Two Birds, One Instruction Type: The Relation Between Students' Affective Learning Gains and Content Assessment Scores


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*The learning of mathematics is a complex phenomenon that is influenced by both cognitive and affective factors. Little is known about the relationship between students' affective and cognitive outcomes, as much work focuses on one or the other, but not the intersection of the two. Therefore, this study examines the relationship between students' affective learning gains as reported on the SALG survey and their content assessment scores for differential equations courses. The goal was to determine if there was a relationship and then investigate if this relationship held for male and female students, as well as those in inquiry-oriented classes. Mixed linear models were used to examine this relationship, while simultaneously taking into account the nesting of students within instructors. Results showed there are some significant relationships between affective learning gains and content assessment scores, but these relationships are not consistent across sub-groups by gender nor instruction type.*

*Keywords:* Student Affective Learning Gains, Content Assessment, Differential Equations

In order to fully understand the complexity of mathematics learning, cognitive and affective factors must be explored. Cognitive outcomes relate to students' mental actions and the application of those actions. Some researchers define these outcomes in terms of "remembering, understanding, applying, analyzing, evaluating, and creating" (Burn & Mesa, 2015, p. 47). With this stance, researchers look at student performance, achievement, grades, and even in a broader sense, knowledge and skills (Dochy et al., 2003; Freeman et al., 2014; Kuster et al., 2017; Laursen et al., 2014; Lazonder & Harmsen, 2016). Only considering student performance can be misleading, as it does not fully capture students' abilities nor how students are participating in class. For example, research has shown that there is a difference in male and female performance in mathematics, with males having higher performance, however, Fennema and Sherman (1977) contribute this difference to low participation from females, as mathematics is typically stereotyped as a masculine subject. By only considering student performance, researchers would miss the intersection of cognitive and affective outcomes that can help explain the differences between males and females in mathematics.

In contrast to cognitive outcomes, affective outcomes consider students' internal factors. These are typically defined in terms of "beliefs, attitudes, and perceptions" (Burn & Mesa, 2015, p. 97). Although much research has been conducted on students' beliefs and attitudes toward mathematics, researchers are challenged with ways to infer beliefs and attitudes from student behavior (Leder & Forgasz, 2002). Because of the synonymous nature of words such as attitude, perception, value, and belief, it is difficult to define a belief (Leder & Forgasz, 2002), making this investigation even more difficult. Nevertheless, affective outcomes can include such things as confidence, enjoyment, persistence, interest, and even an approach to learning (Laursen et al., 2014; Sonnert & Sadler, 2015). These factors are more difficult to identify and investigate as they are personal and not easily observable. While, research has shown that there is a difference between male and female affective outcomes specific to mathematics (Chouinard & Roy, 2008), there is more work to be done to better understand these outcomes. Instead of obtaining a snapshot of what is happening in classes by focusing exclusively on cognitive outcomes, researchers are able to paint a clearer picture by matching cognitive outcomes with affective outcomes. Therefore, the purpose of this paper is to investigate student's affective learning gains (ALG) in relation to their content assessment (CA) scores.

## Literature Review

As previously mentioned, it is often difficult for researchers to identify beliefs, as there is no one definition that captures their essence. Philipp (2007) states that "affect is comprised of *emotions, attitudes,* and *beliefs*" while beliefs are also "more cognitive than emptions and attitudes" (p. 2.59). Leder and Forgasz (2002) also deduce that beliefs and attitudes are "intrinsically related and that beliefs and attitudes have cognitive, affective, and behavioral components" (p. 96). Due to this overlap in cognitive and affective components concerning beliefs, it is important to note that this can create room for biases, as well as the use of multiple methods and frameworks, and can result in contradictory findings.

Throughout psychological literature, there is a focus on affective issues in relation to mathematics; demonstrating an expansive range of beliefs, which are measured in a variety of ways (Leder & Forgasz, 2002). Even though the methods and definitions vary, many studies show there is a difference in males' and females' motivation when it comes to mathematics (e.g., Chouinard & Roy, 2008). When males and females have similar levels of achievement, females demonstrate lower competence beliefs and more anxiety (Eccles et al., 1985; Kloosterman, 1990; Seegers & Boekaerts, 1996; Stipek & Gralinski, 1991). Males contribute their success to ability and failure to bad luck or lack of help (Hackett & Betz, 1992; Randhawa et al., 1993), which is in stark contrast to females who perceive their success comes from being determined, receiving help from others, or being provided with simple tasks (Stipek & Gralinski, 1991). This highlights the differences in males' and females' affective outcomes in mathematics.

Over time, there is a substantial transformation in student attitudes toward studying mathematics (Eccles et al., 1985; Fredricks & Eccles, 2002; Jacobs et al., 2002; Ma & Cartwright, 2003). Many high school students are more pessimistic when it comes to their ability to succeed in mathematics and they also place a lower value on their feelings toward mathematics (Chouinard & Roy, 2008). In their work, Chouinard and Roy (2008) examined high school students' attitudes towards mathematics. They specifically looked at whether their attitudes change over time, if changes are related to grade level, and if there are gender differences. Overall, results showed there was a regular decline in mathematics motivation throughout high school, especially between 9th and 11th grade, where the gradual drop represented a decrease between and within grade levels. These results confirm a steady decrease in students' attitudes towards the utility of mathematics for male and female students, and additionally indicate a more significant decrease for males than females.

Although Chouinard and Roy (2008) found a greater decrease in males' attitudes toward mathematics than females', other studies indicate a decline in positive attitudes toward mathematics has more of an effect on females than on males (e.g., Eccles et al., 1985; Fennema & Sherman, 1977). Additionally, researchers have found there are differences in confidence and anxiety between females and males, with females having lower levels than males (Leyva, 2017; Lubienski & Ganley, 2017). Not only are there differences between genders in terms of affective outcomes, research has shown that there are also differences in cognitive outcomes, based on the type of instruction provided. For example, Laursen et al. (2014) found that students in inquiry-based learning (IBL) classes had higher cognitive and affective outcomes than students not in IBL classes. Results from their study also showed that that students in IBL classes reported higher cognitive gains than those in non-IBL classes. Based on the self-report, IBL students had a better understanding and could think more deeply about the mathematics than their non-IBL peers. Although this research base has greatly contributed to the body of knowledge on student attitudes, beliefs, cognitive and affective behavior, future research is necessary to expand these findings. Therefore, we accept this charge and explore the relationship between students' cognitive and affective outcomes in inquiry-oriented (IO) classes, a more specific branch of IBL (Kuster et al., 2017). Specifically, we investigate the following questions:

1. What is the relationship between students' ALG and their CA scores?
2. Is this relationship the same for males and females?
3. Is this relationship the same for students in IO and non-IO classes?

## Methods

This quantitative study uses a relational design to investigate the relationship between students' ALG and their corresponding CA scores, using data from related projects designed to support instructors interested in implementing IO instructional materials. The affective data used for this study stems from the Student Assessment of their Learning Gains (SALG) survey, developed by Laursen, Hassi, Kogan, Hunter, & Weston (2011) to help faculty gather insights about their instructional practices. The CA data comes from Hall, Keene, and Fortune's (2016) work on creating a common written assessment to better understand student learning in differential equations (DE) courses. To explore the relationship between students' reported SALG survey scores and their CA scores, we constructed a linear mixed model. Finally, we investigated whether the relationships identified for all students held when the groups were disaggregated by gender and IO instruction.

### Participants

A total of 23 instructors were involved in this study. Of those 23 instructors, 16 were instructors who engaged in professional development focused on using IO materials. These 16 instructors were then asked to identify another instructor who was not participating in the IO project; these non-IO instructors were then recruited to participate in this study. Six out of seven comparison instructors came from the same institution, while the last was from a different university of comparable size located in the same city. The comparison instructors taught DE either in the same semester or within one year that their mapped IO instructor did. The instructors involved in the IO project define our IO sample; the non-IO instructors define our non-IO sample.

Students from these 23 instructors were then recruited to participate, resulting in 448 undergraduate students enrolled in DE courses across the nation. Of those 448 students, 296 (66.1%) of those students were taught by IO instructors, while 152 (33.9%) of those students were taught by non-IO instructors. In addition, from the students who reported gender, 225 (66%) students identified as male and 101 (29.6%) identified as female. Out of those students, 151 (33.7%) were males in IO classes, 68 (15.2%) were females in IO classes, 74 (16.5%) were males not in IO classes, and 33 (7.4%) were females not in IO classes.

### Instrument and Data Collection

Affective data stems from the SALG-M survey developed by Laursen et al. (2011). The SALG-M survey is a modified version of the SALG survey, more specific to mathematics instruction. Laursen et al. (2011) modified the original survey to more effectively measure students' learning gains in mathematics classrooms. The SALG-M survey is broken four sections that measuring students' experiences during the course and two sections that measure their learning gains. The term learning gains encompasses cognitive, affective, and social gains as one holistic measure. Therefore, after conducting a factor analysis, some instrument items did not load to those three factors, and were not included in the latest revision, resulting in the modified SALG survey (Laursen et al., 2011). For the purposes of this study, we will only be looking at the 13 learning gains questions from the modified SALG survey that focus on students' cognitive, affective, and social gains. These items were rated on 6-point Likert scale indicated by 1 no gain, 2 little gain, 3 moderate gain, 4 good gain, 5 great gain, and 6 not applicable. The CA scores derive from a DE common assessment developed by Hall et al. (2016) to help support IO instructors implement IODE curriculum[1]. This common assessment consisted of 15 multiple choice items designed to evaluate students' conceptual understanding of DE. These questions focused on the following concepts: (1) solving first order differential equations analytically, graphically, and numerically (2) linear systems of differential equations, and (3) second order differential equations (Hall et al., 2016). This test was given to both IO and non-IO instructors to use at the end of semester.

**Data Analysis**

To begin, we compared students' mean CA scores by gender and instructional treatment using t-tests. Then, we examined the relationship between students' CA scores and their reported scores on the 13 ALG items from the modified SALG survey. Students' scores on the ALG items were centered, and scores of 6 (not applicable) were removed from analysis. This was done using a mixed linear model, which accounts for the effect of classroom instruction factors, and allows for the prediction of students' CA scores based on their Likert scores on the ALG items. Mixed linear models were also used to assess these relationships by gender and instructional treatment.

## Results

Initial descriptive statistics indicate DE students' mean CA score to be 53.59 (SD=16.66). The mean CA score for males is 52.67 (SD=16.83) and the mean for females is 53.51 (SD=15.56). Despite the mean for females being slightly greater than that of males, there is no significant difference in the CA scores of males and females ($t(324)=-.43$, $p=.67$). In a comparison of IO (M=54.94, SD=17.11) and non-IO (M=50.97, SD=15.48) students, IO students were found to score significantly better than their non-IO peers ($t(446)=2.40$, $p=.02$).

Results of mixed linear models indicate that ability items 1, 2, 3, 6, 7, 8, 9, and 13 are significantly related to students' CA scores (Table 1). For example, ability item 1 asks students if they feel confident that they can do math. Students who strongly disagree with this statement (Likert score 1) are predicted to have a CA score of 47.07 ($t(74.61)=17.24$, $p<.001$). Also, for each one point increase in their Likert score on ability item 1, students are predicted to have a 2.51 point increase in CA score ($t(322.81)=3.18$, $p=0.002$). Accordingly, students who strongly agree that they feel confident that they can do math, are predicted to have a CA score of 57.11. Similar interpretations hold for ability items 2, 3, 6, 7, 8, 9, and 13. Ability items 4, 5, 10, 11, and 12, however, were not found to be significantly related to CA scores, as indicated by the results of the mixed linear models (Table 2). Therefore, increasing Likert scores on these items are not related to changes in CA scores.

[1] The CA asked students to report their gender identity as male, female, other, or prefer not to answer; accordingly, we use the language of male and female throughout this study to match their reported gender identity.

*Table 1*. Significant Results of Mixed Linear Models, by Ability Items

| | *t* | Slope | Predicted Score if Student Reports 1 (Intercept) | 5 |
|---|---|---|---|---|
| Ability 1: I feel confident I can do math | 3.18(322.81)** | 2.51 | 47.07 | 57.11 |
| Ability 2: Comfort working with complex ideas | 2.70(318.34)** | 2.30 | 47.85 | 57.05 |
| Ability 3: Development of a positive attitude about learning math | 2.86(314.17)** | 2.06 | 48.37 | 56.16 |
| Ability 6: Appreciation of mathematical thinking | 2.88(319.88)** | 2.35 | 47.50 | 58.90 |
| Ability 7: Comfort in communicating about math | 3.42(311.50)** | 2.75 | 46.54 | 57.54 |
| Ability 8: Confident you will remember what you learned in class | 2.94(305.66)** | 2.34 | 48.29 | 57.65 |
| Ability 9: Persistence in solving problems | 2.94(323.51)** | 2.40 | 47.18 | 56.78 |
| Ability 13: Ability to stretch your own math capacity | 2.06(317.58)* | 1.77 | 48.86 | 55.94 |

*Note:* Slopes indicate the predicted increase in CA score per one point increase in Likert score on the corresponding ability item.
*p<.05, **p<.01

*Table 2*. Non-significant Results of Mixed Models, by Ability Items

| | *t* | Slope | Predicted Score if Student Reports 1 (Intercept) | 5 |
|---|---|---|---|---|
| Ability 4: Ability to work on your own | 1.94(324.00) | 0 | 49.63 | 49.63 |
| Ability 5: Ability to organize your work and time | 1.59(320.40) | 0 | 50.97 | 50.97 |
| Ability 10: Willingness to seek help from others | .02(317.41) | 0 | 53.96 | 53.96 |
| Ability 11: Ability to work well with others | -.10(321.55) | 0 | 54.34 | 54.34 |
| Ability 12: Appreciation of different perspectives | .38(317.19) | 0 | 53.11 | 53.11 |

*Note*: As the relationships in this table between ability items and CA scores are not significant, students are predicted to have the same CA score regardless of changes in their Likert ability scores.

When separated by gender, increases in female students' Likert scores on all of the ability items with significant relationships for both genders continued to predict increases in CA score (Table 3). However, for males, the only significant differences in CA score based on ability items were for items 6 and 7. Thus, female students who strongly disagree with ability item 1 are predicted to have a CA score of 40.08, but for every one point increase in their Likert response to ability item 1, female students are predicted to have a 5.08 point increase in their CA score. This is not true for males, for whom a strong disagreement on ability item 1 corresponds to the prediction of a CA score of 49.67, but increasing Likert scores on ability item 1 are not predicted for male students. Thus, for males, increasing levels of confidence (ability 1), comfort with complex ideas (ability 2), positive attitudes toward math (ability 3), confidence in remembering ideas from class (ability 8), persistence (ability 9), and stretching one's mathematical activity (ability 13) are not related to higher CA scores; for females, these increases are related to higher CA scores.

*Table 3*. Results of Mixed Linear Models, by Ability Items and Gender

| | Male *t*(df) | Male Intercept | Male Slope | Female *t*(df) | Female Intercept | Female Slope |
|---|---|---|---|---|---|---|
| Ability 1 | 1.60(219.91) | 49.67 | 0 | 4.22(98.50)*** | 40.08 | 5.08 |
| Ability 2 | 1.48(217.32) | 49.84 | 0 | 3.47(98.42)** | 41.67 | 4.59 |
| Ability 3 | 1.46(214.22) | 50.36 | 0 | 3.91(96.94)*** | 42.22 | 4.31 |
| Ability 6 | 2.05(217.41)* | 48.50 | 2.07 | 2.56(98.88)* | 44.66 | 3.31 |
| Ability 7 | 2.63(214.10)** | 47.31 | 2.55 | 3.38(93.33)** | 41.01 | 4.73 |
| Ability 8 | 1.60(213.47) | 50.40 | 0 | 4.36(95.21)*** | 39.43 | 5.98 |
| Ability 9 | 1.97(218.04) | 48.38 | 0 | 3.09(96.87)** | 41.88 | 4.24 |

| Ability 13 | .90(216.80) | 51.38 | 0 | 3.66(95.56)*** | 40.25 | 4.73 |
|---|---|---|---|---|---|---|

*p<.05, **p<.01, ***p<.001

*Note:* Intercepts indicate the predicted CA scores for students who report a 1 (strongly disagree) on the corresponding ability item. Slopes indicate the increase in CA score per one point increase in Likert score on the corresponding ability item.

Another result is that for males, all of the predicted intercepts are higher than those for females (e.g., ability item 1, 49.67 > 40.08). However, as the scores for males students are not predicted to increase significantly based on increasing Likert scores for ability item 1, it is predicted that male students with a Likert score of 5 on ability item 1 will also be 49.67. In contrast, the CA scores for female students are predicted to increase by 5.08 points per one point increase in their Likert score on ability item 1, giving female students who strongly agree with ability item 1 a predicted CA score of 60.4. Thus, when comparing the predicted CA scores of students who strongly disagreed with ability item 1, males outscores females; however, when comparing the predicted CA scores of students who strongly agree with ability item 1, females outscores males by more than 10 points. Similar trends are predicted on all of the ability items in Table 3 (1, 2, 3, 6, 7, 8, 9, and 13).

Disaggregating the data by instructional method results in similar trends (Table 4). Students in IO classes are predicted to have increased CA scores based on increasing Likert scores on all of the ability items with significant relationships for both types of instruction. Students in non-IO classes are only predicted to have increased CA scores related to increasing Likert scores for ability item 7. For example, students in IO classes who strongly disagree with ability item 1 are predicted to earn a CA score of 47.66, but for each point increase in their Likert score, they are predicted to have an increase in their CA score of 3.15 points. Students in non-IO classes are predicted to have a lower CA score regardless of their Likert score on ability item 1. Similar interpretations hold for ability items 3, 6, 7, 8, 9, and 13. Non-IO students who strongly disagree with ability item 2 are predicted to score higher than IO students who strongly disagree, but with a one point Likert increase, IO students are predicted to outscore non-IO students. Even on ability item 7, for which the relationship between Likert score and CA score was significant for non-IO students, non-IO students are predicted to have lower CA scores regardless of their Likert score, in comparison to their IO peers.

*Table 4*. Results of Mixed Linear Models, by Ability Items and Instructional Treatment

| | IO | | | Non-IO | | |
|---|---|---|---|---|---|---|
| | t(df) | Intercept | Slope | t(df) | Intercept | Slope |
| Ability 1 | 3.23(190.49)** | 47.66 | 3.15 | 1.41(103.31) | 44.01 | 0 |
| Ability 2 | 3.29(167.65)** | 47.20 | 3.38 | .40(104.50) | 48.18 | 0 |
| Ability 3 | 3.05(158.78)** | 48.61 | 2.76 | 1.13(104.67) | 46.10 | 0 |
| Ability 6 | 3.25(158.20)** | 47.23 | 3.21 | .85(102.61) | 46.47 | 0 |
| Ability 7 | 3.11(143.80)** | 47.73 | 3.02 | 2.23(103.03)* | 41.85 | 2.84 |
| Ability 8 | 3.26(111.23)** | 48.07 | 3.20 | .94(103.10) | 47.05 | 0 |
| Ability 9 | 2.83(201.15)** | 47.70 | 2.90 | 1.23(103.78) | 45.29 | 0 |
| Ability 13 | 2.47(178.69)* | 48.77 | 2.54 | .34(103.88) | 48.18 | 0 |

*p<.05, **p<.01, ***p<.001

## Discussion and Conclusions

When all students' CA scores and ability items were considered together, regardless of gender or instructional treatment, ability items 4, 5, 10, 11, and 12 were not significantly related to students' CA scores. Interestingly, these items are not related specifically to mathematical learning, but rather, to other metacognitive skills such as studying, time management, and group work. The other ability items each had a specific connection to mathematics, ideas learned in class or complex ideas, and problem solving, which are more directly tied to mathematics. Thus, while improving metacognitive skills is important, the improvement of such skills was not related to students' CA scores while increases in affective items directly related to mathematics, mathematical ideas, and problem solving were positively related to students' CA scores.

Considering gender, females and males did not score significantly differently on the CA. However, when the data was disaggregated to show differences in the relationships between students' affective items and their CA scores, it was demonstrated that affective increases for female students are predictive of higher CA scores, whereas they generally are not for male students. Thus, the inclusion of instructional practices that support affective gains such as those identified by the ability items support females in increasing their math achievement, as gauged by the CA. This supports previous research indicating that females tend to report lower affective levels, but have similar achievement to males (Eccles et al., 1985; Kloosterman, 1990; Seegers & Boekaerts, 1996; Stipek & Gralinski, 1991), and adds to previous literature by indicating that fostering female students' affective gains may foster higher achievement. Interestingly, while previous literature indicates that males tend to claim success comes from ability and confidence (Hackett & Betz, 1992; Randhawa et al., 1993) and that females believe their success comes from being determined and working with others (Stipek & Galinski, 1991), the results of this study show reported increases in confidence and determination are related to higher achievement more so for females, and increasing the ability to work well with others was not related to higher achievement for students.

Also, females have been previously shown to be more concerned with abilities, confidence, comfort, and persistence (Eccles et al., 1985; Fredricks & Eccles, 2002; Jacobs et al., 2002; Ma & Cartwright, 2003). The results of this study compliment these existing findings; perhaps female students' concern with these affective outcomes stems from their understanding that they tend to perform better academically when their confidence and persistence are supported.

Finally, we found that students in IO classes had statistically significantly higher CA scores than those in non-IO classes. Moreover, increases in IO students' ability item scores (1, 2, 3, 6, 7, 8, 9, and 13) were related to increases in their CA scores; for non-IO students, this was only true for ability item 7. Thus, as with females, increases in affective outcomes are related to increases in CA scores for IO students. This suggests that in an IO classroom, fostering students' affective growth is linked to higher achievement. This supports Laursen et al.'s (2014) findings, which suggest that IBL, or in this case IO, is beneficial for increasing students' affective and cognitive gains.

Taken together, these findings suggest that in IO classrooms, increases in affective and cognitive levels are related, whereas in non-IO classrooms, they generally are not. The implication is that IO instruction simultaneously addresses both the affective and cognitive needs of students, thereby metaphorically killing two birds (affective and cognitive issues) with one instructional stone. Conversely, in non-IO classrooms, cognitive and affective gains were disconnected. This study did not seek to make claims of causality, but rather, to offer one insight into the relationships between the increases, both cognitive and affective, that students make in mathematics classrooms. More research should address students' affective outcomes in relation to cognitive outcomes, particularly studying if a predictive relationship exists; this will provide a more holistic view of the field of student learning in mathematics.

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