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Dewey Spangler is an instructor in the department of Mechanical Engineering at Virginia Tech. Mr. Spangler holds an M.S. in Civil Engineering and a P.E. license in the Commonwealth of Virginia. He has served as faculty advisor to over two hundred mechanical engineering sophomores in the area of product design and has taught over the last nine years in the areas of physics, engineering mechanics, object oriented programming, geographical information systems, engineering economics, project management, product design, and contract law. His research interests involve active magnetic bearings, product design, K-12 engineering education, solid mechanics, and non-linear structural mechanics. He has ten years of full-time industry experience in steel manufacturing and nine years of consulting experience in the areas of mechanical and civil design. He is currently pursuing a Ph. D. in the department of Mechanical Engineering at Virginia Tech.

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Implementation of Tablet PC Technology in ME 2024 – *Engineering Design and Economics* at Virginia Tech

Introduction

The education of engineering students at Virginia Tech is a dynamic process adapting to meet the demands of the industry. Engineering students participate in basic problem solving and hands-on experiences representing the essence of the engineering profession. New engineering tools, a deeper understanding of the responsibilities of engineers to society and the environment, and an appreciation for the diverse and global nature of the workplace are continually incorporated into the engineering curriculum (Gilbert, 2003).

For incoming freshman in 2006, a Tablet PC computing initiative mandated the purchase of a Tablet rather than the previously required laptop. The initiative is supported by an alliance between Virginia Tech’s College of Engineering, Fujitsu Computer Systems Corporation, and Microsoft Corporation offering students higher levels of hardware and software purchasing power and support. A current technology, the Tablet PC incorporates the portability of the laptop with the flexibility of writing. In conventional notebook mode, the Tablet PC offers a keyboard for typing. When the screen is rotated it transforms into a tablet, and using a stylus students can make handwritten notes and drawings.

Due to the Tablet PC initiative, in fall 2007 sophomore students with the declared major of mechanical engineering (approximately 300 to 350 total) have Tablet PCs. In an attempt to utilize this emerging technology, a pilot study was conducted by the Mechanical Engineering department to integrate Tablet PC functionality with course material in two sections of ME 2024 – *Engineering Design and Economics*. With the special capabilities of the Tablet PC, it is important to understand how the Tablet PC is an improvement from the previously required laptops. Some anticipated benefits of the Tablet PC include: improved notetaking, ability to highlight and annotate key points, increased classroom interaction, the facilitation of student inquiry, simplified drawing in support of concepts, and increased communication for group work. While it is important for the College of Engineering to stay current with technology, the engineering departments and their faculty have a vested interest to examine how this new technology is changing classroom teaching and student learning. While the overall value of technology to undergraduate instruction is now widely recognized, emergent technologies must still be carefully examined to insure their contribution to student learning; therefore, this study includes an assessment component to measure student learning strategies.

ME 2024 is required for sophomore mechanical engineering students and provides an introduction to product development and design. Seven to eight sections of ME 2024 are offered in the fall semester of each academic year with two sections offered in the spring. Class sections are limited to 30 to 36 students to facilitate personalized instruction. Often students from other engineering disciplines such as industrial, civil, and construction engineering take ME 2024 for elective credit. In this course, strong team collaboration and technical writing skills are developed with an introduction to topics such as project management, industrial design,
engineering economics, and ethics. Several mechanical dissections are conducted during the semester.

**Team Collaboration with Microsoft OneNote and Groove**

Students in each section of ME 2024 are divided into teams of three and collaborate in and out of class on specific activities related to a semester-long design project. Teams select from a list of 10 to 15 product ideas and develop an economically feasible product of sufficient technical complexity. Students learn to apply engineering and industrial design methodologies to a product before taking more advanced topics such as mechanics of materials and machine design. Teams are required to meet outside of class, either face-to-face or electronically, for a minimum of two hours per week. Examples of team projects from previous semesters include an automated pet feeder, a collapsible office chair, and an electrically powered car jack.

In the past collaborative exercises involved traditional pen and paper mediums and face-to-face interaction. With the Tablet PC students are encouraged to collaborate electronically. Using Microsoft’s OneNote, students establish team intranets in and out of the classroom. Each team initiates a session by designating a host to share the IP address with the team. To facilitate the sharing of content with the instructor or other teams, the host can share the IP with others. When the session is open an active list of team participants appears in a live session pane. Participants can leave a shared note-taking session at any time.

In a shared note-taking session, team members work in real time. As team members sketch or annotate on their Tablet PCs the other members can see their work and make additional edits to the sketch. Team members can be on or off campus and still engage in the creative process of concept generation and product development. This is an added benefit to students living far off campus. See Appendix A for a procedure using OneNote for team collaboration.

Students often use Microsoft Groove to share files electronically when real-time collaboration is not necessary. Groove allows a team member to archive all team material in one folder. Members can modify content in the team folder using their own PC thus eliminating the sending of email attachments and the transferring of data through travel drives or CDs.

**Classroom Collaboration with Dyknow Vision**

Using Dyknow Vision (www.dyknow.com) instructor-lead classroom collaborations are conducted during in-class activities. The in-class activities, discussed in this paper utilize tablet collaboration in the design team. During the final third of the class teams are required to submit completed work to the instructor using Vision as individual “panels” after the instructor has initiated a session. Class rosters are uploaded to a Dyknow server at the beginning of the semester; therefore, as the instructor starts a session and students log in a dedicated intranet exists between both parties. Instructors are not required to distribute IP addresses to students each time the Tablet PC is used for classroom collaboration. Then, at the instructor’s discretion,
panels are displayed to the students in the session and the teams discuss their work with the class at large. Panels are displayed at each student’s Tablet PC thus eliminating the need for classroom projection. Student teams are informed at the beginning of the activity their work may be displayed for discussion at the end of class; therefore, teams tend to be more attentive to produce work products worthy of sharing.

**Concept Generation and Selection Using Tablet PCs**

In ME 2024 students develop skills necessary for effective product design. An important component of product design is concept generation incorporating brainstorming and final idea selection. Once a team has a verbal description of their product design idea generation begins. Traditionally, concept generation used pen and paper media. In an unstructured gallery concept generation activity students first worked individually with colored markers on a shared sheet of paper located at each table. Team members then combined ideas into one final concept drawn at the center of the sheet as shown in Figure 1.

![Figure 1](image)

**Figure 1** – Unstructured Gallery Method of Concept Generation Using Traditional Media

At the end of the class period teams gave an unrehearsed, impromptu presentation of their final design project idea. (Figure 2).
Often, the class period would end before all teams had the opportunity to present final concepts as time was wasted gathering materials and moving to the front of the class.

With Tablet PC technology, collaboration is within the framework of a team OneNote intranet session. Students use their Tablet PCs to electronically sketch concepts on their own. Then, team intranet is established allowing members to share ideas electronically. Teams work within the intranet to generate a final concept sketch. The completed design is sent to the instructor during the Vision classroom session at the end of class. Teams discuss their concept with annotation via the stylus to highlight important attributes of the design to the class while remaining at their table. All teams are able to share their final ideas with the class due to the time saved using Vision as a presentation tool. Also, an electronic archive of the presentation is available to each team and the instructor that can be reviewed and played back later using Vision’s *Replay Panel* function.

In a OneNote intranet environment the same procedure is used to develop team functional diagrams using functional decomposition. Functional decomposition is often used in concept generation, prior to the unstructured gallery activity, to break complex problems into simpler constituent sub-problems. After each member independently develops a functional diagram, the team uses a single diagram showing further refinements and at least three sub-functions. The last steps in the idea development process include concept screening and final concept selection. Students perform these procedures in a similar fashion using Tablet PCs within OneNote and Vision collaborative environments. Once panels are submitted to the instructor they are graded and returned to the teams using Vision. Figure 3 shows a graded Vision panel of a team concept screening matrix.
The instructor can return graded panels by simply opening the Vision software and having an active internet connection. Panels are stored on the dedicated Dyknow server until the student opens Vision on their computer. At that time the graded panels are sent from the server to the student’s notebook folder. Each submitted panel has a date and student identification stamp (such as a student PID number). Each graded panel has a date stamp indicating when the panel was returned. The instructor and student do not need to be in a classroom Dyknow session to send and receive graded work. Instructors send and students receive graded panels whenever it is convenient without the generation of paper versions of completed work.

**Electronic Engineering Design Logbook**

In addition to developing enhanced team collaboration techniques, students use Tablet PCs to maintain an electronic design logbook. Logbooks must conform to intellectual property rules because entries can be used to establish the date of concept origination in securing U.S. patents (Ulrick and Eppinger, 2004). Previously, students used permanently bound paper notebooks similar to the Edison “Use Your Imagination” lab notebook. Entries were made in ink and signed and dated at the bottom of each page. To simulate this electronically, students are required to start a new page within OneNote each day that class meets and sign and date the bottom of that page at the end of class. Then, the page is converted to a PDF file and stored in a dedicated folder. The PDF has a date stamp assigned to its property attributes to establish the time and day of file creation. Once the PDF is created the corresponding entry cannot be modified.

In the past, when students used paper logbooks, they had difficulties understanding the methodology of logbook entry. Some students never fully grasped the importance of properly maintaining a logbook with respect to intellectual property law. With the incorporation of Tablet PCs students are given daily instruction in proper logbook entry. During each lecture the instructor uses his or her own tablet to write notes as opposed to writing on a chalkboard. These notes are projected on an overhead for the class to see. At the end of the lecture the instructor dates and signs the bottom of the last page and saves the page as a PDF. The PDF file is archived.
in a properly named folder. With repeated instructor modeling, by the third or fourth week of class students are well acclimated to the correct creation and archiving of electronic logbook entries conforming to intellectual property law. Figure 4 illustrates a typical logbook entry showing the functional decomposition of an automated adjustable bed.

![Functional Decomposition Diagram]

**Figure 4** – Student Engineering Design Logbook Entry Using OneNote

The entry is signed and dated and has an “X” placed over the bottom third of the page in conformance with U.S. intellectual property rules. “Team 1, CRN 39” is written by the student in a special white space at the top. OneNote saves the individual page using that designation as a file name. Then, the student saves the file as a PDF for permanent archiving.

**Mechanical Dissection with Tablet PCs**

ME 2024 is the first mechanical engineering course for students in this field. Therefore, an important component of the course is the dissection of mechanical components. During the fifth or sixth week of the semester students perform a dissection of a 5 HP Briggs and Stratton lawn mower engine similar to the one shown in Figure 5.
Students examine the kinematics (relative motion) of the piston, intake valve, and exhaust valve by causing the piston head to translate in its cylinder housing located in the engine block (Figure 4). Students examine other major components of the engine such as the crank shaft, connecting rod, and crank rod while constructing detailed sketches of these components (see Figures 6a and 6b).

An important outcome of the exercise is the ability to identify major components of the motor and the determination of how components relate to one another in the operation of an internal combustion engine (ICE).
The sketching activity is facilitated by the Tablet PC because it allows students to draw different components of the engine individually and then combine sketches via a team intranet. The component sketches are compiled into a collection of panels and submitted electronically to the instructor for grading using Vision. The instructor returns the graded panels without exchanging paper versions of the sketches. Figure 7 shows a graded team panel returned using Vision. The panel shows the relative location of the piston, fan, drive shaft, and intake/exhaust valves of the dissected ICE.

![Figure 7 – Vision Panel of a Team Sketch of a Briggs and Stratton 5 HP ICE](image)

**Product Design Review**

In the final weeks of the semester teams form pairs to review and critique each other’s product design. The exercise simulates real-world industry practice and requires teams to articulate their design to peers and to receive constructive criticism. Appendix B shows an example of the worksheet distributed to students during this in-class activity. Teams are paired randomly resulting in groups of six students. A single host is designated to establish a OneNote intranet. The reviewed team distributes a CAD drawing to the critiquing team showing orthographic views of their final product design. Final, marked-up CAD drawing Vision panels returned to the reviewed team and the instructor for credit.

**Engineering Transfer Students and Tablet PCs**

With only Virginia Tech freshmen engineering students required to purchase Tablet PCs, issues surfaced concerning requirements for students who transfer into the program from other colleges. Typically, these students do not have Tablet PCs. For the pilot study approximately eight out of the 69 students did not own Tablet PCs. Initially these students were paired with teams of students having tablets so no more than one member per team lacked a tablet. During the fall 2007 semester a program was established through the engineering dean’s office to loan transfer students Tablet PCs to maintain continuity for this study. The loaner program will be in effect for
the spring semester as well. Starting in the fall of 2008, transfer institutions will be required to inform potential engineering transfer students of the need to purchase a Tablet PC before starting academic work at Virginia Tech.

Assessment

To study the impact of the new Tablet PC technology on learning in undergraduate engineering courses, a questionnaire was developed to measure changes in the learning strategies of the students in ME 2024. The pilot study not only allowed for implementation of new technology, it allowed us to field test the measure with pilot study participants (69 students total) to ensure the validity of the instrument. A section of the assessment included questions mirroring the ECAR Research Study 6 (Educause, 2005) that examined student skill level with technology using a national sample. We were interested to see if ME 2024 students had the same perceptions of their technology skills as other college students across the country. In addition, questions evaluating student use of the Tablet PC and their opinions about what worked well were included. The online measure also quantifies learning strategies used with the Tablet PC including notetaking, integration of knowledge, critical thinking, and self-regulation. The results of the field test will drive final questionnaire modifications as well as inform future class activities to optimize the use of the Tablet PC to improve student learning.

Instrument development. With the increased capabilities of the Tablet PC as compared to the previously required laptop, the faculty was interested in assessing more than the success of implementation; they wanted to know how the new technology affected teaching and learning. After a literature review of measures of student learning, the Motivated Strategies for Learning Questionnaire (MSLQ) presented itself as an appropriate measure adaptable to the study’s purpose. In the past, the MSLQ had been used to assess the motivational and cognitive effects of educational technology and computer-based instruction. The 15 scales of the MSLQ are designed to be used together or singly and can be used to fit the needs of the researcher. Developed using statistical and psychometric analyses including internal reliability coefficient computation, factor analyses, and correlations with academic performance and aptitude measures, the MSLQ measures have proven to generalize appropriately in different educational settings (Duncan & McKeachie, 2005).

For the purpose of measuring the technology’s impact on learning, the learning strategies scales were chosen. The learning strategies include items measuring student use of cognitive and metacognitive strategies as well as items related to student management of resources. Each section is divided into scales with between three to twelve items comprising the scales. The scales and items selected were based on content relevance and representativeness to the latent trait of student self-regulation of learning strategies as they relate to note-taking with the Tablet PC. The College of Engineering faculty anticipates an increased complexity of student cognitive strategies with the use of the Tablet PC to take notes and organize ideas; therefore, the cognitive strategies scales of rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, and effort regulation were included. See Appendix C for a list of the MSLQ subscales and items originally chosen.
After choosing items for content relevance, one of the original developers of the MSLQ, Bill McKeachie, was contacted for feedback or suggestions for the use of MSLQ items to meet the study’s needs. McKeachie agreed with the appropriateness of the items and offered a suggestion for a wording change in one of the items.

**Administration procedures.** The questionnaire was formatted using SNAP survey software’s web-based delivery. In the final week of class students were directed to a link and asked to complete the survey. Students completed the online survey at their convenience. Survey results were stored on a College of Engineering server and downloaded after a reasonable amount of time had passed for completion (approximately 2 weeks).

Designed to be used twice a semester as a pretest/posttest the instrument will measure change in student learning strategies and levels of collaboration. The instrument allows for future comparison of one class to another. For the spring semester of 2008 two sections of ME 2024 will be offered using the same instructor. One class will fully incorporate Tablet PC technology while the other class will be taught using traditional instructional and collaborative media. The traditional course will provide an experimental control to enable a comparison of student learning strategies and performance between the two sections.

**Field Test Results**

*Pilot study sample.* With a sample size of 55 (47 male, 7 female, 1 nonresponse), the pilot study had a sufficient response rate of 80%. However, with this relatively small sample size, the representativeness of the sample was a concern. Therefore comparing our students’ responses to the responses from a national sample provides support for the validity of the preliminary findings of the pilot study. Using two questions similar to those in the ECAR study (N>17,800) asking students to self report their technology skill level and their need for training our findings show the ME 2024 students have similar perceived skill levels and training needs as displayed in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Variable and Values</th>
<th>ECAR</th>
<th>Pilot Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Reported Skill Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Much more skilled</td>
<td>7.9%</td>
<td>16.4%</td>
</tr>
<tr>
<td>More skilled</td>
<td>29.7%</td>
<td>21.8%</td>
</tr>
<tr>
<td>About the same</td>
<td>49.3%</td>
<td>54.5%</td>
</tr>
<tr>
<td>Less skilled</td>
<td>11.5%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Much less skilled</td>
<td>1.6%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Need for Training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly agree</td>
<td>6.0%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Agree</td>
<td>20.7%</td>
<td>23.6%</td>
</tr>
</tbody>
</table>
**Instrument validity.** With the sample showing similar response patterns as the national sample, the modified MSLQ subscales were examined for internal reliability using coefficient alpha (Cronbach, 1951). The coefficient alpha for each subscale is displayed in Table 2.

<table>
<thead>
<tr>
<th>MSLQ Subscale</th>
<th>Original Instrument (α)</th>
<th>Field Test (α)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rehearsal</td>
<td>0.69</td>
<td>0.73</td>
</tr>
<tr>
<td>Elaboration</td>
<td>0.75</td>
<td>0.71</td>
</tr>
<tr>
<td>Organization</td>
<td>0.64</td>
<td>0.78</td>
</tr>
<tr>
<td>Critical Thinking</td>
<td>0.80</td>
<td>0.77</td>
</tr>
<tr>
<td>Metacognitive Self-Regulation</td>
<td>0.79</td>
<td>0.63</td>
</tr>
<tr>
<td>Effort Regulation</td>
<td>0.69</td>
<td>0.37</td>
</tr>
</tbody>
</table>

All modified subscales show acceptable reliabilities except for the Effort Regulation subscale. Prior to use as a pretest/posttest in spring 2008, this subscale will be reexamined and most likely eliminated from the instrument.

**Informing classroom activities.** The pilot study proved helpful in gathering student opinions for course improvement as well as field testing the assessment instrument. Students were asked about the activities best supported with the Tablet PC and the activities for which the Tablet PC was not the best choice. Of the 55 respondents to the questionnaire, 41 responded to the open-ended course improvement questions.

When the students were asked what worked well with the Tablet PCs, three responses were most common. Over half of the students reported PowerPoint note taking using the stylus to annotate slides provided by the instructor was extremely effective and engaging. Online collaboration and group work also worked well as reported by over one third of the ME 2024 students. Many students also discussed the effectiveness of the Tablet PC for sketching and drawing.

When asked when the Tablet PC did not work well, the overwhelming majority of responses discussed problems with high capacity using DyKnow. Students complained of DyKnow being “slow” and “tedious” when many students were collaborating or trying to send work at the same time. This student feedback is important for the instructor as well as the technical support staff. If the Tablet PC is to be an effective tool issues such as server problems and available bandwidth must be addressed.

Although logistical issues still exist with the implementation of this new technology in the classroom, the students are aware of the added benefits of the Tablet PC in the learning and
design process. The Tablet PC is functioning well as a tool to increase student engagement during note taking and it facilitating student collaboration both in and out of class.

Conclusion

With the introduction of Tablet PC technology into the engineering curriculum students utilize this electronic tool in new and exciting ways. The mechanical engineering department is putting this technology to work by switching from old modes of communication and collaboration to new ones involving the Tablet PC. With the increase in globalization in many technical fields students benefit from being able to perform seamless real time electronic collaboration using tablet personal computers. Electronic Tablet PC collaboration allows individual team members to be in different places and still have the capability of contributing in real time to product concept creation and cross-team design reviews.

Using the information gained from this pilot study, activities can be further developed using the Tablet PC to enhance the learning of mechanical engineering students. With the study expanding in spring 2008 to include a control group, our goal is to better understand the Tablet PCs impact on the teaching and learning process. Using a refined assessment instrument in a pretest/posttest design, we will measure the change in student learning strategies from the beginning to the end of the semester and determine if the table PC is changing the way in which future engineers use information to learn.

The mechanical engineering department at Virginia Tech plans to increase implementation of Tablet PC based learning in the fall of 2008 when additional ME 2024 instructors will be trained on the use of this technology. Typical sophomore enrollment in mechanical engineering at Virginia Tech is between 300 to 350 students spanning seven to eight fall sections of ME 2024 of 30 to 33 students each. Further development also involves the enhancement of junior and senior level mechanical engineering courses over the next two years.

Bibliography


Appendix A - Team Collaboration with Microsoft OneNote

Step 1 – Share a current section (host)

1. After opening OneNote go to the Share menu, point to Live Sharing Session, and then click Start Sharing Current Section. The Start Live Session task pane opens.
2. Click Start Live Sharing Session.
3. In the Warning GUI click OK.
4. In the Current Live Session task pane select the Allow participants to edit check box.
5. Click Invite participants.
6. The names of all of your team members should appear in the Current Live Session task pane as they join a secession. Participants can leave a shared note-taking session at any time.

Step 2 - Participate in a shared note-taking session (other team members)

1. Start OneNote.
2. On the Share menu, point to Live Sharing Session, and then click Join Existing Session.
3. In the Live Sharing Session Address box in the Join Live Session task pane, type the IP address of the session host's computer.
4. Click Join Session.

Step 3 - Leave a shared note-taking session (all members)

In the Current Live Session task pane, click Leave Live Sharing Session. Closing the Current Live Session task pane does not end the session if other members are still logged on. To end the session all members must log off.
Appendix B – Collaborative Design Review Worksheet Involving Two Teams

ME 2024 – Engineering Design and Economics
Design Review

Submission: CRITIQUING TEAM: this worksheet and CAD drawing submitted as a Vision panel directly to the instructor

Due: At the end of this class

If a team member is absent or did not contribute to this review place an asterisk (*) by their name. It is a violation of the Virginia Tech Honor Code to do otherwise.

CRITIQUING TEAM (indicate missing team members with an *):

Team Number_______ CRN _______

Member 1_________________________ Member 2_________________________
Member 3_________________________

REVIEWED TEAM (indicate missing team members with an *):

Team Number_______

Member 1_________________________ Member 2_________________________
Member 3_________________________

Designate a one host from one of the teams to establish a OneNote collaboration for all participants in the design review. This should take no more than five minutes to complete.

NEATLY answer the following question in complete and legible sentences. PLEASE KEEP TRACK OF TIME:

1. (4 minutes) What customer needs are being addressed in this product design? Indicate at least two.

2. (4 minutes) What failure mode do you predict will be most significant and how do you plan to address this limit state in your design?

3. (3 minutes) What CAD software package did you use to prepare the preliminary design drawings and why did you pick this particular one?
4. (4 minutes) In developing your CAD model did you discover any interference problems with components? How much of your product will involve “off the self” (OEM) components and why did you (or why did you not) use these.

5. (4 minutes) Provide one recommendation for the reviewed team. Communicate it to them at the time of the review and indicated below.
Appendix C – MSLQ Subscales Included During Instrument Development

Rehearsal
1. When I study for this class, I practice saying the material to myself over and over.
2. When studying for this course, I read my class notes and the course readings over and over again.
3. I memorize key words to remind me of important concepts in this class.
4. I make lists of important items for this course and memorize the lists.

Elaboration
1. When I study for this class, I pull together information from different sources, such as lectures, readings, and discussions.
2. I try to relate ideas in this subject to those in other courses whenever possible.
3. When reading for this class, I try to relate the material to what I already know.
4. When I study for this course, I write brief summaries of the main ideas from the readings and my class notes.
5. I try to understand the material in this class by making connections between the readings and the concepts from the lectures.
6. I try to apply ideas from course readings in other class activities such as lecture and discussion.

Organization
1. When I study the readings for this course, I outline the material to help me organize my thoughts.
2. When I study for this course, I go through the readings and my class notes and try to find the most important ideas.
3. I make simple charts, diagrams, or tables to help me organize course material.
4. When I study for this course, I go over my class notes and make an outline of important concepts.

Critical Thinking
1. I often find myself questioning things I hear or read in this course to decide if I find them convincing.
2. When a theory, interpretation, or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence.
3. I treat the course material as a starting point and try to develop my own ideas about it.
4. I try to play around with ideas of my own related to what I am learning in this course.
5. Whenever I read or hear an assertion or conclusion in this class, I think about possible alternatives.

Metacognitive Self-Regulation
1. During class time I often miss important points because I’m thinking of other things (R).
2. When reading for this course, I make up questions to help focus my reading.
3. When I become confused about something I’m reading for this class, I go back and try to figure it out.
4. If course readings are difficult to understand, I change the way I read the material.
5. Before I study new course material thoroughly, I often skim it to see how it is organized.
6. I ask myself questions to make sure I understand the material I have been studying in this class.
7. I try to change the way I study in order to fit the course requirements and the instructor’s teaching style.
8. I often find that I have been reading for this class but don’t know what it was all about (R).
9. I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for this course.
10. When studying for this course I try to determine which concepts I don’t understand well.
11. When I study for this class, I set goals for myself in order to direct my activities in each study period.
12. If I get confused taking notes in class, I make sure I sort it out afterwards.

Effort Regulation
1. I often feel so lazy or bored when I study for this class that I quit before I finish what I planned to do (R).
2. I work hard to do well in this class even if I don’t like what we are doing.
3. When course work is difficult, I either give up or only study the easy parts (R).
4. Even when course materials are dull and uninteresting, I manage to keep working until I finish.