered. Perhaps, the spirit of egalitarianism has made these students flexible in making the team worked. As the design evolved, each individual member of the team seemed to be able to “fill-in” other’s imperfection. A team that consists of individuals, who are inclined to be task focused and resource management persons, may make a good self-regulated learning team.

References