Examining the Delivery Modes of Metacognitive Awareness and Active Reading Lessons in a College Nonmajors Introductory Biology Course

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Current research supports the role of metacognitive strategies to enhance reading comprehension. This study measured the effectiveness of online versus face-to-face metacognitive and active reading skills lessons introduced by Biology faculty to college students in a nonmajors introductory biology course. These lessons were delivered in two lectures either online (Group 1: N = 154) or face to face (Group 2: N = 152). Previously validated pre- and post- surveys were used to collect and compare data by paired and independent t-test analysis (α = 0.05). Pre- and post- survey data showed a statistically significant improvement in both groups in metacognitive awareness (p = 0.001, p = 0.003, respectively) and reading comprehension (p < 0.001 for both groups). When comparing the delivery mode of these lessons, no difference was detected between the online and face-to-face instruction for metacognitive awareness (pre- p = 0.619, post- p = 0.885). For reading comprehension, no difference in gains was demonstrated between online and face-to-face (p = 0.381); however, differences in pre- and post- test scores were measured (pre- p = 0.005, post- p = 0.038). This study suggests that biology instructors can easily introduce effective metacognitive awareness and active reading lessons into their course, either through online or face-to-face instruction.

INTRODUCTION

Nationwide, many students are under-prepared for freshman biology courses due to a lack of reading and study skills. In a survey of 1,100 faculty from various campuses and departments, only ten percent felt their students were “very well prepared” to read and understand college material (19). Teachers of undergraduate introductory courses have encountered numerous freshmen students who admit the difficulty of reading college textbooks (9). This issue is further compounded because reading instruction ends in fifth or sixth grade for most students (23). The reading and study skills needed for high school are not adequate for the material covered in college courses since college reading covers a larger volume and broader range of topics (20).

In 2012, 52% of high school graduates took the American College Testing (ACT), and of these students 52% met the reading benchmark of 21 and 31% met the science benchmark of 24 (http://www.act.org/research-policy/college-career-readiness-report-2012/). At South Dakota State University (SDSU), only those students with a reading score of 17 or below are required to take remedial reading courses. Studies indicate that even with an ACT reading score of 21 students struggle with reading comprehension at the college level (11). It is common to experience test scores below 70% in college level biology courses. In our nonmajors biology course, about 50% of the students receive a D or F on their exams, and the overall course D, F or withdrawal rate is 36%. While reading is only one aspect of course performance, it is an area that is often overlooked by STEM faculty and which deserves the attention of both faculty and students.

Improving metacognitive skills in reading is one way to improve reading skills. Metacognition in reading uses reading comprehension strategies and is the groundwork of one’s own processes and the ability and willingness to control these processes. In a broad sense, metacognition is thinking about thinking. Flavell provided the first formal definition as “knowledge and cognition about cognitive phenomena” (4, 5). He continued his definition to include the strategies that control cognitive processes and the active monitoring of these processes. In simple terms, metacognition is the knowledge of thinking processes, awareness of one’s own processes, and the ability and willingness to control these processes.

Science faculty may not be comfortable implementing metacognitive theory or active reading strategies in their classroom. However, when these strategies are introduced into the classroom, both faculty and students benefit. In 2011, the Associated Colleges of the Midwest (ACM) Collegium on Student Learning reported that by asking metacognitive questions of students, the faculty became more aware of their students’ learning and increasingly self-reflective about their own teaching practices and
effectiveness (14). They also report that metacognition improved student learning and was an effective tool for focusing students’ attention more consciously on their learning. Additionally, students were able to think about the larger purpose of their education (14). Carlston found that when students use active reading strategies in an introductory college psychology course they retain more information and achieve higher exam scores (1). Taraban has shown that college students with higher academic performance utilized more reading comprehension strategies than students with lower GPAs (20, 21). Introducing formal metacognitive and reading skill activities into introductory biology courses may help colleges and universities improve student learning, persistence, and graduation in STEM fields.

The learning problem we address centers around the premise that many incoming college students are under-prepared for introductory science courses. Due to under-developed metacognitive and reading skills, students have difficulty using their science textbooks, performing well on exams, applying basic concepts, and connecting topics. They develop negative perceptions and attitudes toward science due to a lack of confidence and poor performance in introductory science courses and they do not attain deeper learning. This lack of confidence, motivation, and performance negatively affects attitudes and retention rates in the sciences. Solving this problem will affect student success as measured by gains in metacognitive skills, gains in reading comprehension, and changes in attitudes and motivation toward biology.

Since metacognitive awareness strategies play an important role in reading comprehension, the initial research question we investigated was: Does spending time in a biology course teaching metacognitive skills and/or active reading strategies improve student success, metacognitive awareness, reading comprehension, and attitudes about biology? To answer this question, SDSU Biology faculty introduced lessons on reading and metacognitive awareness in reading strategies to freshman Biology majors enrolled in the First Year Seminar for Biology Majors. A research study was designed to measure the effect of these lessons on student performance, metacognitive awareness, reading comprehension, and student attitudes toward biology.

In fall 2011, preliminary data was collected on introducing metacognitive and reading lessons in a majors Biology class (8). The group that did not receive any intervention did not improve in metacognitive awareness in reading strategies ($p = 0.071$), declined in attitude ($p = 0.001$), and improved in reading comprehension ($p < 0.001$). This data suggests that the reading activities as taught did not have a statistically significant impact on understanding comprehension, as reading comprehension significantly increased with or without treatment. However, the results do suggest that teaching metacognitive awareness strategies in reading has a statistically significant impact on metacognitive awareness scores.

Building from our previous work, this present study aims to answer the following research question: Is there a difference in the effectiveness of the delivery method of teaching metacognitive skills and active reading strategies as measured by metacognitive awareness, attitudes about biology, and reading comprehension? To explore this question, a nonmajors Survey of Biology course was studied. This large section course is divided into two lecture sections. One section was taught metacognitive and reading skills in a face-to-face lecture format, and the second section was delivered this same material online via narrated PowerPoint. We hypothesize that teaching metacognitive and reading skills will improve metacognitive awareness and reading comprehension, and both modes of delivery of these lessons will produce positive results. If science faculty can implement high return on investment methods of helping students in introductory courses learn in complex ways, the entire educational experience will be more effective and student learning would be promoted not only throughout students’ college careers but also beyond the university experience.

**METHODS**

**Participants**

This project evaluated the effectiveness of online versus face-to-face instruction of reading and metacognitive awareness to first-semester freshman students enrolled in a nonmajors Survey of Biology course at SDSU. The large lecture format course is taught by the same instructor in two lecture sections and surveys many broad topics for students who are not majoring in the sciences. The participation rate was 51% and 306 students completed both the pre- and post- survey (Group 1: $N = 154$, Group 2: $N = 152$). The treatment group was randomly assigned based on lecture section. Both sections were taught face to face by one instructor, with the reading and metacognitive lessons delivered by the PI of this study. Project design, surveys, and worksheets were approved by the South Dakota State University Institutional Review Board (IRB-1208004-EXM) prior to the start of the study.

**Intervention**

During the first week of the semester, two 50-minute study-skills lectures were given to the students in one of two methods: online or face-to-face. The two treatment groups were decided by self-registration into one of two sections of the Survey of Biology course. There is no reason to indicate that this self-selection caused a difference in group demographics and neither section time was more preferred. The intervention lectures addressed study skills for a college science course, reading skills using the Survey-Question-Read-Recite-Review (SQ3R) method, and metacognition. The SQ3R method is a widely used active reading strategy that improves comprehension (16, 10). The lectures were followed by a homework assignment including metacognitive reflection questions and the SQ3R reading method from an
assigned section of the course textbook (see Appendix 3). The assignment was repeated during week 5 of the semester with a different section of the textbook to reinforce reading and metacognitive skills. These worksheets were not a measure of content knowledge but rather a tool to model and develop metacognitive and active reading skills. The online delivery of the two 50-minute study-skills lectures included a narrated PowerPoint of the same material presented to the face-to-face group. Both intervention groups completed the same homework assignments.

Quantitative analysis

Pre- and post- surveys were conducted at the start of the semester (week 1) before treatment and at the end of the semester (week 14) after the two reading and metacognition lessons (see Appendices 1 and 2). Surveys were voluntary and student identification was collected, allowing the researchers to match the data. The pre- and post- surveys were identical with the exception of the ACT reading passage and comprehension questions, which were altered to reduce an exposure effect. The surveys were offered to 588 students.

Data collected from both groups at the start of the semester (pre- survey, before intervention) was compared to data collected at the end of the semester (post- survey, after intervention) by using independent t-test (within groups and between groups) using the significance level of α < 0.05. Confidence interval and effect size were also calculated when appropriate. Pearson’s r correlations and multiple regression analysis were used to assess the strength of the relationship between dependent and independent variables. Independent variables in this study were high school grade point average (HS GPA), ACT Reading, ACT Composite, ACT Math, pre- and post- scores from Metacognitive Awareness in Reading Strategies Inventory (MARSI), Biology Attitude Scale (BAS), and Reading Comprehension. The dependent variable was the Introductory Biology course grade.

Instrumentation

Three self-report survey instruments were used to measure metacognitive skills, reading comprehension, and attitudes: MARSI, ACT, and BAS (see Appendices 1 and 2). MARSI is a validated survey that was used to evaluate metacognitive awareness in reading strategies in adolescents and adults (12). Participants read 30 statements about what people do when they read academic materials and rate their level of agreement on a five-point scale from 1 = “I never or almost never do this” to 5 = “I always or almost always do this.” Student scores are added and divided by the total items. Scores range from 1 to 5 and standards for interpretation are high (mean of 3.5 or higher), medium (mean of 2.5 to 3.4), and low (2.4 or lower). The overall score indicates how often students use metacognitive strategies in the inventory when reading academic materials (12). For this study, internal consistency reliability (Cronbach’s α) for the MARSI was 0.90 for the pre- test and 0.92 for the post- test, compared to 0.93 for the original validation of the survey.

The second component of the survey used ACT reading passages to measure reading comprehension. The ACT is a national college entrance exam that has four sections: English, Reading, Math and Science (http://www.actstudent.org/testprep/descriptions/readdescrupt.html). As a college entrance exam, the reading portion of the exam measures reading comprehension through the use of referring and reasoning skills. The reading passages require students to determine main ideas, interpret significant details, understand sequences of events, make comparisons, comprehend cause-effect relationships, and draw generalizations. The test is divided into prose fiction, social studies, humanities, and natural sciences. For this study, natural science passages from the ACT exam were used. Students read two passages and answered multiple-choice questions about the reading. The pre- and post- surveys were identical with the exception of a different but similarly difficult ACT reading passage.

A third component, Russell and Hollander’s validated BAS, was added to collect information regarding attitudes toward biology (18). This tool uses 22 questions to measure feelings of like or dislike about biology. The instrument is not intended to measure absolute attitudes toward biology but instead it is designed to measure changes in attitude over a course. Eight of the questions use a semantic differential scale and the remaining 14 questions use a Likert scale analysis. The Likert scale of this tool was used for this study. In this portion of the survey, participants read 14 statements regarding positive and negative attitudes toward biology and rated their level of agreement on a five-point Likert scale from 1 = strongly agree to 5 = strongly disagree. For this study, internal consistency reliability (Cronbach’s α) for the BAS was 0.94 for the pre- test and 0.95 for the post- test, compared to 0.90 for the original validation of the survey.

RESULTS

Pre- and post- test means were calculated for all surveys and are summarized in Table 1.

Metacognitive Awareness in Reading Strategies Inventory (MARSI)

The paired t-test was used to compare pre- to post-survey MARSI scores in each of the groups. Post- survey scores were higher than pre- test scores in both the online and face-to-face instruction groups and the t-test revealed the difference was statistically significant (t = -3.554, df = 156, p = 0.001 two-tailed; t = -2.967, df = 156, p = 0.003 two-tailed, respectively) (Fig. 1). Effect size calculations show a small effect (d = 0.26 and d = 0.21, respectively) indicating improvement in metacognitive awareness in reading strategies.

To investigate the relationship of MARSI improvement to the method of instruction, the independent t-test was used to compare pre-MARSI scores of Group 1 and Group
2. There was no difference between the pre- scores of the two groups (t = -0.497, df = 312, p = 0.619 two-tailed, 95% CI [-1.32, 0.785]) or the post-scores (t = -0.145, df = 314, p = 0.885 two-tailed, 95% CI [-0.12, 0.103]) indicating that there is no difference between the initial and final scores of each group.

Reading comprehension

The same statistical tests were used to compare pre- and post- survey scores for reading comprehension. Figure 2 shows the comparison and improvement of pre- and post- survey scores for reading comprehension. The paired t-test was used to compare pre- and post- test reading scores in each of the groups. Post- test scores were significantly higher than pre- test scores in both the online and face-to-face instruction groups and the t-test revealed the difference was statistically significant (t = -3.554, df = 156, p = 0.001 two-tailed; t = -2.967, df = 156, p = 0.003 two-tailed, respectively) (Fig. 2). Effect size calculations show a very large effect (d = 1.52 and d = 1.82, respectively) indicating improvement in reading comprehension.

To investigate the relationship of reading skills to the method of instruction, the independent t-test was used to compare pre-reading scores of Group 1 and Group 2. There was a difference between the pre- scores of the two groups (t = 4.783, df = 310, p = 0.001 two-tailed; t = -2.967, df = 156, p = 0.003 two-tailed, respectively) (Fig. 3). Error bars depict 95% confidence intervals.
Attitudes toward biology

To assess changes in attitudes toward biology the paired t-test was used to compare pre- and post- survey scores. Group 1 (online delivery) showed a significant change in attitudes toward biology ($t = 5.422$, df = 154, $p < 0.001$ two-tailed) with a small effect size ($d = 0.28$) and a more negative perception at the end of the semester (Fig. 4). Data from Group 2 (face-to-face delivery) showed no significant difference in attitudes from the start of the semester to the end ($t = -0.861$, df = 153, $p = 0.390$ two-tailed) (Fig. 4).

Independent t-test analysis of pre- attitude scores of Group 1 to Group 2 revealed a difference in attitudes in pre- test scores with a small effect size ($t = 2.295$, df = 311, $p = 0.022$ two-tailed, $d = 0.25$), but no difference was found in post- test scores ($t = -1.296$, df = 310, $p = 0.196$ two-tailed, $d = 0.28$). Gains showed a significant difference between the two groups with a small effect size ($t = -0.201$, df = 201, $p = 0.046$ two-tailed, $d = 0.23$).

Correlation between variables

The Pearson’s $r$ procedure was used to measure the correlation between the dependent variable, Biology course grade, and the various independent variables (Table 2). A moderate to strong positive correlation exists between HS GPA and overall course grade, $r (309) = 0.652$, $p < 0.001$. A moderate to strong positive correlation also exists between ACT Composite scores and overall course grade, $r (305) = 0.613$, $p < 0.001$. Correlations between ACT math, ACT reading and post-reading comprehension scores were moderate and correlations between metacognitive awareness, attitude, and pre-reading comprehension were weak to non-existent. Table 2 presents correlations for all independent variables.

Multiple regression of predictor variables

Using the predictor variables identified in the Pearson’s $r$ analysis, a multiple regression model was used to measure the influence of these variables on students’ grades in Introductory Biology. The seven variables account for 47% of the variation in Biology course scores. The analysis revealed the multiple $R$ to be 0.688; the seven variables accounted for 0.474 ($R^2$) of the variance in the final course grade. Standardized beta coefficients showed that three variables contributed in a statistically significant way to course grade: ACT math scores ($\beta = 0.247$, $p = 0.007$), HS GPA ($\beta = 0.189$, $p < 0.001$) and reading comprehension post- scores ($\beta = 0.181$, $p < 0.001$). Table 3 presents the model from incoming predictors.

DISCUSSION

The results of this study support the hypothesis that teaching metacognitive and reading skills may improve metacognitive awareness and reading comprehension, and both modes of delivery of these lessons produce positive results among college freshman nonmajors biology students. Metacognitive awareness and reading comprehension improved in both treatment groups (Figs. 1 and 2). The results also suggest that Biology faculty members can effectively teach basic metacognitive and reading skills in a limited amount of time, even though this may not be their area of expertise.

Research regarding metacognitive knowledge is important to higher education, including science education. Too often the study of thinking strategies and conceptual knowledge are disconnected in science education, yet there is a relationship between the two (24). Ford and Yore believe that metacognition, critical thinking, and reflection are essential components of scientific literacy, proposing that reflection and metacognitive processes should be used together in overlapping ways (6). This research suggests that
metacognition and reading skills can be effectively introduced with positive outcomes, either face to face or through online instruction, into an introductory science course. The next hypothesis to investigate is if this integration improves student understanding in subject matter knowledge.

Data on attitudes was also collected and evaluated. It was unexpected that the online and face-to-face groups would show different attitudes. The online group showed a significant change in attitudes toward biology with a more negative perception at the end of the semester, and the face-to-face group maintained its attitudes toward biology. Analysis of overall gains shows the shift in attitude is considered significant. It is surprising that this intervention would have a direct effect on attitudes, and the researchers caution the interpretation of these results and further study of this topic is warranted.

To increase our understanding of the influence that attitude toward biology has on overall course grade, correlational and multiple regression data was used. In this study, there is not a correlation between pre-attitude scores and course grade, and only a weak correlation between post-attitude scores and course grade (Table 2). Another surprising find was that post-attitude scores were not a significant predictor of course success (Table 3). These results contradict other literature regarding attitude and performance in biology classes.

Attitude is important in how students confront educational challenges, though the issue is complex (17). Russell and Hollander and Rogers and Ford measured the attitudes of students toward various introductory biology courses and showed a correlation between attitude and achievement (18, 17). Uno reports an indifferent or negative attitude is one of the reasons that nonmajors struggle in college biology courses (22). Attitude has also been evaluated for web-based delivery of lectures. Cooke et al. examined first year nursing students’ experiences of receiving online lecture material for the first three weeks of class (2). Evaluation of academic performance and attitudes supports the use of web-delivered lectures during the initial weeks of the semester, but indicates this should be a supplement to face-to-face lectures. As educators continue to study factors that influence student motivation and attitudes toward biology, strategies to improve courses will be better understood.

The self-report data collection process and voluntary participation limits the generalizability of these findings to other populations. Although descriptive analysis does not indicate a difference between respondents and non-respondents, unknown differences may exist between these groups. Replication of this study would verify current findings or identify unknown differences not detected through the data collected.

The primary limitation in this study is the lack of a control group without treatment. As mentioned in the introduction, a prior study does indicate that these lessons are effective for improving metacognitive awareness.

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**TABLE 2.**

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<th>Variable</th>
<th>Pearson’s r</th>
<th>p value</th>
<th>N</th>
<th>Strength of Correlation</th>
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<tr>
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<td>0.652</td>
<td>&lt; 0.001</td>
<td>309</td>
<td>moderate – strong</td>
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<tr>
<td>ACT Comp</td>
<td>0.613</td>
<td>&lt; 0.001</td>
<td>305</td>
<td>moderate – strong</td>
</tr>
<tr>
<td>ACT Math</td>
<td>0.569</td>
<td>&lt; 0.001</td>
<td>305</td>
<td>moderate</td>
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<tr>
<td>ACT Read</td>
<td>0.480</td>
<td>&lt; 0.001</td>
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<td>moderate</td>
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<tr>
<td>Reading Comprehension Post</td>
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<td>&lt; 0.001</td>
<td>309</td>
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</tr>
<tr>
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<td>&lt; 0.001</td>
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<td>weak</td>
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<tr>
<td>BAS Post</td>
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<tr>
<td>MARSI Post</td>
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<td>0.934</td>
<td>316</td>
<td>zero</td>
</tr>
</tbody>
</table>

HS GPA = high school grade point average; ACT = American College Testing; BAS = Biology Attitude Scale; MARSI = Metacognitive Awareness in Reading Skills Inventory.

**TABLE 3.**

<table>
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<th>Variable</th>
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<th>p value</th>
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<tr>
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<tr>
<td>HS GPA</td>
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<td>ACT Comp</td>
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</table>

ACT = American College Testing; HS GPA = high school grade point average; BAS = Biology Attitude Scale.
in reading (8). This experiment is based on an inference that the improved metacognitive awareness and reading comprehension is a result of two lectures and worksheets, and not other factors. This inference does not take away from the research finding comparing the delivery mode of the lessons. Further research is necessary to determine the effectiveness of metacognition and reading lessons.

We also used correlational and multiple regression analysis to better understand the relationship of the independent variables with final course grade. High school GPA and ACT scores (composite, math, and reading) are correlated with overall course grade (Table 2). To a much lesser degree, reading comprehension and biology attitudes correlate to biology course grade. Using these variables to predict student grades indicates that ACT math, HS GPA and post-reading comprehension scores are the strongest predictors (Table 3). These results suggest that focusing on improving reading skills in the introductory biology classroom is beneficial. Though metacognitive awareness in reading can help improve reading, perhaps future studies should focus on other active reading strategies and reading for understanding.

In summary, our work reveals that both online and face-to-face delivery of metacognitive skills and active reading strategy lessons in a college nonmajors biology course produce positive outcomes. Students in both groups improved their metacognitive awareness and reading comprehension skills. The results also suggest that Biology faculty members can and should teach basic metacognitive and reading skills in a limited amount of time, even though this is not their content area. Educational researchers and psychologists understand that helping students transform to independent, self-regulated learners is one way to improve student success (15, 3, 21). Specifically, improving metacognitive skills in the science classroom is one way to accomplish this goal by achieving knowledge transfer and deeper learning. Metacognitive and reading lessons taught by biology faculty may lead to more sustainable ways of helping students in introductory science courses connect concepts, improving the entire educational experience. This research can be transferred from the biology classroom to other STEM fields, and science faculty can be more effective and efficient in their teaching.

SUPPLEMENTAL MATERIALS

Appendix 1: Pre-survey
Appendix 2: Post-survey
Appendix 3: Reading worksheet

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