STRUCTURAL EQUATION MODELING: AN INVESTIGATION OF SELF-REGULATED LEARNING

A RESEARCH PROJECT

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ABSTRACT

CREATIVE PROJECT: Structural Equation Modeling: An Investigation of Self-Regulated Learning

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The fields of science, technology, engineering, and math (STEM) experience elevated levels of attrition. The broad research agenda of this work aims to investigate these levels of attrition through the lens of self-regulated learning (SRL). Zimmerman's (2000) SRL model was incorporated, consisting of three, interdependent phases: the forethought phase, performance phase, and self-reflection phase. The three phases were structured around a single task, a biology exam. Before the role of SRL model on academic performance could be assessed, a preliminary study was conducted. This preliminary study included two mediational models, a full and partial. The mediation models aimed to establish the functioning of the SRL model within a domain-specific sample. Results indicate that a fully mediated model did fit better, aligning with the literature. However, the model fit and differences between the two models was not significant enough to establish definitive results.

Structural Equation Modeling: An Investigation of Self-Regulated Learning

Several fields, such as science, technology, engineering, and math (STEM) experience elevated levels of attrition (Sass, 2015). Students can begin preparation for a career in STEM as early as high school. Once students begin their undergraduate careers, many decide to leave the STEM field (van den Hurk, Meelissen, & van Langen, 2019). Attrition within STEM majors often surfaces as students drop out, fail, or withdrawal (DFW) from courses. This study considered attrition through the lens of self-regulated learning (SRL). Self-regulated learning (SRL) refers to a cyclical process aimed to enhance learning and achievement (Callan & Cleary, 2018; Bandura, 1977).

Before research into attrition rates can be conducted, the foundational structure of the model must be considered. More specifically, this study will examine the structural modeling of the SRL framework. One proposed strength of Zimmerman's SRL model is the consistent functionality across domains (Bandura, 1986, Zimmerman, 2000). While the model has been employed in studies with specific populations (Rubenstein, Callan, & Ridgely, 2017), the model's function has not been examined within a sample of students studying biology. In other words, few SRL studies have tested the structural nature of the model prior to running analyses of focus. Without considering the model's preliminary structure, it is unclear if the model is functioning adequately.

Theoretical Framework

Zimmerman's SRL model considers the environmental and contextual factors that contribute to learning (Bandura, 1977; Zimmerman, 2000). For example, the model emphasizes the motivational, metacognitive, and behavioral components that students can regulate to enhance learning. This particular model follows a social cognitive perspective, focusing on the

context-specific components of the model, such as how students approach a task, how students engage with a task, and how students reflect upon the task. Being that this study is embedded within a biological context, the task for this study consists of a biology exam. The various processes of interest are captured includes three interdependent phases: forethought, performance, and self-reflection. Each phase enhances performance on the consecutive phase. For example, the forethought phase predicts performance on the performance phase, while the performance phase predicts the outcomes in the self-reflection phase. Due to the cyclical nature of the model, the self-reflection phase is also expected to contribute to a future, forethought phase.

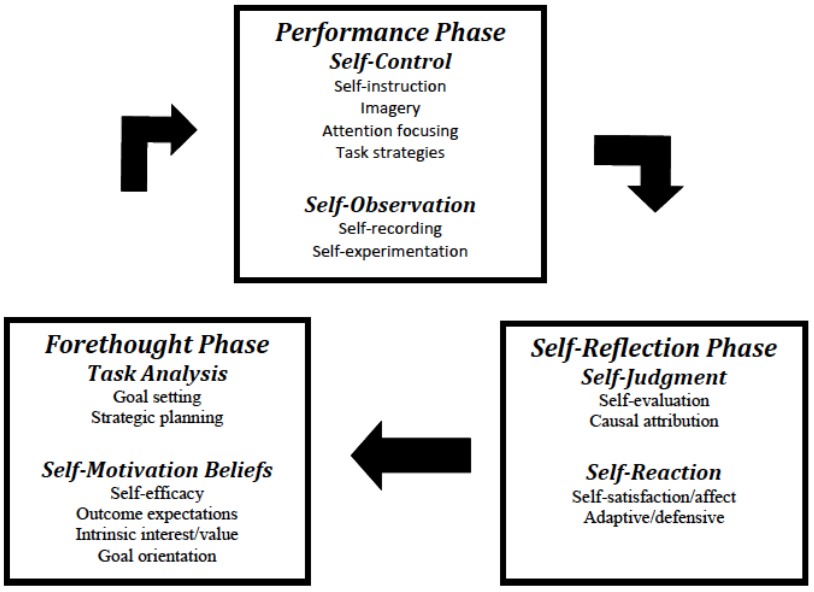
The forethought phase, occurring before the task, focuses on an individual's actions and thoughts leading up to a task. Within the phase, these thoughts and actions are bifurcated into two main categories: task analysis and self-motivational belief. Within the task analysis category, goal setting occurs when an individual decides upon an outcome. Additionally, planning occurs when an individual determines their plan to approach the task. Within the self-motivational belief category, motivational beliefs refer to self-efficacy and intrinsic motivation. Without motivation, it is not likely that an individual will plan and monitor their progress accordingly.

The performance phase, occurring during the task, focuses on an individual's engagement during a task. Moreover, engagement is divided into two main categories: self-control, and self-observation. Self-control refers to general strategies, such as strategizing behaviors and emotions. Similarly, self-observation refers to an individual's ability to monitor their strategic approach to the task. Monitoring during a task allows individuals to adjust their strategies, when necessary.

The self-reflection phase, occurring after the task, guides individuals to reflect upon their forethought and performance phases. Self-reflection is carried out in two ways: self-judgement and self-reaction. Self-judgement refers to self-evaluation, how well the individual performed on the task. Complimentary, self-reaction helps individuals to attribute their success or failure back to their strategies and performance. Zimmerman's (2000) proposes that self-reflection can enhance future learning. This occurs when individuals take feedback from the task and apply it to a similar task, enhancing their strategies from the first attempt. This cyclical nature has been established with academic, specifically within academic achievement literature (Zimmerman & Schunk, 2011). (See Figure 1).

Figure 1

Zimmerman's (2000) Self-Regulated Learning Model



Broadly, the purpose of this study is to confirm the cyclical nature of the model, within a domain-specific sample. A full mediation places more emphasis on the mediating variable, the performance phase, to affect the dependent variable, self-reflection. Conversely, a partial

mediation places the emphasis on the independent variable, the forethought phase, affecting the outcome, self-reflection predominately more than the mediating variable.

The purpose of this study is to understand the structural functioning of Zimmerman's SRL model within the biology sample.

RQ1: A fully mediated model will align more closely with the model's structure, compared to partial mediated model.

Once a full mediation model is established, with the performance phase significantly affecting the self-reflection, the model's integrity was be confirmed. Once the structural functioning has been established, future research will be able to efficiently assess STEM attribution within this sample.

Methods

Participants

Participants were 151 undergraduate students (female, n = 102 (67.5%); *age,* M = 20.47, SD = 2.39; Caucasian, n = 128 (82.1%) enrolled in an introductory Biology course at a midsized, Midwestern university. The majority of students were in their second and third year of study (freshman, n = 5; sophomore, n = 53; junior, n = 70; senior, n = 23).

Materials and Measures

Scales. Measures were embedded within the three processes of self-regulation (see Table 1). The forethought phases included Need for Cognition (NFC) to capture self-motivation (Cacioppo & Petty, 1984). The performance phase included several subscales from the Motivated Strategies for Learning (MSLQ) questionnaire, including elaboration, critical thinking, metacognition, rehearsal, expectancy, value, and organization (Duncan, Pintrich, Smith, & McKeachie, 2015). These measures aimed to capture students' self-control and self-

observation. Finally, the self-reflection phase included an attributional component, the Revised Causal Attribution Scale (RCAS; McAuley, Duncan, & Russell, 1992). The measure aimed to capture self-judgment and self-reaction.

Need for Cognition: Need for Cognition measure (NFC).

The forethought phase was assessed using Cacioppo and Petty's (1984) Need for Cognition scale. NFC is an 18-item instrument measuring enjoyment of cognitively effortful tasks (Cacioppo & Petty, 1984). The NFC uses items such as "I would prefer complex to simple problems", which are measured by a 7-point Likert scale ranging from 1 (*Strongly Disagree*) to 7 (*Strongly Agree*). Specifically, higher scores on the NFC indicate more enjoyment when completing a challenging task (Cacioppo & Petty, 1984). Psychometric testing of the measure has established sound internal consistencies within college populations ($\alpha = .90$; Cacioppo & Petty, 1984).

Motivated Strategies for Learning Questionnaire (MSLQ).

The performance phase was investigated by the Motivated Strategies for Learning Questionnaire (MSLQ). The MSLQ is a self-report measure that evaluates learning strategies and motivation within college populations (Duncan, Pintrich, Smith, & McKeachie, 2015). This measure focuses on both student motivation and learning. Items of this section include "I usually study in a place where I can concentrate on my course work" and "I make good use of my study time for this course." This section also consists of 19 items assessing student management of various academic resources (Duncan, Pintrich, Smith, & McKeachie, 2015). This measure also consists of various factors ($\alpha = .52\text{-}.80$; Duncan, Pintrich, Smith, & McKeachie, 2015). The MSLQ utilizes a 7-point Likert scale ranging from 1 (*Not True of Me*) to 7 (*Very True of Me*).

Revised Causal Scale (RCAS).

The self-reflection phase was assessed using the Revised Causal Dimension Scale (RCDS ; McAuley, Duncan, & Russell, 1992). The RCDS consists of 12 items, factoring into four subscales: locus of causality, stability, personal control, and external control (α = .59-.77). This study conducted a confirmatory factor analysis to ensure the factor structure of this measure. The measure included a prompt proposing students to reflect upon their performance on their most recent exam. The prompt was then responded to using items such as "That reflect an aspect of yourself" to "That reflects an aspect of the situation." Overall, higher scores indicated increased external control and more variable beliefs.

Procedures

Data collection occurred during an introductory cell biology course, prior to students' third exam. During a class period, researchers used a standardized protocol to outline the study, which included consent and Family Education Rights and Privacy Act forms (FERPA). After consent was given, the questionnaires were administered via Qualtrics. Students completed the survey electronically. The duration of the study extended to the end of the class period, which was roughly an hour long. At the end of the period, all students were compensated $5.00 and given participation credit for the day.

Results

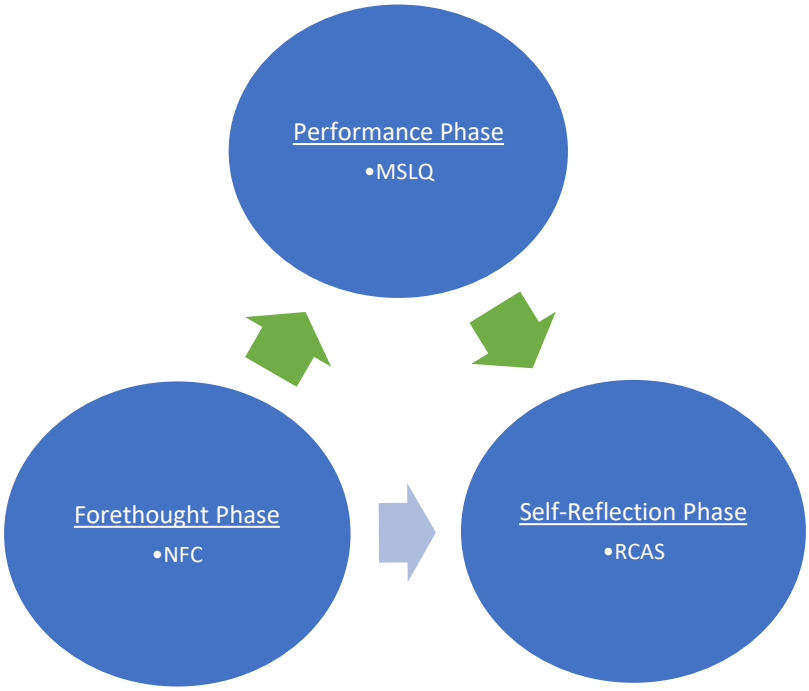
Analysis

This study considers several latent variables, captured by the various measures. The mediation, model structure includes the forethought phase, the independent variable, and self-reflection, the dependent variable. The performance phase is the mediating variable of interest.

Two mediation models were conducted using the library lavaan, a latent variable analysis, in R statistical software. While many estimators exist, this study used a maximum likelihood estimator (MLE). Specifically, the MLE with Satorra-Bentler test statistics and robust standard errors. Due to the complete dataset, this approach was possible. A partially mediated model, model focuses on the relationship between the forethought phase and the self-reflection phase. Conversely, the full mediation model focused on the effect of the performance phase on the self-reflection phase. (See Figure 2).

Figure 2

Mediation Model Structure



Note: The forethought phase is the independent variable, the performance phase is the mediating variable, and the self-reflection phase is the dependent variable. The green arrows indicated the path of a fully mediated model, while the blue arrow indicates the path of a partially mediated model.

Findings

RQ: A fully mediated model will align more closely with the model's structure, compared to partial mediated model.

Three model were employed during this study. (See Table 2). To organize the data into the appropriate format, a preliminary model was constructed. Model construction included the formatting of the forethought phase, performance phase, and self-reflection phase. Within the forethought phase, the Need for Cognition was incorporated. During the performance phase, the various subscales of the Motivated Strategies for Learning were used, while the RCAS was utilized from the self-reflection phase.

The second model proposed a partially mediated analysis. Overall, the model fit was not ideal. For example, the Comparative Fit Index (CFI) is lower than anticipated. This also is the case with the Tucker Lewis Index (TLI). Similarly, the Standardized Root Mean Square Residual (SRMR) did not indicate goodness of fit. However, the Root Mean Square Error of Approximation (RMSEA) did offer a good fit. The results from this model did not indicate significant findings between the forethought phase and the self-reflection phase. Additionally, the model does not yield significant findings between the performance phase and the self-reflection phase.

The third model analyzed a full mediation model. Similar to second model, the model fit was not ideal. For example, the CFI is lower than anticipated. This also is the case with the TLI, along with the SRMR. Conversely, RMSEA did offer a reasonable fit. The results from this model also do not indicate significant findings between the forethought phase and the self-reflection phase. Additionally, the model did not yield significant findings between the performance phase and the self-reflection phase.

Table 2

Mediation Results

Model	CFI	TLI	RMESA	SRMR
Partially Mediated	0.530	0.515	0.079 (p=0.00)	0.094
Fully Mediated	0.530	0.515	0.079 (p=0.00)	0.095

A likelihood ratio test was conducted to compare the model fit between model two and model three. Aligning with the findings above, both models were relatively similar in fit. With the poor fitness outlined by the individual fit statistics, the model comparison does not offer much weight. Between the partially and fully mediated models, the fully mediated model did fit slightly better than the partially mediated model. These findings indicate that the mediating variable, performance, affected the self-reflection phase more than the forethought phase. These findings do align with existing literature.

Discussion

STEM attrition is visible within undergraduate programs. Student struggles often result in dropping out, failing, or withdrawing from STEM based courses. This problem was considered through Zimmerman's (2000) SRL framework. By utilizing an undergraduate biology course, this study captured how students approached their third exam, how the strategies faired or changed during the exam, and how students attributed their performance. Before attrition levels could be considered, a preliminary study was conducted. This article focused on the cyclical nature of the SRL. It was hypothesized that a fully mediated model would align more closely with SRL literature, compared to a partially mediated model. While the fully mediated model was a better fit, the fit statistics discredited any significant difference between the fully mediated model and the partially mediated model.

These findings could have been influenced by the number of measures used. The two mediation models utilized only one measure per phase. Perhaps building a more robust mediated model, including additional measures, would yield a more accurate mediation model. Due to the exploratory nature of this study, simple mediation models were employed. The sample size could also be a limitation. While the sample was large enough to conduct a structural equation model, the sample was relatively small. This is area of interest for future research. Future research could consider the differences between simple SEM models against more robust models. Sample sizes could also be enhanced with future research. Overall, this article did highlight the importance of structural modeling.

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Table 1

Material and respective descriptive statistics

Variable	M (SD)	Alpha	Sample Item	Correlation with Exam 3
Forethought Phase				
Need for Cognition Questionnaire (Cacioppo, Petty, & Kao, 1984)	3.329 (.599)	0.782	"I would prefer complex to simple problems."	.197*
New Self Efficacy Questionnaire (Chen, Gully, & Eden, 2001)	3.953 (.654)	0.89	"I will be able to achieve most of the goals that I have set for myself."	.354**
Performance Phase				
MSLQ* Elaboration	5.330 (.998)	0.756	"When I study for this class, I pull together information from different sources, such as lectures, readings, and discussions."	.128
MSLQ Rehearsal	5.288 (.985)	0.618	When I study for this class, I practice saying the material to myself over and over.	.075
MSLQ Organization	5.081 (1.085)	0.655	"When I study the readings of this course, I outline the material to help me organize my thoughts."	.149
MSLQ Critical Thinking	4.155 (1.147)	0.792	"I often find myself questioning things I hear or read in this course to decide if I find them convincing."	.172*
MSLQ Metacognitive Self-Regulation	4.801 (.697)	0.665	"When reading for this course, I make up questions to help focus my reading."	.032
MSLQ Value	4.964 (1.133)	0.779	"In a class like this, I prefer course material that really challenges me to so I can learn new things."	.235**

MSLQ Expectancy	4.033 (1.606)	0.853	"If I study in appropriate ways, then I will be able to learn the materials in this course."	.245**
Self-Reflection Phase				
RCAS** Locus of Causality	6.766 (1.396)	0.738	"That reflects an aspect of yourself; Reflects an aspect of the situation"	.112
RCAS Stability	5.748 (1.620)	0.596	"Permanent; Temporary"	.054
RCAS Personal Control	6.991 (1.359)	0.751	"Manageable by you; Not manageable by you"	.087
RCAS External Control	5.993 (1.630)	0.765	"Over which others have control; Over which other have no control"	.172*

* Motivated Strategies for Learning (MSLQ; Pintrich, Smith, García, & McKeachie, 1993)

** Revised Causal Attribution Scale (RCAS; McAuley, Duncan, & Russell, 1992)