Entry-level, college science courses provide students with the opportunity to establish foundational knowledge, explore their interests in a discipline, and develop skills in solving problems relevant to the discipline. The confidence required to meet problem-solving, learning objectives contrasts with student experience in knowledge accumulation and recall. This lack of confidence in problem-solving can be addressed when teachers use metacognition teaching strategies (Lester et al., 1989) as a means to promote students’ academic success and encourage the idea of disposition to understand for oneself (Entwistle and McCune, 2013). Metacognition refers to meta-level knowledge and mental actions used to direct or manage cognitive processes. In its simplest definition, metacognition is “thinking about one’s own thinking” (Flavell, 1979). DeBono (1976) describes metacognition as knowing what to do, when to do it, how to do it, and what to take into consideration.

Metacognition is a skill that develops over time where the learner is self-aware of his/her thinking and regulates his/her processes used to solve a problem and/or execute a task. As such, it is intentional and leads one to become a self-regulated learner where the learners set standards or goals to strive for in their learning, monitor their progress toward these goals, and then adapt and regulate their cognition, motivation, and behavior in order to reach these goals (Pintrich 2000; Vrugt and Oort, 2008).

In science education, metacognitive skills enable the learner to understand science concepts removing misconception and strategies that are barriers to acquiring new concepts (White and Frederiksen, 1998). Sperling et al. (2012) in their analysis indicated metacognition is a significant predictor in science achievement and overall achievement. Developing metacognitive skills in students requires teaching and modeling the metacognitive process in the classroom, cultivating in students explicit knowledge about when and where to use strategies. Promoting metacognition begins with building an awareness among learners that metacognition exists and increases academic success (Schraw, 1998). As such, teachers need to explicitly use the thinking language both verbally and in action in the classroom (Schraw, 1998). In creating a classroom atmosphere that nurtures metacognition, consideration must be given to what is said, how it is said, what is being done, and how it is being done. Marzano (1998) documented that explicit metacognitive talk as one of the most important tools for improving student learning. Costa (2008) suggests using language that evokes thinking and the thinking process rather than vague abstract terms allowing students to internalize these terms and begin to make them part of their vocabulary. For example instead of asking students “What is the effect of climate variability on soil functions?” the teacher should ask “What evidence do you have on how climate variability affects soil functions?” or “What hypothesis do you have to support climate variability effect on soil functions?” The metacognitive process is a self-reflection, asking process that includes asking oneself “What do I know? What tools do I have to address these questions/problems? What are the appropriate steps? How could I do this better?” The work of Mevarech and...
Kramarski (1997) on metacognitive instruction emphasizes reflective discourse to teach mathematical knowledge and reasoning. This metacognitive instruction known as IMPROVE entails:

1. Introducing the new material;
2. Metacognitive questioning (what is the problem, connecting problem to past experience, identifying appropriate strategies, evaluating appropriateness of the solution);
3. Practicing;
4. Reviewing;
5. Obtaining mastery on higher and lower cognitive processes;
6. Verification; and
7. Enrichment and remediation.

In an effort to create a "thinking classroom" and promote efficiency in learning for academic success, a pilot project was initiated to evaluate the efficacy of course activities in helping students develop self-awareness in learning. The overall goal was to explicitly integrate metacognitive practices in both lower- and upper-level courses. The courses in this pilot project were large enrollment (n > 100) entry level 3-credit-hour course, is required for many students majoring in the Agronomy and Horticulture Department at UNL. The course is taught so that students attend two lectures (50 minutes each) and one recitation period (110 minutes) per week. In the semester that the pilot study was conducted there were a total of four recitation sections with approximately 25 students in each. In the fall of 2011, this course was also taught online in which all course requirements were completed over the Internet and as a hybrid section (lectures and material delivered online with a once per week, face-to-face recitation meeting).

Both courses run for a full semester (16 weeks). The lab-recitation period consists of short, up-front instruction (10–20 minutes) during each meeting in addition to some interactive elements (questions, student-centered reviews, in-class quizzes, hands-on activities). Students work in groups of approximately three to four students to complete activities and problems (Fig. 1). Metacognition was explained and instruction given at the beginning of the semester. An instructor was available to answer questions and help guide learning throughout each lab-recitation period.

**Activities Enforcing Metacognition**

Both Soil Resources and Plant Sciences implemented metacognitive activities in the classroom in similar ways. Metacognitive activities can be categorized into three areas: planning, monitoring, and evaluation (Schraw et al., 2006). Activities such as developing goals and planning exam strategies fall under the metacognitive area of planning. Monitoring activities included items like developing concept sketches and maps, using models to explain course topics, and generating questions as content is reviewed. Concept sketches engage students in

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**Table 1. Metacognitive activities implemented in Soil Resources and Plant Science in fall semester 2011 at the University of Nebraska-Lincoln.**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Soil resources</th>
<th>Plant science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop course goals at the beginning of the semester and assess whether you have achieved them at the end.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Complete a knowledge survey at the beginning and end of each unit.</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Complete an exam wrapper and evaluate what went well and what did not and how you plan to prepare for the next exam.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Develop conceptual maps and sketches for ideas/concepts and to connect ideas.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Use models (for the gene expression process) to illustrate processes/concepts.</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Write reflection on topics and/or units recently completed.</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Generate questions when reviewing notes.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Discuss responses to oral questions with group.</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Discuss responses to activities with group.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Solve problems with group.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Explain to instructors how answers were derived.</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Based on the Holmes Lake (Lower Platte South Basin) case study:

A. Develop a concept sketch for this case addressing how soil erosion contributed to Holmes lake impairment. Consider the following in your overall sketch:
   1. Type of erosion and process within the Holmes Lake watershed
   2. Role of land use and land use change
   3. Role of Antelope creek banks
   4. Impact on lake functions (aquatic life, recreation etc...)
B. Develop recommendations for the Antelope Creek watershed to reduce future damage to the Lake (What can builders do? What can home owners do?, etc...). **Present your evidence** for each recommendation of how it would efficiently work to reduce sedimentation/pollution of the lake and resource loss (soil loss by erosion) within the watershed.

Fig. 2b. Example concept sketch activity on erosion in Soil Resources at the University of Nebraska-Lincoln (example student sketch for this activity is presented in Fig. 2a).

The learning process, develop critical thinking skills, teach communication skills, and at the same time help identify student misconceptions (Johnson and Reynolds, 2005). The evaluation area pertains to students’ reviewing goals at the end of the semester or reviewing graded exams to identify misconceptions, inaccuracies, and develop better strategies for future exams. The goal of using these activities in the classroom was to provide opportunity for students to practice metacognitive skills while learning Soil or Plant Sciences content. The two courses implemented the metacognitive activities listed in Table 1 (examples of activities in Fig. 2 and 3).
Description of the Evaluation

The survey administered asked students to respond to questions assessing their perception of the metacognitive activities and other teaching tools used in the classroom on their overall learning in the course. The survey was deployed using Survey Monkey, which allowed anonymous electronic data collection (Table 2).

Data were collected at the end of the semester. The survey included demographic information on students’ year in school and major and was administered with Institutional Review Board Approval (IRB #200306328 EX) to ensure student confidentiality. Completion of the survey indicated that students were consenting to participate in the study. A scale of 0 to 3 was used on questions where students were asked to rank specific activities (Table 2). The survey given was very similar for both Plant Science and Soil Resource students but asked for specific feedback related to activities conducted in each course. Students in both courses were given extra credit points for participating in the survey.

RESULTS AND DISCUSSION

Academic Major Descriptions

In Soil Resources, 44% of students were in an agriculture-related major, whereas 19% were in an environmental-related major. In Plant Science, almost 60% of students were in an agricultural-related major and only 2.5% were in an environmental area (Table 3).

An important question of interest was whether a majority of students in each class acknowledged that the emphasis on metacognition was useful. Another question was how students of different class standing would view the emphasis on metacognitive activities. Open-ended item responses were included in the survey questionnaires.

In the Soil Resources course, 69% of all students thought the emphasis on metacognition was useful, 19% said it was not, and 12% were unsure. In Soil Resources, 94% of the freshmen said the emphasis on metacognition was useful. Seventy five percent, 68%, and 48% of the sophomores, juniors, and seniors, respectively, found the emphasis helpful. Here are two sample comments from this course:

- The metacognition processes were helpful in outlining course objectives and staying focused on the end result.
- If this was the first time I had come into contact with these methods I would definitely have said yes but I've had this all throughout high school. I can see how they may be applicable to younger students or different majors though.

In Plant Science, 82% of the students said the emphasis on metacognition was useful, 8% said it was not, and
Almost 84% of the freshman, 71% of the sophomores, 86% of the juniors, and all of the seniors said it was useful. Sample comments from this course were:

- I feel like these strategies and skills would have helped me greatly in a class that I was not very interested or involved in. But since I found this class to be very interesting I was able to study and learn perfectly fine the old fashion (sic) way.
- Yes and no. I felt I was still learning, and it was great to pick up new strategies, but it seemed a bit overwhelming to me.

The evaluation included which strategies students valued most and least (Table 4). One series of questions focused on learning strategies: "You were asked to participate in a number of activities to improve your learning strategies and study skills. Please evaluate them in terms of their usefulness for you in this course."

Students were asked to evaluate each of the following strategies in terms of how often they used them. The evaluation included which strategies students valued most and least (Table 4). One series of questions focused on learning strategies: "You were asked to participate in a number of activities to improve your learning strategies and study skills. Please evaluate them in terms of their usefulness for you in this course."

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Students were asked to evaluate each of the following strategies in terms of how often they used them. Students in the Soil Resources course gave the highest
frequency rating to using the pre-examination reflection (Fig. 4) as a learning tool for each topic, followed by reviewing their completed worksheets. They gave the lowest frequency rating to generating questions from the topic and trying to answer them. Students in Plant Science gave the highest frequency ratings to answering all questions in their problem set before taking the quiz and applying course content to a case study. They gave the lowest frequency ratings to generating questions from the topic and trying to answer them.

When students were asked how useful the following supporting resources were, those in the Soil Resources class gave the highest rating to the course manual, then the lab group and hands-on learning. They gave the lowest rating to the textbook. In Plant Science, students gave the highest ratings to instructor communication and working problems. They gave the lowest ratings to online resources. However it should be said that the online ebook was highly valued by some students. Sample comments were:

- I liked the ebook quizzes because you got initial feedback and that helped me understand what I needed to study more.
- The online ebook that went with each week. This allowed us to read and see how the material was applied to a real life situation, which is helpful as it shows us how we may use it in our futures as well.
- The problem set and ebook was a great repetitive learning strategy.

Students in each class were asked whether the exams and graded assignments measured how much they really learned. Soils students gave the highest rating to lab quizzes and exams. They gave lowest ratings to the group project. Students in Plant Science gave their highest rating to the quizzes and their lowest ratings to experiment write-ups. In both courses the textbook (traditional or as the online eBook), projects, and generating questions seemed to be the least preferred learning activities. It is possible that textbook-assigned reading can be objective based and linked to specific activities. The experiments and project write-ups as well as generating questions require higher-order thinking and self-reflection to interpret the data, connect the data to concepts, and articulate explanations in writing using the data as evidence.

The instructors began teaching with this emphasis on metacognition so students would begin to think about their own thinking. The best positive indication came from responses to the open-ended questions, which indicated a degree of success to explicitly integrate certain activities to enhance questioning, monitoring, and evaluation of one’s own thinking.

- I feel the test review/reflections were a valuable tool. They allowed me to go back through the sections on the test and gain more information about what was going to be covered on the exam.
- Pre-reflections for exams. It was a good way of forcing us to study the correct materials.
- Filling out the Pre-Exam sheets really helped me to understand the lessons. I liked having to make the word webs because it cemented how concepts were connected.
- I learned a lot of discipline throughout this course. It wasn’t something that could be put off and I had to discipline myself to get some studying done around the rest of my schedule.

Please address each of the four items separately. Turn in a clean copy the day of the exam.

1. Develop a list of vocabulary words with your OWN definition (suggested 5 vocabs. per topic).
2. What are the main ideas from each topic?
3. In your opinion, what essential knowledge and skills have you taken from this unit?
4. Create a visual representation of the connection of main ideas (see #2 above) learned thus far (Hint: Think concept sketch and model format).

**Checklist**

- Re-review topics exercises.
- Find a study group and ask questions or explain to each ideas and calculations.
- For problem solving questions, draw pictures to help you understand what the problem is asking and evaluate the given information within the problem, and then seek appropriate solution.
- Rework the calculations and know when to use the appropriate equation relationships. Understand what story the calculations are telling you.
- Work the calculation problems backward to check yourself.
- Use online quizzes as review tool.
- Use knowledge survey questions as study guide.
- Re-review assigned readings.
- Use past exam to prepare for exam.
- Attend review session if offered.
- Others...

Fig. 4. Example guidelines for developing post-lesson and pre-examination reflection in Soil Resources fall semester 2011 at the University of Nebraska-Lincoln.

- The metacognition processes were helpful in outlining course objectives and staying focused on the end result.
- Turning in reviews of the chapters we went over before each test helped me review the concepts and make sure I understood them.
- I found the summary and reflections for each section to be quite useful. By the time I was done completing them, I was already pretty well prepared for the coming exam.
- I believe when actually taking the time to think about the way your (sic) thinking, you learn more about how your (sic) going to remember this and not just throw out an answer. You try and think about all aspects of the topic, and not just memorize a question.
- I believe the learning quizzes helped me after lectures because they made me think about what I learned in the lecture.
- Exam Reviews, Jeopardy Tests and Quizzes let me prepare for the exam. They let me know the kind of questions I have to be prepared for and offer a high quality feedback.
- I would review the Problem Set questions a lot because they always seemed to help me better understand the lesson.
This study suggested that the metacognitive activities were having a positive effect. However, there are a few students who felt this was unnecessary or “busy work.” See example comments below:

- I already study well and did not feel that being told how to study a certain way was a good use of my time.
- I would have liked more time spent on the material, a better manual, and more helpful teaching techniques, rather then (sic) all of the busy work.
- There were way too many surveys, course wrap ups, evaluations, etc. I realize it’s a freshman level course but if I was looking for ways to improve my learning I would take a psychology course. The best measure of my learning was from the exams.

CONCLUSIONS AND IMPLICATIONS

Students reacted positively in terms of the usefulness of many items. The highest perceived preference in Plant Science was the models (Fig. 5), whereas it was group problem solving for Soil Resources. Soil Resources students reported using the course manual, developing a summary, and relating ideas frequently. Plant Science students reported using problem sets, applying concepts to a case study, and relating ideas most often. Students in both courses reported that generating questions and critiquing ideas were not frequently used.

Instructors recognized the importance of being explicit with discussion about metacognition in the classroom so that students can begin making connections between activities and learning. Students are novices in metacognitive skills and may resist such approaches during the course. However, they may value these skills later as independent thinking is expected in other courses and careers. Based on the findings from this pilot study, it seems that a high percentage of students recognize the value of actively engaging in metacognition. Instructors in both courses are motivated to continue expanding these activities, given 82% of the Plant Science students and 69% of the Soil Resources students responded that the metacognition emphasis was useful. Recognizing metacognition as a valuable learning tool for both instructors and students is a long process. Therefore, exposure to metacognitive activities needs to be implemented throughout curriculum to maximize effectiveness for students, at the same time, authentic activities that enhance metacognitive skills require time to prepare, plan, and implement.

Instructor Reflections and Metacognition Resources for the Classroom

Instructors for both courses observed students being more engaged with the course content when metacognitive activities were implemented. At times this translated into more student questions or even students self-correcting when completing the activities. With certain metacognitive activities, like the concept map/sketch and using models, students appeared to also be more engaged with their peers in the class by posing questions to one another, creating more discussions, and demonstrating more depth of content knowledge. Instructors for both courses also commented that it was necessary, at times, to revise metacognitive activities after the first use to better fit the needs and the level of the students and course content. Occasionally, some students would choose to construct a reflective narrative about the content rather than construct

![Photosynthesis Model Instructions](image)

Use the paper pieces to construct and show the process of both the light reaction and the dark reaction in photosynthesis. You should be able to explain and show the steps in each process to your instructor using the model.

![Photosynthesis Model](image)

Fig. 5a. Photosynthesis model (hands-on activity) constructed by students in Plant Science fall semester 2011 at the University of Nebraska-Lincoln.

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Fig. 5b. Photosynthesis model instructions students were given in Plant Science fall semester 2011 at the University of Nebraska-Lincoln.
REFERENCES
