University of Nevada, Reno

Effectiveness of Mandatory Online Supplemental Instruction in an Introductory Cell and Molecular Biology Course

A dissertation submitted in partial fulfillment of
the requirements for the degree of Doctor of
Philosophy in Education

by

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December, 2022

THE GRADUATE SCHOOL

We recommend that the dissertation
prepared under our supervision by

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entitled

Effectiveness of Mandatory Online Supplemental Instruction in an Introductory Cell and Molecular Biology Course

be accepted in partial fulfillment of the
requirements for the degree of

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Abstract

EFFECTIVENESS OF MANDATORY ONLINE SUPPLEMENTAL INSTRUCTION IN AN INTRODUCTORY CELL AND MOLECULAR BIOLGY COURSE

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The purpose of this study is to assess the effectiveness of a mandatory online supplemental instruction program in an introductory cell and molecular biology course at a community college in Northern Nevada. To accomplish this, the study focused on the dependent variable of course GPA, and the issuance rate of “D” or “F” letter grades and withdraws for students who enrolled in sections which used mandatory online supplemental Instruction.

The theoretical framework of Vincent Tinto’s departure theory and Steve Astin’s student involvement theory guided this quantitative study. To accommodate this study, sections of introductory cell and molecular biology were re-designed to fit mandatory supplemental instruction into the weekly schedule. Student course GPA differences were assessed using the non-parametric Mann-Whitney *U* test. Student demographics and environmental demographics, including mandatory supplemental instruction attendance, were assessed using a multiple linear regression model. A chi-square test of independence was used to identify any relationship between students who earned a D, F, or withdrew from the course, and their participation in mandatory supplemental instruction.

Results indicate that students who enrolled in sections of introductory cell and molecular biology which incorporated mandatory supplemental instruction had significantly higher course GPA scores as compared to their counterparts. It was further identified that the number of sessions attended is directly proportional to a student's GPA. These findings were strongest in traditionally disadvantaged populations suggesting that mandatory supplemental instruction is an effective way to bring equitable education to our systems of higher education.

Acknowledgments

This endeavor would not have been possible without the support of Dr. David T. Crowther (advisor), Laura Briggs (co-advisor), Dr. Leping Liu, Dr. William Toledo, Dr. Elizabeth Xeng de los Santos, and Dr. Elena Pravosudova.

I am indebted to my advisor Dr. Crowther for his faith in me and his commitment to see me through this adventure. He has ushered me through the process of learning how to be an effective STEM education researcher. Further, my time with him has made me a better teacher.

I thank Dr. Briggs for her guidance and support of the MOSI program. Dr. Briggs oriented me towards studying a mandatory model of academic support and helped me design and run the project. I would not have been able to navigate the complexities of implementing this program on campus without the unwavering support of Dr. Briggs.

I am forever grateful to my advisory committee members for their service and individualized help throughout the past years. Dr. Liu for her expertise and guidance on quantitative research. Dr. Toledo for his pedagogical insight and thoughtfulness, both of which have rubbed off on me. Dr. de los Santos for her qualitative expertise and feedback which added further depth and relevance to this work. And Dr. Pravosudova, who's 15-years of work with biology students provided the basis for this study.

And to my favorite non-academics who have supported this academic pursuit – Karen, Georgiabelle, and Linus – thank you for everything. Especially your patience.

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Chapter I: Introduction

Need for the Study

Science, technology, engineering, and mathematics (STEM) education is a pipeline which fills the needs of industries required to maintain the health and safety of society. Medical, biomedical, pharmaceutical and many other industries rely on the skills of scientists, mathematicians, and engineers (Hinton et al. 2020). This is a point discussed often among STEM educators; however, it is also discussed at the highest levels of our government. In 2013, President Obama stated:

> "One of the things that I've been focused on as President is how we create an all-hands-on-deck approach to science, technology, engineering, and math… We need to make this a priority…to make sure that all of us as a country are lifting up these subjects for the respect that they deserve." (Obama, 2013)

Despite this, the latest numbers out of The Program for International Student Assessment (PISA), show the U.S. ranks 25th among all nations in science and math education (Schleicher, 2019). From life expectancy to income levels, educational attainment is directly correlated to the standard of living within a nation (Luy et al., 2019; Kampelmann et al., 2018). There is a need to improve STEM education in the U.S. for the sake of the nation.

When diving into undergraduate STEM education statistics, data which reflects what is colloquially referred to as "the leaky pipeline" presents itself (Hinton et al., 2020; Hernandez, 2013). This is a reference to the observation that while 23% of U.S. undergraduates begin their college career in a field related to STEM, only 16% of U.S.

college graduates go on to work in a STEM related field (Duncan, 2009; Augustine 2007). Therefore, while students enter STEM related fields in college, many discontinue on their path. This retention problem in STEM is particularly salient among women and ethnically minoritized students who are less likely to complete their STEM related undergraduate and/ or graduate degrees than their male and white counterparts (Hernandez, 2013).. For the purposes of this study, minoritized students are defined as those who self-identified as either American Indian, Asian, Black, Hispanic, or as two-or-more races because these populations are relatively underrepresented in comparison to their white identifying counterparts at the research location. Thus, STEM has both a diversity and retention problem at the national level.

Previous research has shown that this retention and diversity problem in STEM is due in part to the relatively high rate of withdrawal from and a relatively high rate of "D" and "F" grades in STEM courses. This is referred to as the DWF rate. Often, we see this pattern in introductory courses; those referred to as "weed-out" or "gate keeper" courses. Poor grades in these courses have a relatively greater deleterious impact on minoritized students, women, and first-generation students while white males persist at a higher rate through these difficult early courses (Thompson, 2021). Moreover, grades can differ broadly among minoritized demographic groups therefore exacerbating issues related to persistence within these groups (Freeman et al., 2014; Ma & Liu, 2017).

Many educators, institutions, and organizations have worked to stem the tide of the leaky STEM pipeline. It has been shown that providing additional academic resources which focus on mentorship and encourage peer interaction in courses with high DWF rates improves student achievement and retention (Hernandez, 2013; Tinto, 1998). One such academic resource is supplemental instruction (SI). SI was developed in 1973 at the University of Kansas Missouri-City (UKMC) in response to low academic performance among students. At UKMC, as the student demographic rapidly changed, and the student body grew, Deanna Martin was tasked with bridging the gap between faculty expectations of student academic performance and the actual academic capabilities of the student body. Out of this task the student-centered support service of SI was developed (Martin & Arendale, 1992).

SI is a peer-led form of tutoring intent on helping students understand the difficult topics associated with a course. It requires regular participation by students, the SI leader, and most importantly, the professor of record for the course. The fundamental characteristics of SI differentiate SI from traditional tutoring in several ways:

1) SI is proactive. It is not reactionary. Whereas students may attend traditional tutoring when their grades slip, or they need specific help with a specific assignment or concept, SI is there throughout to support the students with specific lesson plans.
2) A given SI leader is linked to the course section that a student is in. This allows the professor and SI leader to work together to coordinate weekly SI lesson plans and ensures that students are benefitting from the SI sessions.
3) SI is run by a peer. Typically, this is an undergraduate student who has successfully completed the course in the past but could be a grad student. The purpose of this is to create a genuine “safe space” where students feel more comfortable asking questions they may not otherwise ask of the professor in-class.

4) SI is fundamentally a group learning experience. This allows for discussion among peers and generates a learning community among the students outside of regular class time.
5) SI targets courses with a DWF rate of 35% or higher.

SI has been shown in many studies to improve student retention and achievement (Blanc et al., 1983; Congos, 2002; Ning & Downing, 2010; Skoglund et al., 2018; Martin & Arendale, 1992; Malm, 2012; Stanich et al., 2018). At a prominent community college in Northwestern NV (CCNV), the Introductory Cell and Molecular Biology lecture course (ICMB) has a 35% DWF rate and reflects a "leak" in the STEM pipeline. Further, there is already a SI program at CCNV. Traditional feedback from students and faculty over the previous 5-years suggests that the SI program at CCNV could be improved to better achieve its goals. Faculty report discouragement with the program because students attend at low rates. Further, faculty and students have stated that SI at CCNV feels more like traditional tutoring than SI – therefore not fulfilling the intended role of the program (K. Phillips, personal communication, October 7, 2020).

As higher education moved courses online in the Spring of 2020 in response to the COVID19 pandemic, support services moved online as well. For CCNV, this meant moving SI online. In response to this, a novel form of mandatory online SI (MOSI) developed for the ICMB course at CCNV.

Purpose of the Study

The purpose of this quantitative study is to test the hypothesis that participation in a mandatory model of online supplemental instruction can improve student success in ICMB at a community college in Northern Nevada. To test this hypothesis, the independent variable of MOSI attendance was compared to the dependent variable of ICMB course GPA. The independent variable of MOSI attendance was defined as having participated in at least one MOSI session. The dependent variable of course GPA was defined by the letter grade earned by the student over the course of the semester. Mediating variables for this study include the number of MOSI sessions attended, the self-reported binary gender of the student, student age, student first-generation status, student credit load, student ethnicity, and student type (i.e. transfer, returning, new, high school).

This study provides insight for educators and administrators at CCNV by providing means to improve general student achievement and narrow equity gaps in the traditional environment and the growing virtual environment.(Morris et al., 2020).

Research Questions

The following research questions were used to guide this study:

1. Are there observable differences in the mean GPAs from an Introductory Cell and Molecular Biology course when comparing students who attended MOSI and those who did not?
2. Can Introductory Cell and Molecular Biology student course GPA be predicted by a linear combination of the seven variables (gender, minority status, first-generation status, age, credit load, student type, number of MOSI sessions attended)? If yes, which variables contribute significantly to the model? Define "significantly"?

3. Is there a relationship between MOSI attendance and DWF rates in Introductory Cell and Molecular Biology as measured by a chi-square test of independence?

Theoretical Framework

The SI research presented here is guided by two supporting theories related to student engagement. Alexander Astin's Student Involvement Theory describes how favorable outcomes for an institution of higher education – such as retention and graduation rates – are positively correlated with the student's level and quality of involvement. Astin defines involved students as ones who devote energy to academics, spend most of their time on campus, participate in extracurricular student organizations and activities, and interact regularly with faculty. In his theory, Astin presents three core elements to the theory of student involvement. These core elements are the inputs a student brings to campus, the environment campus presents, and the outcomes of involvement (Astin, 1984). SI represents an environmental variable which can be controlled by institutions to encourage more academic involvement by the student body.

Vincent Tinto's Departure Theory helps explain how SI can be used effectively to mitigate a student's decision to withdraw from a course. Among other points discussed later in this paper, Tinto's Theory of Student Departure states that for students to choose to persist, they need to be integrated into the academic and social structure of an institution. Ultimately, Tinto suggests that integration has the most profound impact on student persistence (Tinto, 1975).

Tinto defines both social and academic integration as being important for students and further categorizes these social and academic opportunities as either formal or informal. Informal interactions might include a study group or other peer interaction, such as SI (Tinto, 1993). In Tinto's model, integration takes place in three different stages with the second stage being defined as a transitionary stage between a student's pre-college life and life on campus. It is this stage that is most crucial in determining whether a student will fully integrate into college life or choose to depart college. Further, it is this stage which the institution has the most control over. Tinto defines a student's level of integration into academic and social life on campus as a product of their involvement. Therefore, integration is inextricably bound to involvement, and as such, Tinto's Student Departure Theory has been used to understand how transition occurs in students (Milem & Berger, 1997).

Both Tinto's Departure Theory and Astin's Theory of Student Involvement have been applied to understanding the intervention of SI (Goldstein, Sauer & O'Donnell, 2012; Terrion & Daoust, 2011; Raitboy, Hoffman & Person, 2015; Martin & Aredale, 1993). To date all studies investigating SI from this theoretical framework have done so in the context of voluntary and in-person SI. This is the first study investigating mandatory SI held in the online environment from the theoretical framework provided by Astin and Tinto.

Procedure of the Study

This quantitative study was carried out at a community college in Northern Nevada. Data was collected over the Fall 2020 and Spring 2021 semesters.

The move to online presented an opportunity to redevelop the SI program at CCNV. As a part of this redevelopment process, SI supervisors participated in the SI

Supervisor Training program through the University of Missouri-Kansas City. Following this, SI training was reorganized, and SI leaders were trained using “Bybee’s 5e” model of lesson planning (Bybee, n.d.).

To facilitate mandatory attendance, weekly sections of introductory cell and molecular biology were delivered in three 50-minute sessions rather than two 75-minute sessions with the third session every week being their MOSI meeting.

The SI leaders for this study were student peers selected by the lead instructor based on their previous performance in ICMB. SI leaders were taught a variety of active learning techniques to use over Zoom for their sessions. These techniques were then included in their weekly lesson plans. To ensure that SI leaders were planning as they had been trained, weekly meetings between the lead instructor and the SI leaders were held.

At CCNV ICMB has a max class size of 32 students per section. For any given section of ICMB at CCNV which uses SI, only one SI leader will be assigned. Over the course of the period of the study, SI sessions at CCNV averaged 4.4 attendees per session. This suggests that the average SI session for ICMB at CCNV included 13.75% of students enrolled in a given section. Because of the mandatory nature of MOSI, attendance by students was high in these sessions with an average attendance of 9.7 students per MOSI session. Further, there were two SI leaders per section of ICMB in sections which used MOSI so that neither SI leader had more than 16 students per session. Therefore, weekly MOSI attendance averaged 19.4 students per section. This corresponds to a weekly MOSI attendance rate of 60.1%. Moreover, the mandatory approach allowed the research team to control for self-selection. The concern is often raised in SI that the students who attend are the ones who would do well even without SI.

This can skew data in an SI study (Paloyo, 2015). By making SI mandatory, the concern over self-selection has been controlled for.

This study used the nonequivalent control group design model often used in quantitative education research (Krishnan, 2019). There were a total of 30 sections of ICMB included in the study. Students who composed the control and experimental groups reflected 26 sections of ICMB offered over the study period. Students in the control group attended sections of ICMB which had access to traditional SI but did use MOSI. The classrooms which reflected the control group were taught by 7 different instructors ($N = 754$). MOSI was run in four sections of ICMB over the two semesters. All MOSI sections were taught by the same instructor ($N = 131$).

Deidentified data were collected from the office of institutional research at the end of the 2021 Spring semester. Along with the dependent variable of “course GPA”, the mediating variables of gender, ethnicity, age, student type, and credit load were gathered. This helped control for the data by further elucidating the relationship between the dependent and independent variables. Further, these mediating variables allowed the research team to investigate the impact of MOSI on any observed achievement gaps (Stanich et al., 2018).

Chapter II: Literature Review

Introduction

High paying careers in science, technology, engineering, and math (STEM) are becoming more prevalent in the U.S. and will continue to be so for the foreseeable future. Cite? Further, the U.S. relies heavily on those in STEM related fields to maintain the economic and physical health of the country (Hinton, 2020; Luy, Zannella, & Wegner-Siegmundt, 2019; Kampelmann, Rycx, Saks, & Tojero, 2018). However, there is a leak in the pipeline from college to career. Of the 23% of college undergrads who begin their college career as a STEM major, only 16% go on to work in a STEM related field (Hinton, 2020; Hernandez, 2013). Therefore, it is imperative that colleges in the U.S. create STEM programs which help ensure STEM student success.

Introductory STEM courses are required for students to successfully complete in order continue with their STEM education. Despite this, many introductory STEM courses are considered “high-risk” because 30% or more of students either receive an “F”, “D”, or withdraw from the course (Martin & Arendale, 1992). The result is that nearly half of all students who do not persist in a STEM major leave the major within the first year (Meaders et al., 2020). This phenomenon is particularly salient among female and non-dominant cohorts in STEM majors. These populations are impacted by low first year grades at a relatively disproportionate rate as compared to their dominant male counterparts (Thompson, 2021). While efforts to improve persistence among all cohorts in STEM have shown progress in the past decades, persistence efforts in gateway STEM courses must still be made.

Theoretical Foundation

Two supporting and well-practiced theories provide the foundation for this project (Tinto, 1998; Martin & Aredale, 1993; Raitboy, Hoffman & Person, 2015). First, influence is drawn from Astin's Student Involvement Theory which supports the idea that student success is positively correlated with student involvement (Astin, 1984). Finally, Tinto provides insight into retention issues with his Model of Student Departure (Tinto, 1993). These two models provide a road map for administrators to design programs which can improve both student success and retention.

Astin's Student Involvement Theory describes how favorable outcomes for an institution of higher education – such as retention and graduation rates – are positively correlated with the student's level and quality of involvement. Another way to put it would be that students learn more the more involved they are. Five basic assumptions define the Student Involvement Theory:

1. Involvement requires the investment of psychosocial and physical energy into various objects. These can be general or specific.
2. Involvement is continuous, and that the amount of energy invested varies from student to student across all objects.
3. Aspects of involvement may be qualitative and quantitative.
4. What a student gains from being involved is directly proportional to both the quantity and quality of their involvement.
5. The success of any academic policy is positively correlated with the degree to which it increases student involvement (Astin, 1984; Milem & Berger, 1997).

Astin defines involved students as ones who devote energy to academics, spend the majority of their time on campus, participate in extracurricular student organizations and activities, and interact regularly with faculty (Astin, 1984). Taken in summary, Astin's model incudes three primary core features. One, the "inputs" the student brings with them to the institution. These include cultural values, academic background and other various experiences and attributes. In what manner are these understandable inputs? Two, the educational "environment". The policies of an institution directly impact college environment and whether it is inviting to involvement. And three, the "outcomes" (Astin, 1984; Pascarella, et al., 2006). With regard to these outcomes, research has shown that students who participate in educational practices which increase on campus academic and extracurricular involvement have higher grades, are retained at a higher rate, receive bachelor's degrees at higher rates, and ultimately, have higher incomes (Astin, 1984; Tinto, 1997; Pascarella et al., 1996; Astin, 1993; Avalos, 1996; Pascarella et al., 2006; Johnson, Johnson, & Smith, 1998; Fredricks et al., 2004; Boulton *et al.,* 2020; O'Keeffe, 2013; Kahu & Nelson, 2018).

Vincent Tinto's Theory of Student Departure is the most often cited source on retention and persistence in higher education (Milem & Berger, 1997; Guiffrida, 2006). The Theory of Student Departure states that for students to persist, they need three things: 1) they need to see that their efforts correlate to improved academics, 2) they need to see that their academic goals are related to their professional goals, and 3) they need to be integrated into the academic and social structure of the institution. Ultimately, Tinto suggests that integration has the most profound impact on student persistence (Tinto,

1975) The integration needs to happen both formally and informally (Tinto, 1975; Tinto, 1993). From an academic perspective, formal integration refers to being enrolled in and engaged in course work. Informal academic integration can include engaging with a learning community on campus, meeting regularly with a professor, or volunteering in an on-campus lab. Formal integration in a social context can include being a part of a formal campus sports club or debate team. Informal interactions might include a study group other peer interaction (Tinto, 1993).

The process of integration is proposed by Tinto to take place in three different stages. The first stage, separation, is when the student separates from their previous life and enters the college environment. This can pose a challenge to the student as he/she leaves traditional norms and comforts behind in their previous community. In the second stage, transition, the student has successfully negotiated the separation from their old life and is beginning to identify the academic and social norms of the college environment. Integration is established once the student has academically and socially adapted to whichever a niche they have chosen to occupy on campus (Milem & Berger, 1997; Tinto, 1993; Tinto, 1986; Tinto, 1987). Because integration into academic and social life on campus is inextricably bound to involvement, Astin's Student Involvement Theory has been used to understand how transition occurs in students (Milem & Berger, 1997).

Interestingly, after many years of applying these two theories, retention remains an issue in higher education. Tinto has revisited this phenomenon. His conclusion is that higher education and their students have a fundamental difference in thinking about this problem. Students, Tinto proposes, want to persist in pursuit of their goals. However, institutions want to retain in pursuit of higher enrollment numbers. Tinto suggests that these fundamental differences in philosophy are why policies and programs established by colleges rarely have their intended impact. Thus, students continue to fail to persist (Tinto, 2017)

The Current State of STEM Education in Higher Education

Science, technology, engineering, and mathematics (STEM) education is a pipeline which fills the needs of industries required to maintain the health and safety of society. Medical, agricultural, computer science and many other industries rely on the skills of scientists, mathematicians, and engineers (Hinton et al. 2020). Because of the ubiquitous nature of STEM skills in modern industry, STEM-related job opportunities are projected to grow by 8.8% by 2029. Cite This includes a 15% increase in medical jobs and a 22% increase in computer science jobs. Cite Further, STEM related careers pay on average more than double the median income (U.S. Labor Bureau). Despite this, STEM education, the "pipeline" into these lucrative careers, has a persistence problem.

When investigating undergraduate STEM education statistics, data which reflects what is colloquially referred to as "the leaky pipeline" presents (Hinton et al. 2020, Hernandez, 2013). This is a reference to the observation that while 23% of U.S. undergraduates begin their college career in a field related to STEM, only 16% of U.S. college graduates go on to work in a STEM related field (Duncan, 2009; Augustine 2007). Therefore, while students enter STEM related fields in college, many discontinue on their path.

The STEM pipeline has a fragile foundation in the U.S. and this has downstream consequences. The U.S. ranks 30th in math and 11th in science as ranked by The Program for International Student Assessment (PISA, 2021). This test is given to 15-year-old students and the results in part reflect a lack of preparation for STEM related subjects in U.S. youth. This lack of preparation for STEM is further reflected by the observation that by the time these 15-year-old students graduate high school, only 20% are prepared for college level course work in STEM (ACT, 2018). It is important to add here that this lack of preparation may reflect a lack of interest on the part of the student and not reflect a judgment on the primary or secondary education system. Several studies have indicated that a large percentage of qualified U.S. high school graduates have little interest in pursuing a STEM career (Bettinger 2010; Lowell et al. 2009; Zumeta & Raveling 2002). This lack of interest is exemplified in the physical sciences which reflect only 3% of all STEM related bachelor's degrees awarded. Lack of interest is further demonstrated in the observations that U.S. STEM field students perform at a lower level and have less academic success than their Australian, Chinese, Japanese, English and Russian counterparts (Sithole *et al*., 2017).

The observed persistence problem in STEM is particularly salient among women and minoritized students who are less likely to complete their STEM related undergraduate and/ or graduate degrees than their male and white counterparts (Hernandez, 2013). In middle school, 74% of women express interest in STEM related fields, yet only 18% of computer science bachelor's degrees awarded are earned by women (Bureau of Labor statistics, 2015). And despite equal representation in the population, women only hold 31% of STEM degrees and make up just 25% of the STEM workforce (Bahr, Jackson, McNaughtan, Oster & Gross, 2017). Non-dominant populations are also unrepresented in STEM while being overrepresented in the persistence data. Black workers make up 11% of the workforce, however, they only represent 9% of the STEM workforce. This disparity is even greater in the Hispanic population which represents 16% of the workforce but only 7% of the STEM workforce. This disparity in employment can be drawn back to persistence observations in these populations. Nearly 40% of Black and Hispanic students who begin college as a STEM major will change to a non-STEM major or dropout while in college (Riegle-Crumb, King & Irizarry, 2019).

Thus, STEM education doesn't only have a systemic persistence problem, it has a systemic equity problem as well.

STEM Education in the Community College

The role of the community college system in the U.S. has been to democratize higher education. Community colleges across the U.S. have done this by offering affordable education which results in either the earning of a 2-year associates degree or students transferring to complete a 4-year degree (Cohen, Kisker, & Brawer, 2014). As such, community colleges are an attractive option to students and they account for nearly 50% of all public college enrollment in the U.S. (Ginder, Kelly-Reid, & Mann, 2014). Given the rising costs of a 4-year degree, most first-time community college students enroll with the intention of transferring to a 4-year college. Nearly 80% of community college students state that they intend to complete a 4-year degree or higher (Horn & Skomsvold, 2011). The percentage of students who earned either a bachelors or masters in a STEM related field and began their college course work at a community college increased from 41% to 46% from 2008 to 2013 (National Science Board, 2014). These are encouraging statistics because they imply that community colleges have great potential for being an important partner in expanding the STEM workforce.

As an affordable entry point into higher education, the community college system serves an outsized portion of the non-dominant U.S. population. In total, 36% of community college students come from historically marginalized communities which are otherwise underserved at traditional 4-year colleges and underrepresented within the STEM workforce (Bailey, Jenkins, & Leinbach, 2005; Riegle-Crumb, King & Irizarry, 2019). This statistic suggests that community colleges could help fill the persistence gap between seen between dominant and non-dominant populations in STEM degree programs. However, the real opportunity here is that the population of non-dominant students at community college represents the largest pool of potential STEM graduates, and by extension, STEM workers (Bahr, Jackson, McNaughtan, Oster & Gross, 2017).

The argument that the community college system is a reservoir for future non-dominant STEM degree holders and workforce participants can be extended to women in STEM. The underrepresentation of women in STEM is demonstrated by the fact that women make up more than 50% of all postsecondary degree holders while only holding 31% of STEM related degrees. However, considering all students who earn a bachelor's or master's degree in a STEM related subject, the percentage of women who at some point attended a community college is 25% higher than men. Therefore, the community college system reflects a large potential pool of female STEM degree earners (Mooney &

Foley, 2011). This suggests that the community college system has the potential to both narrow equity gaps seen in STEM and fill the needs of the STEM workforce in the U.S.

Historically, community colleges have not lived up to the promise of democratizing education (Zhang, 2019; Wang, 2015; Rouse, 1995; Clark, 1960). It's true, community colleges do offer the opportunity for underserved and non-traditional populations to attend college (Ma & Liu, 2017)). They offer affordability, they offer remedial classes, and they offer flexibility. Because of these qualities it is likely that community colleges will play a larger role in traditional postsecondary education as tuition costs rise (Cohen, Kisker, & Brawer, 2014). Disturbing trends in student success are however pervasive and unyielding within the community college system. While 80% or more of community college students say that they intend on transferring to a 4-year college to complete their degree, fewer than 50% do so, and of those who do transfer, only 1 out of 10 graduate (Hoachlander, Sikora, & Horn, 2003). Further, transfer students are statistically less likely to complete their 4-year degree than students who begin their college career at a 4-year university (Zhang, 2019). This in part can be explained by transfer student perceptions of their new environment. Transfer students from community colleges have reported that academic standards are higher at 4-year universities, the pacing is faster, and the writing expectations are greater (Zhang, 2019; Townsend, 2008). The difficulties encountered by transfer students are only compounded in the STEM field. Students who transfer from a community college to a 4-year institution in a declared STEM field have even greater difficulties due to the rigors of the discipline and the strict academic pathways which define these subjects (Wang, 2013: Zhang, 2019; Perna *et al.,* 2009). As a result, 69% of community college students who transfer to a 4-

year college to complete a STEM related degree are diverted from their goal and fail to persist (Snyder & Cudney, 2018).

Online Supplemental Instruction in Community College

Introductory STEM courses traditionally have a high rate of “D” and “F” grades given. Further, STEM courses tend to have a high withdraw rate. Taken together, this is known as the “DWF rate” (Thompson, 2021; Freeman et al., 2014; Ma & Liu, 2017). In response to this observation, some members of the education community will refer to these courses colloquially as “gate keeper” or “weed out” courses. Citation The implication being that those who may not otherwise succeed in future classes will be “weeded out” from the system and discontinue the pursuit of their STEM education. It’s important to remember in talking about these difficult courses that to “weed one out” is not the literal consequence of failing one of these courses. If one is “weeded out” in an introductory STEM course it is because they have been discouraged beyond the point of feeling that they can persist (Weston, Seymour, Koch, & Drake, 2019).

It has been found that receiving low grades in introductory courses has a disproportionate impact on non-dominant and female students. When a non-dominant or female student receives a low grade in an introductory course, they are less likely to persist than their dominant male counterpart (Thompson, 2021; Freeman et al., 2014; Ma & Liu, 2017; Weston, Seymour, Koch, & Drake, 2019; Field, 2018; Mervis, 2011). Therefore, many of these more difficult introductory STEM courses do not support diversity in STEM. It therefore stands to reason that improvements in student success in introductory STEM courses will lead to greater numbers of and a more diverse cohort of 4-year STEM graduates.

Various academic support services are a common feature of the community college environment and are aimed at helping students succeed in difficult courses (Kim, 2015; Vance, 2016; Okada & Channing, 2019). Tutoring and other peer-led support services have been shown to increase student success in high-risk courses with a greater than 30% DWF rate (Okada & Channing, 2019; Freeman et al., 2014). Peer-led tutoring services with a focus on mentoring which encourage peer-to-peer interactions have been shown to increase student success and lower attrition in high-risk STEM courses (Hernandez, 2013; Stanich *et al.,* 2018).

One such academic resource is supplemental instruction (SI). SI was developed in 1973 at the University of Kansas Missouri-City (UKMC) in response to low academic performance among students. At UKMC, as the student demographic rapidly changed and the student body grew, Deanna Martin was tasked with bridging the gap between faculty expectations of student academic performance and the academic capabilities of the student body. Out of this task the student-centered support service of SI was developed (Martin & Arendale, 1992).

SI is a peer-led form of tutoring intent on helping students understand the difficult topics associated with a course. It requires regular participation by students, the SI leader, and most importantly, the professor of record for the course. The fundamental characteristics of SI differentiate SI from traditional tutoring in several ways:

1) SI is proactive. It is not reactionary. Whereas students may attend traditional tutoring when their grades slip, or they need specific help with a specific assignment or concept, SI is there throughout to support the students with specific lesson plans.

2) A given SI leader is linked to the course section that a student is in. This allows the professor and SI leader to work together to coordinate weekly SI lesson plans and ensures that students are benefitting from the SI sessions.

3) SI is run by a peer. Typically, this is an undergraduate student who has successfully completed the course. It also could be a graduate student. The purpose of this is to create a "safe space" where students feel more comfortable asking questions they may not otherwise ask of the professor in-class.

4) SI is fundamentally a group learning experience. This allows for discussion among peers and generates a learning community among the students outside of regular class time.

5) SI targets courses with a DWF rate of 30% or higher (Martin & Arendale, 1992; Rabitoy, Hoffman, & Person, 2015; Stanich et al., 2018).

Concerns related to retention and student success in STEM are ones directly addressed by SI. A large body of literature provides evidence that students in STEM courses with SI have greater academic success, are retained at higher rates, graduate at higher rates, learn problem solving skills, and develop study habits required by students to effectively assimilate the information they are learning in a course (Blanc et al., 1983; Congos, 2002; Ning & Downing, 2010; Martin & Arendale, 1992; Malm, 2012; Stanich et al., 2018; Okada & Channing, 2020; Lyle & Robinson, 2003; Zaritsky & Toce, 2006).

Lyle and Robinson (2003) describe a model of SI used in an organic chemistry lab called peer-led team learning (PLTL). Their study, conducted over a 7-year period, showed year after year that those who regularly attended PLTL sessions were retained at higher rates and scored higher on student achievement as measured by GPA . Stanich et al. (2018) further demonstrates the effectiveness of PLTL in the STEM learning environment. Over a 2-year period, Stanich and associates developed and implemented a PLTL workshop called STEM-Dawgs. Here, with regard to retention and student success, not only was the effectiveness of PLTL in the STEM classroom reenforced, , but impacts on non-dominant and female populations were quantified as well. Stanich et al*.,* found that SI can disproportionality increase student retention and success in populations typically underrepresented in STEM.

While the two previously mentioned studies were conducted at 4-year universities, research on student success and retention has also been performed at the community college level. One of the first major studies to pilot SI at community college was done at LaGurdia community college over a 12-year period. In this study, Zaritsky and Toce analyzed SI data over a 12-year period, between 1993 and 2005. What they found was that students who attended SI received – on average – a 10% higher GPA in any given course as compared to their non-SI attending counterparts. It was also found that, because these students passed at higher rates, they were also retained at higher rates (2006).

Observations related to student achievement are supported in further research on SI in the community college environment. Rabitoy, Hoffman, and Person (2015) delve deeper into the student success data on SI at the community college. In a study out of a

Hispanic Serving Institute (HIS) in Southern California, the researchers showed that both student demographics and student college preparedness levels impact the degree to which SI participation impacts student success. Crucially, the researchers identified that SI attendance in female and non-dominant populations has a disproportionate impact on their success as compared to their white male counter parts. Why is this crucial? This observation – that SI has a relative greater impact on student success in non-dominant populations – supports the work performed by Stanich et al. (2018*)* in the 4-year environment.

Despite the well-documented arguments for SI use in the in-person learning environment, little research has been performed on assessing the effectiveness of online SI (OSI). However, a few teams have provided insight into the effectiveness of OSI. In a study done at Texas A&M University Corpus-Christi, participants across introductory biology, chemistry, engineering, and math courses participated in a study on the effectiveness of OSI. It was observed across all demographics that OSI, in this study, was just as effective as traditional SI. Student success, as measured by GPA, improved by the same proportion as compared to traditional SI. Further, students persisted at the same rate as observed in traditional SI programs (Spaniol-Mathews, Letourneau, & Rice, 2016).

More to the point, OSI has been shown to be effective in the introductory biology classroom. In a study out of the University of California San Marcos (UCSM), researchers showed that students who participated in OSI performed similarly to those who attended traditional SI sessions for their courses. It was further found that these students persisted at similar levels. Most importantly, however, was that this research also asked students about their perceptions of OSI. What they found was those students at

UCSM have similar perceptions of OSI as compared to traditional SI (Hizer, Schultz, & Bray, 2017).

What follows is an assessment of mandatory online supplemental instruction (MOSI) in an introductory cell and molecular biology course at a community college in Northern Nevada.

Chapter III: Methodology

The purpose of this study was to investigate the effectiveness of MOSI in an introductory biology course for students looking to major in biology at a local community college. This study was most interested in identifying what impact MOSI attendance has on student performance and retention in introductory cell and molecular biology. There was also interest in investigating whether early intervention with MOSI can narrow the observed achievement gap in introductory cell and molecular biology students.

The theoretical framework used to approach this study has its basis in the work of Vincent Tinto and Alexander Astin. Both Tinto and Astin have presented theories which state that student success and is an outcome of student involvement on campus (Tinto, 1997; Astin, 1993). Supplemental instruction (SI) has been investigated previously within the context of both Vincent Tinto's Departure Theory, and Alexander Astin's Student Involvement Theory (Raitboy, Hoffman, & Person, 2015; Tinto, 2005; Tinto, 1998; Martin, & Arendale, 1992). However, SI has never been investigated in this theoretical context when made mandatory or delivered online. Here, a mandatory model of online SI (MOSI) is investigated in the context of the theoretical framework defined by Tinto and Astin. The following research questions were used to guide this study:

1. Are there any differences in the mean GPAs from an Introductory Cell and Molecular Biology course between students who attended MOSI and those who did not?
2. Can Introductory Cell and Molecular Biology student course GPA be predicted by a linear combination of the seven variables (gender, minority status, firs-

generation status, age, credit load, student type, number of MOSI sessions attended)? If yes, which variables contribute significantly to the model?

3. Is there a relationship between MOSI attendance and D/W/F rates in Introductory Cell and Molecular Biology as measured by a chi-square test of independence?

This chapter is focused on providing the methodology which will be used to assess the effectiveness of mandatory online supplemental instruction (MOSI) in an online introductory cell and molecular biology course. This includes a detailed discussion of the setting, course, participants, and procedures. All sections of Introductory Cell and Molecular Biology which offered MOSI were included in the study. Those who attended MOSI formed the experimental group while those who did not formed the control group. In both groups, course GPA was used to measure the effectiveness of MOSI.

The Setting

This study took place at a community college in Northwestern Nevada (CCNV). While primarily offering transfer opportunities and two-year associate degrees, the college further offers a number of bachelor's degree programs. The college has a 51% Caucasian population and 36% Hispanic population. Asian students make up 5% of the population while black students make up 2% (College Website, 2022). The county in which this college is located has an average Hispanic population of 25% (Census, 2022). With such high representation at the college, the college aims to serve its Hispanic population and was recently designated a Hispanic Serving Institute. The college's international student body represents less than 1% of the total student body and represents 51 different nations. The college had an enrollment of 10,137 students for the

2020-2021 AY. 28% of students attend full-time while 72% attend part-time. The college boasts that 56% of its courses are taught by full-time faculty. Students aged 18-24 make up 56% of the student body. 17% of students are between the ages of 25-34 and 61% work twenty or more hours per week (College Website, 2022).

The college offers four-year degrees, two-year degrees, and transfer opportunities. It serves a predominantly low-income population. 51% of students at this college report an income of less than $30,000 and 89% of students are on scholarships or grants. This college is an attractive opportunity for students who might not otherwise have the opportunity to earn a four-year degree. Further, this college is located three miles from a large public four-year university. Due to CCNVs close proximity to a 4-year institution, the college has a high rate of transfer at 14%.31% of students graduate with a four or two-year degree (College Website, 2022).

Academic programs at this college offer various degrees, certificates, and opportunities for study in 50 career fields. Programs here are housed in five sperate divisions which offer courses throughout the day in a variety of modalities: Math and Physical Sciences Division, Business and Social Sciences Division, Liberal Arts Division, Technical Sciences Division, and Life Sciences, Allied Health, and Public Safety Division (LAP). Programs within these divisions are supported by local industry and reflect the needs of the local community. As a reflection of the college's commitment to create community and belonging for students on campus, the college supports a soccer team, a sorority, and several clubs including the Art Club, the Business Club, and the Dungeons and Dragons Adventure Club (College Website, 2022). Is there a purpose for including this trivia for the dissertation? If so perhaps add a sentence at the beginning that clarifies why it is important to the work. I understand the idea of providing an overall profile of the college but we stayed nonspecific deliberately earlier.

The college has 790 staff and faculty. This includes: 156 full-time faculty, 349 part-time faculty, and 285 full-time staff and administration. 17% of the faculty represent a minoritized population and 51% are female. Of the full-time faculty, 102 are tenured, 39 are on the tenure-track, and 15 are in non-tenured positions. Ditto.

The college offers several support programs to help students deal with academic and personal challenges. This includes two federally funded programs that provide assistance to discrete disadvantaged populations at the college. Veterans Upward Bound provides academic and personal support services to the veteran population while TRIO student support services provide similar services to disadvantaged and disabled students of first-generation status. General student population support programs include the career hub which offers resume writing and interview advice, the "Financial Literacy and Management Education Support" (FLAMES) program, counseling, and academic advising. The Learning Commons also offers services to students including access to group and individual study space, computers and printers. Further, the library, WebCollege (the colleges online learning support center), and the tutoring and learning center are all housed in the Learning Commons (College Website, 2022).

The Tutoring and Learning Center on campus offers students an ad hoc learning community. Here, tutors, embedded tutors, and supplemental instructors support the academic mission of the institution. Trained in best practices, tutoring staff provide tutoring, embedded tutoring, and supplemental instruction as a free service to students. Staff at the Tutoring and Learning Center can provide services for students in several fields including biology, chemistry, foreign languages, math, physics, and writing. Supplemental instruction is offered as available. Commonly, supplemental instruction is offered for biology and chemistry courses (College Website, 2022).

Courses which offer supplemental instruction offer at minimum one supplemental instruction session each week. These sessions are not a continuation of or a re-hashing of the week's lecture. These sessions are not traditional style tutoring. These are collaborative peer-led discussion and activity-based sessions which follow a lesson plan designed by the supplemental instructor. Lesson plans are designed in conjunction with a lead supplemental instructor and approved by the lead instructor. Supplemental instructors attend weekly lectures when budgeting and schedules allow. In these sessions, the weekly content which the lead instructor has lectured on in-class is engaged in, explored, explained, elaborated upon, and in some cases evaluated (Bybee & Landes, 1990). These sessions start the first week of class and are offered throughout the semester. While traditionally voluntary, some instructors make attending supplemental instruction a mandatory component of the course.

Supplemental instructors are trained by a certified supplemental instructor trainer and use a lesson planning template which ensures that each 60-minute session incorporates best practices in collaborative studying (UKMC Supplemental Instructor Training Manual, 2020). These sessions are intended to "help students engage in the course content", but they are also intent on "helping students learn how to learn". Many of the activities which supplemental instructors use to engage students help students become better test takers, better note takers, and more confident in their own ability to learn (Martin & Aredale, 1992).

The Course

In the Nevada System of Higher Education (NSHE), Introductory Cell and Molecular Biology (ICMB) is a lecture-based required course for students choosing to pursue careers in the biological sciences, medicine, or allied health fields. Course learning objectives, expectations, pre-requisites, and co-requisites vary between institutions within NSHE. However, a common course numbering system requires at least 85% overlap between courses with the same course number. ICMB generally covers a diverse array of topics from evolutionary theory, chemistry, cell anatomy, metabolism, genetics, and gene expression. Instructors who teach the course at a given institution are bound by the institutions learning objectives.

Despite the importance of ICMB, the DWF rate remains high at 35% or higher (College Website, 2022). Due to the difficulty of the course, and the high D/W/F rate, ICMB has been targeted for SI at CCNV. While supplemental instruction has been available at the college for students in ICMB for several years, the attendance rate and general stewardship of the program are in wane (Channing & Okada, 2019). Further, with COVID forcing the move to online instruction in the Spring of 2020, the college recognized the need for additional support for the ICMB students. For these reasons, supplemental instruction was reorganized and moved online for ICMB.

Supplemental instruction attendance is voluntary on campus and therefore not all sections of ICMB had students attend supplemental instruction over Fall 2020 and Spring 2021. Out of twenty-eight sections offered over the two semesters, thirteen had students represented at Supplemental Instruction. During these supplemental instruction (SI) sessions, the SI leader would use best practices to actively engage students in collaborative learning over an hour-long session. Activities regularly included note review, homework review, question answer discussion, informal quizzes, sharing study tips, and developing plans for studying. Students weren't simply engaging with the content of the course but were also building study skills. Further, all SI leaders are assigned a specific class section, and as a result, that peer SI leader often forms a relationship with their students which permits for communication outside of sessions. This means that the SI leader becomes another resource for the student to seek help outside of traditional class time.

Due to the online nature of the course, SI leaders were trained in best practices for online instruction. SI sessions were held via the teleconferencing platform Zoom. Sessions were one-hour long and held during regular class time as described in the procedure.

One limitation of the design of the study was related to the grading scheme the lead instructor implemented for sections using the MOSI intervention, and new grading criteria offered by CCNV in response to COVID. CCNV, like many colleges around the country, offered students the opportunity to change the grade they received for courses over Fall 2020 to pass or fail (S/U). Therefore, it would be difficult to include students with these grades in the study given that these grades do not conform to the research questions. To deal with this, students who either received an S or U grade were not included in the study.

All students enrolled in a section using MOSI earned 10% of their grade by attending MOSI sessions. These grades were earned by completing quizzes at the beginning of a MOSI session. Therefore, the grades of students attending MOSI sessions were dependent on MOSI attendance and this grading scheme has the potential to impact the data analysis. However, course GPA is determined by the letter grade given to the student and not the percent a student earns in the course. Therefore, the impact of the MOSI grade would need to have changed a student's grade percentage to the point where their letter grade would be changed. Of the 51% of students in MOSI sections who did not attend all MOSI sessions (N = 67), 47% (N = 31) received a MOSI grade which moved their GPA into another letter grade category. Of the 31 students whose letter grade w~~ere~~ was impacted by the grade associated with MOSI attendance, 61% (N = 19) had grades which were deleteriously impacted (their grades dropped into another letter grade category) by their lack of attendance in MOSI. Together, the impact of not attending MOSI had an average impact of 0.3 GPA points for these students. Of the 39% of students (N = 12) who did not attend all MOSI sessions but whose grade was not deleteriously impacted, 25% (N = 3) had grades which improved by an average of 0.3 GPA points when the MOSI grade was considered. Taken together, this suggests that the 10% of the course grade which was associated with MOSI had little impact on the overall GPA of those attending MOSI.

Of the students enrolled in sections offering MOSI, 13% (N = 17) never attended MOSI. These students were included in the control data. Their average course GPA was 1.45. Given that the average course GPA for the control group is 1.453, this cohort of students will likely not have a big impact on the data analysis.

Participants

The participants in this study include the students, supplemental instructors, and faculty at CCNV. Students participating in this study included all students enrolled in ICMB at CCNV over the Fall of 2020 and Spring of 2021 (N = 885). 51% of student participants are non-minoritized (N = 448), while 49% of students in the study come from a minoritized background (N = 437). 76% of student participants are female (N = 672) and 24% of student participants are male (N = 213). The age range of the students varied as well with 66% (N = 584) being in the under 18 – 24-year-old range, while 34% (N = 301) represented non-traditional students over the age of 25. 78% (N = 690) of students were returning students while the remaining 22% (195) were either new students, transfer students, or high school students. Credit loads varied as well with 45% (N = 398) of students being full-time students and 55% (N = 487) taking courses part-time. Non-first-generation college students represented 55% (N = 488) and the remaining 45% (N = 397) represented students of a first-generation background.

Because ICMB is a general education course, students participating in the study came from many areas of the college. However, a large number of students are those majoring in fields related to allied health, medicine, and biology. Upon completion of the course, most students go on to take courses in microbiology, anatomy, and physiology.

The SI leaders selected for this study were selected from the tutoring center on campus which employees SI leaders. These SI leaders led the sections of ICMB which used MOSI as a treatment. Three SI leaders were used in Fall 2020, and two SI leaders were used in Spring 2021 (N = 5). SI leaders selected to participate in the study were selected by the lead instructor using MOSI in their section. SI leaders selected must have had taken the course previously and have had passed with a “B” letter grade or better. Many SI leaders fit the same demographic as the students. They are on a career path which will likely take them into a career in allied health, medicine, or biology.

One instructor, InstructorEXP, taught all sections of Introductory Cell and Molecular Biology using MOSI. InstructorEXP is a non-minoritized male with a background in plant biochemistry and STEM education. He has taught in the Biology and Community Health Sciences department at the college since 2015. Since 2019 he has taught at the college full-time and is an active member of tutoring services on campus. He has presented research on supplemental instruction at the National Association of Biology Teachers conference and is a certified supplemental instructor trainer. All experimental group data will be taken from InstructorEXP’s~~s~~ Introductory Cell and Molecular Biology sections which will use MOSI.

Nine different instructors taught the sections which all control data was from. This includes four full-time instructors and five part-time instructors. Two of the full-time instructors are female, and two of the full-time instructors are male. All full-time instructors come from a non-minoritized background. Of the part-time instructors, three are male and two are female. All part-time instructors come from a non-minoritized background. While individual pedagogy varied between instructors, all worked from the same set of institutional learning objectives.

Procedures and Data Collection

Supplemental instruction is traditionally offered in a voluntary format (Aredale, 1993). In this format, SI leaders are employed by the school and managed as an academic service by the tutoring center. SI leaders are traditionally hired based on recommendation by instructors and have been successful in whichever subject area they will be an SI for. At the beginning of a semester, instructors of difficult courses with a 35% or higher D/W/F rate will be approached by tutoring services with regard to using an SI leader for the semester. If an instructor chooses to use an SI leader for the semester, the SI leader, instructor, and tutoring center will work together to find times outside of traditional class time to hold SI sessions. In these sessions, students have the opportunity to explore and further engage in the weekly course content (Bybee et al., 2006, Martin & Aredale, 1992).

In recent years many have had success with mandatory SI models (Stanich et al, 2017). In the Fall of 2019 faculty at CCNV began working with faculty at a local four-year university to develop a mandatory model at CCNV. While exploring mandatory options for SI at CCNV, COVID forced CCNV into the online environment. Given the high DWF rate at CCNV in ICMB it was clear that students would need additional support in the online environment. Investigations into online SI (OSI) in the context of a mandatory model – mandatory online supplemental instruction (MOSI) began. Bringing SI into the online environment has the benefit of maintaining SI for students despite courses being moved online. Having SI mandatory ensured that all students received the benefit of SI. A less obvious benefit, for the purposes of investigations, of making SI mandatory is it provided a sample size large enough for the study. Additionally, a common critique regarding SI data collection and assessment is related to the voluntary nature of a traditional SI program (Rabitoy, Hoffman, & Person, 2015). When voluntary, the impact of self-selection bias is very strong. By making SI mandatory, concerns about self-selection are better controlled ~~for~~. However, since MOSI took place in courses which students self-selected into, this concern could not be entirely controlled.

SI leaders for the MOSI study were selected by InstructorEXP based on their previous performance as students in ICMB. Each section of ICMB which used the MOSI model had their own SI leader. Potential SI leaders were approached individually and if they were interested in working as an SI leader they were directed to the tutoring department on campus to submit an application. Selected SI leaders were trained by the tutoring department in institutional practices and standard operating procedures. Having been previously certified as an SI leader trainer and supervisor through the International Center for Supplemental Instruction at the University of Missouri - Kansas City, InstructorEXP trained the MOSI SI leaders in best practices in SI. InstructorEXP further trained the SI leaders in best practices in synchronous online instruction.

At CCNV the ICMB course is taught during the Fall, Spring, and Summer semesters. During the Fall and Spring, the course is offered in both 16-week and 8-week formats. During the Summer it is only taught in an 8-week format. This study of MOSI was conducted in sections taught using the 16-week modality. Sixteen-week sections are traditionally taught in two 75-min sessions per week. Implementing a mandatory model of SI required respecting the time commitment students had agreed to when signing up for courses. In order to maintain the same weekly 2.5 hours of in-class time, sections offering MOSI were broken into three weekly 50-min meetings with the third meeting being the students' weekly MOSI session. MOSI sessions were led entirely by the SI leaders and all session were held synchronously via the video conferencing platform Zoom. The Zoom video conferencing platform allowed for synchronous meetings between student and SI leader in a virtual face-to-face environment. Here, SI leaders could lecture using a virtual white board, organize groups of students to work together, and administer quizzes.

During the duration of the study, the other two 50-min sessions per week were also held online. These sessions were held synchronously via Zoom and taught by InstructorEXP. To accommodate for the reduced time in class, sections using MOSI were taught in a flipped format. In a flipped classroom, students are expected to have engaged with course material and work prior to being coming to class (Awidi & Paynter, 2019). For the purposes of the ICMB courses with MOSI, students were required to watch lecture videos and complete homework assignments prior to attending the weekly lectures. These two weekly 50-min lectures followed a traditional format with opportunities for discussion (Figure 1).

Figure 1

Weekly Structure of Sections Using MOSI

Note. In order to accommodate a mandatory MOSI session within the context of 2.5 hrs of instruction per week, weekly sessions were divided into three 50-min sessions. To compensate for lost classroom time, courses were taught in a flipped format where students were expected to watch videos and complete assignments prior to coming to class.

A limitation of this study is that all experimental data regarding the effectiveness of MOSI was collected in sections taught entirely byInstructorEXP using a flipped model of instruction. However, all control data was collected from sections taught by other instructors using different pedagogies. A controlling factor for this limitation is that all instructors must teach ICMB with regard to the same set of learning objectives.

This study utilized a quantitative quasi-experimental post-test only nonequivalent control group model (Krishnan, 2019). Because of self-selection bias associated with course registration, randomization of participants was not possible. For the purpose of this study, the control group was the cohort of ICMB students during the Fall 2020 and Spring 2021 semesters who did not attend any SI session. These students came from sections taught by nine different instructors. All students were current students enrolled in the ICMB course at CCNV. The control group consisted of 754 students. Students in the control group were 51% non-minoritized and 49% minoritized. Seventy-six percent of the control group cohort were female while 24% were male. The age range of the students varied as well with 67% being in the under 18 – 24-year-old range, while 33% represented non-traditional students over the age of 25. 79% of the control students were returning students while the remaining 21% were either new students, transfer students, or high school students. Credit loads varied as well for this cohort with 45% of students being full-time students and 55% taking courses part-time. 55% of students were non-first-generation status while the remaining 45% represented students of a first-generation background.

The experimental group was the cohort of ICMB students who attended at least one MOSI session over that timeframe. The experimental group had 131 students and was taught exclusively by InstructorEXP in a flipped format. Students in the experimental group were 49% non-minoritized and 51% minoritized. 76% of the experimental group cohort were female while 24% were male. The age range of the students varied as well with 70% being in the under 18 – 24-year-old range, while 30% represented non-traditional students over the age of 25. 69% of the control students were returning students while the remaining 31% were either new students, transfer students, or high school students. Credit loads varied as well for this cohort with 50% of students being full-time students and 50% taking courses part-time. 56% of students were non-first-generation status while the remaining 44% represented students of a first-generation background.

The experimental group met once a week for a 50 min MOSI session. Participants for this study were students in ICMB at CCNV during the Fall 2020 and Spring 2021 semesters. All students in the control group were those who attended no SI sessions over those semesters. Students in the experimental group were from one of the five sections using MOSI and taught by InstructorEXP.

Data Analysis and Measurements

This study employed three different statistical tests to address the proposed questions; a student t-test, a multiple linear regression model, and chi-square test of independence. To address the first two research questions of this study, ICMB course GPA was used as the dependent variable as a measure of student success. Multiple linear regression is a technique which uses two or more independent variables to predict the outcome of a dependent variable. Here, multiple linear regression was used to predict student ICMB course GPA. The independent variables used in the linear regression model represent two broad categories of variables as defined by the Input-Environment-Output model used to explain Astin's Student Involvement Theory. These include both input variables which are inherent to the student, and environmental variables which are under the control of the institution (Astin, 1983). For this study, all independent variables used in the multiple linear regression model were coded as dummy variables according to the number of categories. Input variables included: gender (male = 0, female = 1), minority status (non-minoritized = 0, minoritized = 1), first generation status (non-first generation = 0, first generation = 1), student type (returning = 0, high school/ new/ transfer = 1), and age (<18 – 24 = 0, 25+ = 1). Environmental variables included: credit load (full-time = 0, part-time = 1), and number of MOSI sessions attended (continuous). The MOSI variable not only captures the number of sessions attended but also whether OSI was attended at all over the semester. Despite OSI being mandatory in all sections taught by InstructorEXP, not all students attended all sessions.

The variables chosen for the linear regression model were selected based, in part, on current literature related to diversity, equity, and inclusion issues in STEM education. It has been shown repeatedly that equity gaps exist across STEM – from elementary school through employment. Cite These gaps exist between the genders, minoritized and non-minoritized students, and students of first-generation status and those with a family history of college attendance (Bailey, Jenkins, & Leinbach, 2005; Hernandez, 2013; Bahr, Jackson, McNaughtan, Oster & Gross, 2017; Riegle-Crumb, King & Irizarry, 2019). Further, it has been shown that SI has a disproportionate impact on minoritized student academic success (Yue, Rico, Vang, & Giuffrida, 2018). Therefore, the variables of gender, minority status, and first-generation status are of great interest within the context of MOSI.

Astin's Student Involvement Theory states that for students to grow, and be successful in college, they must be actively involved in the campus. The degree to which students are involved in quality programs on campus has an impact on their learning and success (Astin, 1983). Astin explains this theory using the Involvement-Environment-Outcomes model. Here, Astin states that the inputs a student brings to campus, the environment the campus establishes, and the outcomes students experience are all related to the degree to which a student chooses to involve themselves on campus (Astin, 1984).

In this model, the inputs students come to campus with include their lived experiences and other objective characteristics such as age and minority status. The environment includes anything related to the campus such as hiring practices, course offerings, and academic advisement. Therefore, the variables chosen for the regression model also reflect student inputs and environmental variables related to CCNV. The environmental variable of credit load was chosen because previous research has shown a correlation between credit load and student success. Further, this is an environmental variable established by the school with the student through academic advising and other related services (Wang, 2017). The other environmental variable, number of MOSI sessions attended, is also a product of the school environment given that it is a program offered by CCNV. Quantifying the number of MOSI sessions attended allowed the researchers to separate those who had attended MOSI and those who had not. Further, this gave the research team the data needed to quantify the impact of MOSI attendance on students by degree of involvement.

To address the third question of whether there is a statistically relevant relationship between MOSI attendance and a student's decision to withdraw, or their earning a "D" or "F" grade, a chi-square test of independence was used. The rate of withdraw and "D", or "F" grades given is known as the D/W/F rate. Tinto's departure theory states that for a student to choose to persist, they must be integrated into the academic and social structure of campus (Tinto, 1975). SI programs represent informal academic experiences where students have the opportunity to incorporate themselves into the academic structure of the school. Further, one of the fundamental arguments for SI is that it lowers the D/W/F rate in difficult courses. Cite Therefore, it is important to measure this relationship when developing a new SI program.

Research Question 1

To address this question, deidentified data on student SI attendance and student course GPA was gathered. The control cohort population (N = 754) was made up of Introductory Cell and Molecular Biology students who over the Fall 2020 and Spring 2021 semesters did not attend SI in any format. The experimental group population (N = 131) was made up of students who attended MOSI over the Fall 2020 and Spring 2021 semesters. The data collected was non-parametric. Therefore, to compare the mean GPA of these two cohorts, a Mann-Whitney U test was used.

Research Question *2*

To determine whether MOSI is a predictor of student success in Introductory Cell and Molecular Biology, a multiple linear regression model was used. Deidentified data was pulled from Institutional Research at CCNV for all students who attended MOSI over the Fall 2020 and Spring 2021 semesters (N = 131). To establish a relationship between MOSI attendance and students' success, Introductory Cell and Molecular Biology course GPA was set as the dependent variable, while multiple independent variables were used. To assess whether MOSI attendance was a predictor of student's success, the number of visits to MOSI was used as an independent variable. Using the number of visits to MOSI, rather simply if a student attended MOSI or not, provided insight into the impact of frequency of MOSI attendance. Further, it has been shown in the past that SI attendance has an impact on student GPA only if SI is attended at least three times within a semester (Freeman, *et al.,* 2014; Dawson, van der Meer, Skalicky, & Cowley, 2014; Rabitoy, Hoffman, & Person, 2015). Both the dependent variable of GPA, and the independent variable of number of MOSI session attended, are continuous variables. The other variables used in the model are categorical and were coded as dummy variables using their corresponding categorical values (table 1).

Table 1

Coding for multiple linear regression variables

Variables	Name	Coding	Measurement	Categories
Y	Student Success		GPA	Continuous
X_1	Gender	(sex)	Male = 0 Female = 1	2
X_2	Minority status	(min)	Minoritized = 0 Non-minoritized = 1	2
X_3	First generation status	(gen)	First generation = 0 Non-first generation = 1	2
X_4	Student type	(type)	New = 0 Continuing = 1	2
X_5	Student age	(age)	Under 18-24 = 0 25+ = 1	2
X_6	Credit load	(credit)	Full-time = 0 Part-time = 1	2
X_7	Number if MOSI sessions attended	(mosi)	Number of times MOSI was attended in the semester	Continuous

The predictive model to be used is: $Y = b0 + b_1(sex) + b_2(min) + b_3(gen) + b_4(type) + b_5(age) + b_6(credit) + b_7(mosi)$.

Research Question 3

The D/W/F rate is defined as the percentage of students who either withdraw from a course or earn a “D” or “F” grade in a course. SI targets courses with a D/W/F rate of over 35% (Martin & Aredale, 1992). Therefore, it is important to assess whether MOSI is improving the precise metric SI aims to improve. In order to identify a relationship, the frequency between course withdraws, “D”, and “F” grades given was compared within the experimental and control groups using the chi-square test of independence. For the purpose of assessing RQ3, the control group was the cohort of BIOL 190 students over the Fall 2020 and Spring 2021 semesters who did not attend MOSI (N = 754). The experimental group was all BIOL 190 students who attended MOSI over the Fall 2020 and Spring 2021 semesters. The independent variables of were coded as follows: D =1, W = 2, F = 3.

Table 2

A sample 2x3 table for the variables assessed in the Chi-square test of independence.

	D	W	F
MOSI			
No MOSI			

Chapter IV: Results

Student Demographics

An a priori power analysis was conducted using G*Power version 3.1.9.7 (Faul et al., 2007) to determine the minimum sample size required to test the proposed hypotheses. Results indicated the largest required sample size at a significance criterion of α=0.05 would be ***N*** = 74. Thus, the experimental (n=133) and control (n=797) sample sizes were large enough for results to be significant. Due to discrepancies in sample sizes, non-parametric tests were used where appropriate.

In this post-test only non-equivalent group design, true equivalence between the control group and experimental group was not possible. This is due to the difference in group sizes, the non-randomized model used, and a lack of access to previous academic records which would allow to control for equivalency between the control and experimental groups. To establish equivalency between the control and experimental group, a Mann-Whitney U test was used to assess for significant differences in the demographic variables of gender, minority status, first-generation status, age, credit load, and student type. SPSS analysis confirmed equivalence in the demographic variables of gender, minority status, first-generation status, age and credit load. The results U = 48359.5, p = 0.028, demonstrate that the two groups were significantly different in terms of student type. In the control group, 7.9% of students were new students whereas 12.0% were new in the experimental group. Another noticeable difference between student types was that in the control group only 3.4% were new high school (HS) students while 7.5% were new HS students in the experimental group (Table 3).

Table 3

Demographics of students

Category	Control Group	Experimental Group	W	p
Gender			52719.000	0.894
Male	23.8% (n=190)	23.3% (n=31)		
Female	76.2% (n=607)	76.7% (n=102)		
Ethnicity			50574.000	0.352
White	51.4% (n=410)	48.9% (n=65)		
Hispanic	33.9% (n=270)	39.1% (n=52)		
Asian	6.0% (n=48)	3.8% (n=5)		
Black	1.9% (n=15)	1.5% (n=2)		
American Indian	0.8% (n=6)	1.5% (n=2)		
Two or more	4.3% (n=34)	3.8% (n=5)		
Unknown	1.8% (n=14)	1.5% (n=2)		
Minority Status				
POC	54.2% (n=71)	54.2% (n=71)	51347.500	0.318
White	45.8% (n=410)	45.8% (n=60)		
Credit Load			54262.000	0.639
12+	45.8% (n=365)	51.1% (n=68)		
9 - 11.9	21.6% (n=172)	14.3% (n=19)		
6 - 8.9	19.6% (n=156)	20.3% (n=27)		
<6	13.0% (n=104)	14.3% (n=19)		
Age Range			55645.500	0.288
<18	6.4% (n=51)	9% (n=12)		
18-24	60.9% (n=485)	61.7% (n=82)		
25-34	26.9% (n=214)	24.1% (n=32)		
35-49	4.8% (n=38)	4.5% (n=6)		
50+	1.1% (n=9)	0.8% (n=1)		
First Generation			53573.500	0.713
Non-first gen.	54.7% (n=43)	43.6% (n=58)		
First generation	45.3% (n359)	56.4% (n=75)		
Student Type			48359.500	0.028
Continuing	78.2% (n=623)	69.2% (n=92)		
Continuing HS	6.6% (n=53)	9.0% (n=12)		
New	7.9% (n=63)	12.0% (n=16)		
New HS	3.4% (n=27)	7.5% (n=10)		
New Transfer	3.9% (n=31)	2.3% (n=3)		

Instructor Demographics and Variables

This study was conducted over the course of the Fall 2020 and Spring 2021 semesters and included 931 students from 30 sections of Introductory Cell and Molecular Biology. Variables and instructor demographics include modality of online instruction (synchronous or asynchronous), Instructor employment status (full-time or part-time), whether the instructor was a faculty of color (FOC) or white, Instructor gender as self-reported (female or male), and whether a supplemental instructor was used. In the control group instructors self-identified as male taught 76% of all sections (n=19) and 24% self-identified female (n=6). The asynchronous modality was the most preferred within the control group. Here, 71.7% of instructors taught sections in an asynchronous (n=23) format while 8.3% of instructors taught in a synchronous format (n=2). Faculty of color taught 20% of the control sections (n=5), while white faculty taught the remaining 80% of sections (n=20). Supplemental instruction (SI) was not a popular course addition in the control sections. Only 16% of sections used SI in the control cohort (n=4). The experimental group was taught by a single instructor. This instructor was a full-time white male who taught all sections in a synchronous online format. All experimental sections used mandatory SI. Further variables unique to the experimental section include that it was taught in a flipped format. Moreover, synchronous lectures were 50-mins long in the experimental sections. Synchronous lectures in the control cohort were 75-mins long. Select instructor demographics and variation in modality can be found in table 4. Binomial testing is SPSS showed significant statistical differences across all instructor and classroom setting variables and therefore equivalency could not be established.

Table 4

Instructor Demographics and Variables

Category	Control	Experimental
Modality		
Asynch online	91.7% (n=23)	0% (n=0)
Synch online	8.3% (n=2)	100% (n=5)
Minority Status		
FOC	20% (n=5)	0% (n=0)
White	80% (n=20)	100% (n=5)
Gender		
Female	24% (n=6)	0% (n=0)
Male	76% (n=19)	100% (n=5)
Employment status		
PT	24% (n=6)	0% (n=0)
FT	76% (n=19)	100% (n=5)
Supplemental Instruction		
Yes	16% (n=4)	100% (n=5)
No	84%% (n=21)	0% (n=0)

Due to organizational limitations, each instructor had a different grading scheme for their section(s). For example, one instructor graded students from 4 lecture exams, and 10 quizzes. In this scheme, exam scores counted for 80% of the student's total grade. Other instructors provided multiple homework assignments, graded discussion opportunities, mandatory review quizzes and other formative assessments which made up a large portion of the students overall grade. This resulted in summative assessment scores counting for as little as 50% of a student's overall grade in some sections. The number of exams and assignments varied among instructors as well. Four equally weighted exams were given by 60% of instructors (n=6). 20% of instructors (n=2) gave five equally weighted exams. The remaining 20% of instructors (n=2) gave three exams which were equally weighted and a final which was weighted higher. This shows that many grading variables existed among the eight instructors whose sections were included in the study.

While many confounding variables exist between the control and experimental groups, unifying features were applied across all sections. Because this study took place during the COVID-19 pandemic, all sections were taught online. Online instruction was administered via the learning management system Canvas by all instructors in all sections. Further, all instructors gave at least four summative exams over the course of the semester as dictated by departmental policy. All exams in all sections were administered via the quiz tool in Canvas and used the proctoring software provided by Respondus LockDown Browser with Monitor. Student learning objectives were also applied evenly across all sections as these are determined via department policy.

In sections which offered OSI, be it voluntary or mandatory, OSI was administered via the online conferencing platform Zoom. In the experimental group supplemental instruction was mandatory and students met once a week as a group for 50-mins with their MOSI leader. Due to the mandatory nature, each section using MOSI had two MOSI leaders and the class was split equally between the two MOSI leaders for each meeting. This resulted in MOSI sessions having regular attendance of up to 16-students per meeting or 32-students per sectionIn sections where OSI was not mandatory, OSI leaders would meet with students in groups of various sizes depending on demand. All OSI leaders were trained at the beginning of the semester using best practices in SI as defined by the International Center for Supplemental Instruction at the University of Kansas Missouri-City.

Research Question One

Research question one asked if there are any differences in the median GPAs from an ICMB course between students who attended MOSI and those who did not.

All students in the study (n=915) met the requirements for enrollment into ICMB. Moreover, all course content was delivered in an online environment for all sections. This included the standardized use of the learning management system Canvas for all sections per department policy. Other departmental policies which were applied across all sections include the use of at least four exams per section per semester, and a standardized collection of course learning objectives. Further, all students had access to the tutoring department on campus and some had access to OSI. It was hypothesized that those students in sections which had a MOSI component would earn higher course GPAs than those who did not have this component associated with their course.

To test this hypothesis and address the research question, deidentified data on student SI attendance and student course GPA was gathered. The control cohort population (N = 784) was made up of Introductory Cell and Molecular Biology students who over the Fall 2020 and Spring 2021 semesters attended OSI voluntarily if it was offered by their section instructor. The experimental group (N = 131) was made up of students who attended MOSI over the Fall 2020 and Spring 2021 semesters.

To identify whether there was a significant difference between the two independent cohorts in this study, tests for normality and equal variance were first carried out to determine which statistical test would be most appropriate. Levene's test of equal variance was used to test for homogeneity between the two cohorts (Levene, 1960). Levene's test showed that the variances for course GPA were equal, $F(1) = 0.263$, $p = 0.0608$. A Shapiro-Wilk test was carried out to assess if normality assumptions were violated. The Shapiro-Wilk test showed a significant deviation from normality in the observed distribution of course GPA scores among both the experimental cohort, $W(130) = 0.871$, $p = 0.001$, and the control cohort, $W(783) = 0.848$, $p = 0.001$. Given these results, and the difference in the sample sizes between the control cohort (n=784) and experimental cohort (n=131), it was decided to use a Mann-Whiney *U* test. A Mann-Whitney test indicated that the course GPA was significantly higher in the cohort of students who were in sections of ICMB with MOSI (*Mdn* = 2.00) than those in sections without MOSI (*Mdn* = 1.30) $U = 43748.500$, $p = .005$.

Research Question Two

Research question two asked if ICMB student course GPA could be predicted by a linear combination of the seven variables (gender, minority status, first-generation status, age, credit load, student type, number of MOSI sessions attended)? If yes, which variables contribute significantly to the model?

Astin's theory of student involvement states that educational outcomes in higher education are directly proportional to a student's level and quality of involvement in their education. The level and quality of a student's involvement is related to three core features: Student inputs, educational environment, and outcomes of involvement (Astin, 1984). It was hypothesized that student involvement in MOSI would be a predictor of student ICMB course GPA. To address this question deidentified data on the student input variables of age, ethnicity, first-generation status, gender, student type, were applied to a multiple regression model along with the educational environment variables of credit load, and number of MOSI sessions attended.

All students in sections of ICMB which incorporated MOSI over the Fall 2020, and Spring 2021 semesters were included in the regression model (n=131). All sections in the experimental cohort were taught by the same instructor using the same pedagogy across all sections. Despite OSI being delivered in a mandatory format, not all students attended all sessions ($M = 5.955$, $Min. = 1.000$, $Max = 43.000$). This allowed for a more detailed analysis on the impact of OSI attendance per session.

The overall regression model of $Y = b0 + b_1(\text{sex}) + b_2(\text{min}) + b_3(\text{gen}) + b_4(\text{type}) + b_5(\text{age}) + b_6(\text{credit}) + b_7(\text{mosi})$ indicated there was a significant collective effect between the independent demographic and environmental variables and the dependent variable of ICMB course GPA ($F(7, 123) = 4.836 = p < 0.001$, $R2 = 0.216$). Among student demographic variable correlations, the relationship between student age, and ICMB course GPA was the strongest ($\beta = -0.195$, $p < 0.5$). When cohorts are disaggregated, the effect of student age on ICMB course GPA remains the strongest predictor for females ($\beta = -0.241$, $p < 0.001$), and non-first-generation students ($\beta = -0.366$, $p < 0.001$). Other significant student demographic variables among disaggregated cohorts include student sex for the POC cohort ($\beta = -0.308$, $p < 0.01$), and student type for the white student cohort ($\beta = 0.297$, $p < 0.05$). Of the chosen environmental variables ICMB course GPA ($\beta = 0.331$, $p < 0.001$). When the environmental variable of number of MOSI sessions attended is disaggregated by cohort, we see that ICMB course GPA for first-generation students is benefiting most from MOSI attendance (β = 0.421, $p < 0.001$). The correlation of the number of MOSI sessions attended in relation to ICMB course GPA remains robust across most cohorts: females (β = 0.354, $p < 0.001$), POC (β = 0.375, $p < 0.001$), white (β = 0.399, $p < 0.001$), non-first generation (β = 0.309, $p < 0.001$). Interestingly, the number of MOSI sessions attended did not have a statistically relevant impact on the male cohort. Credit load had a weaker effect than did number of MOSI sessions attended on course GPA for the POC cohort (β = 0.259, $p < 0.05$) and non-first-generation cohort (β = 0.293, $p < 0.001$). Therefore, after controlling for the student demographic variables of ethnicity, sex, student type, and first-generation status, and after controlling for the environmental variable of credit load, it is ultimately the number of MOSI sessions attended which is the strongest predictor of ICMB course GPA (table 5).

Table 5

Enter Multiple Linear Regression Demographic and Environmental Variables

Variable	Female			POC			White			1st Gen			All		
	B	*SE*	*β*	*B*	*SE*	*β*	*B*	*SE*	*β*	*B*	*SE*	*β*	*B*	*SE*	*β*
Sex	-	-	-	-.970	.363	-.308**	.176	.479	.046	-.500	.453	-.129	-.533	.284	-.154
Ethnicity	-.024	.165	-.014	-	-	-	-	-	-	-.191	.187	-.124	.010	.132	.006
1st-gen status	-.197	.279	-.069	-.564	.338	-.202	-.060	.373	-.019	-	-	-	-.182	.249	-.061
Student Type	.151	.123	.120	-.053	.182	-.036	.374	.143	.297*	.402	.148	.032	.207	.112	.155
Age	-.522	.225	-.241*	-.484	.283	-.222	-.277	.247	-.138	-.159	.281	-.072	-.403	.186	-.195*
# MOSI sessions Attended	.115	.032	.354***	.112	.038	.375**	.092	.028	.399**	.120	.034	.421***	.085	.021	.331***
Credit Load	.144	.132	.114	.339	.166	.259*	-.560	.164	-.043	-.019	.145	-.016	.154	.116	.119

Note. Female: $F(6, 93) = 3.795$, $p > .01$, $R^2 = .197$; POC: $F(6, 60) = 3.140$, $p > .01$, $R^2 = .239$; White: $F(6, 57) = 4.544$, $p > .001$, $R^2 = .324$; 1st generation: $F(6, 50) = 4.535$, $p > .001$, $R^2 = .352$; Overall: $F(7, 123) = 4.836$, $p > .001$, $R^2 = .216$. $p < .05$. $p < .01$**. $P < .001$***. Male and non-first-generation cohorts omitted for clarity.*

Research Question Three

Research question three asked if there was a relationship between MOSI attendance and DWF rates in Introductory Cell and Molecular Biology as measured by a chi-square test of independence.

The relative frequency of students earning a “D” an “F” or withdrawing from a course is known collectively as the DWF rate. STEM courses, particularly at community colleges, have high DWF rates often exceeding 35% (Hayes & Randall, 2019). SI, in any format, has been shown to be an effective intervention in lowering the DWF rate in STEM courses. Lowering DWF rates are often cited as a reason to implement SI programs on campus (Gupta & Hartwell, 2019; Brakke & Halpern, L. C. (2014). For this reason, it was important to quantify the relative rate of D’s, F’s, and withdraws between the experimental and control cohorts. This will allow for the observation of any relationship between these dependent variables and the independent variable of MOSI attendance.

All data came from Fall 2020 and Spring 2021 student populations. All students met the requirements for ICMB and all students took their courses online through the learning management tool Canvas. The control cohort population (n=784) was made up of ICMB students who were not enrolled in a section using MOSI. While some students in this population had access to OSI, it was not mandatory in their sections. The experimental cohort (n=131) was composed of students enrolled in sections which used MOSI.

The frequency between “W”, “D”, and “F” grades given was compared within the experimental and control groups using a 2x3 chi-square test of independence. The independent variables were coded as follows: D =1, W = 2, F = 3. It was found that the overall chi-square test was not significant ($X^2(3) = 7.34$, $p = 0.062$).

Table 6

A 2x3 table with frequency variables assessed in the Chi-square test of independence.

	D	W	F
MOSI	0.108	0.077	0.208
No MOSI	0.104	0.162	0.218

Chapter V: Discussion

The purpose of this study was to assess the effectiveness of a mandatory model of online supplemental instruction in an introductory cell and molecular biology course at a community college in Northern Nevada. This was achieved by developing hypotheses which addressed the following three research questions.

1. Are there any differences in the mean GPAs from an Introductory Cell and Molecular Biology course between students who attended MOSI and those who did not?
2. Can Introductory Cell and Molecular Biology student course GPA be predicted by a linear combination of the seven variables (gender, minority status, firs-generation status, age, credit load, student type, number of MOSI sessions attended)? If yes, which variables contribute significantly to the model?
3. Is there a relationship between MOSI attendance and D/W/F rates in Introductory Cell and Molecular Biology as measured by a chi-square test of independence?

Conclusions:

Research Question 1

The results of testing the hypothesis for research question 1 show that there was a significant difference in ICMB course GPA between the experimental and control cohorts. While confounding variables, including number of exams given, number of assignments given, course structure (traditional or flipped), textbook used, professors' use of OSI, and the faculty employment status, exist between the two groups, this finding supports the already robust suite of literature on SI. Further, the existing literature supports and helps make sense of these findings. Previous literature suggests that students must attend at least three SI sessions in a semester to start seeing benefits from SI attendance (Rabitoy, Hoffman, & Person, 2015; Blanc, DeBuhr, & Martin, 1983). In sections offering voluntary OSI over the Fall 2020 and Spring 2021 semesters, students attended OSI only when they chose to. In the control cohort (n=784), this resulted in 3.8% (n=30) of students attending OSI. Therefore, the control cohort had a mean OSI attendance rate of $M = 0.29$ OSI sessions per semester. This is well below the threshold of three sessions per semester. The experimental cohort (n=131) had an attendance rate of 100% (n=131). This is likely explained by the mandatory nature of MOSI. The experimental cohort had a mean MOSI attendance rate of $M = 5.93$ MOSI sessions per semester. While not all students attended all sessions (*Min.* = 1.00), by making OSI mandatory, students were more likely to attend at least three sessions within a semester.

Research Question 2

The overall regression model for the independent variables of gender, minority status, first-generation status, age, credit load, student type, number of MOSI sessions attended was significant ($F(7, 123) = 4.836 = p < 0.001$, $R2 = 0.216$). When the data is disaggregated, patterns which support the current literature emerge. Not only was MOSI attendance a predictor of success, but success was dependent on the number of sessions attended (Rabitoy, Hoffman, & Person, 2015; Blanc, DeBuhr, & Martin, 1983). The unstandardized coefficient ($B = 0.085$) suggests that students can expect to see a small – but cumulative impact – on ICMB course GPA when attending multiple MOSI sessions over the course of the semester.

Further patterns emerge which support current literature on SI. As has been noted previously, traditional SI has a relatively greater impact on student success in female and minoritized student populations (Rath, Peterfreund, Xenos, Bayliss, & Carnal, 2007; Dawson, van der Meer, Skalicky, & Cowley, 2014). Others have shown the positive impact of traditional SI on first-generation students (Yue, Rico, Vang, & Giuffrida, 2018). Until now, the impact of SI on traditionally disadvantaged populations had yet to be demonstrated in the online environment. Here, the impact per visit is reflected in the unstandardized coefficient and is greater in the female ($B = 0.115$) than male ($B = 0.028$) cohort, and the POC ($B = 0.112$) than white ($B = 0.092$) cohort. Moreover, the population of which MOSI had the largest impact was the first-generation cohort ($B = .120$, $\beta = 0.422$) , see Table 5.

The results of the multiple linear regression model used to address question 2 add to and support the suite of SI based literature which suggests that SI attendance is a predictor of student achievement as measured on a 4.0 GPA scale (Lyle & Robinson, 2003; Okada & Channing, 2020; Stanich *et al.,* 2018, Blanc et al., 1983; Congos, 2002; Ning & Downing, 2010; Martin & Arendale, 1992; Malm, 2012; Raitboy, 2012). More importantly, these results provide evidence in support of the hypothesis that MOSI is as effective as in-person SI at improving student achievement (Spaniol-Mathews, Letourneau, & Rice, 2016; Hizer, Schultz, & Bray, 2017). Further, evidence has been provided in this study that MOSI is an effective approach for community college students looking to improve their chances at success (Raitboy, 2012: Raitboy, 2014; Okada & Channing, 2020).

By running numerous multiple regression analyses and disaggregating both student demographic inputs and environmental inputs, it was possible to assess both *who* was being assisted by OSI, and what inputs are most important for student success. Further, given the moderate R^2 value associated with some of these models, this study supports the idea that there are many factors associated with student success.

Demographic and Environmental variables - Gender

This study examined both student demographic variables, and institutional environmental variables in the context of MOSI. Both the demographic and environmental variables assessed in this study had different effects on the sexes. Interestingly, no variable assessed had a statistically significant effect on male ICMB course GPA. This contrasts with the female cohort. Here we see that there is a strong relationship between the number of MOSI sessions attended and ICMB GPA. This could suggest that women are more open to informal academic intervention than their male counterparts. It could also suggest that the inquiry-based small group learning environment, inherent to MOSI, is a learning environment in which women can benefit more than men as has been shown in the past (Ocker, 2001). Moreover, it is interesting to note that age was a statistically significant predictor of women's ICMB course GPA. This was not the case for the male cohort. This aligns with the overall regression model as well which suggests that as age increases ICMB course GPA decreases. This trend also manifests in non-first-generation student population.

Demographic and Environmental variables - Ethnicity

The Persons of Color (POC) and white student cohort both benefitted significantly in proportion to the number of OSI sessions attended. For both cohorts, the number of MOSI sessions attended was their strongest predictor of ICMB course GPA. However, a comparison of R^2 values suggest that MOSI attendance can explain more variance in white student's course GPA than the POC cohorts GPA. This finding contrasts with previous research on traditional SI at community college. Previous research has shown that students who identify as a POC benefit more from SI attendance relative to their white counterparts (Raitboy, 2012; Raitboy, 2014). Credit load also had a significant impact on the POC cohort but did not impact the white student cohort. This is interesting because, like number of OSI sessions attended, credit load is an environmental variable which suggests academic involvement. This implies that POC benefit more than do white students from greater academic involvement on campus given the two environmental variables examined.

One troubling trend in the POC data is the significant impact gender has on IMCB course GPA. The negative standardized correlation coefficient associated with this relationship suggests that the demographic variable of being a woman of color has a negative impact on ICMB course GPA. It is imperative for institutions to take charge and create a learning environment which works for all their students (Ong, Smith, & Ko, 2018).

The environmental variable of credit load was also a predictor of course GPA for the POC cohort. While not as strong a predictor of success as the number of sessions attended, the result is interesting. Both OSI attendance and credit load reflect academic involvement as defined by Astin's Student Involvement Theory (Astin, 1984). Taken together, this data suggests that to do better for students of color, institutions should implement more policies which encourage POC student academic involvement.

Demographic and Environmental variables - 1st Generation Status

In this study, 43.4% of students were first generation. This reflects the college website's statistics and national trends which both suggest that ~50% of community college students are first generation (Crisp & Mina, 2012). Therefore, this is a cohort of students for whom community colleges should be working actively to promote a productive experience. Data from this study suggests that the number of MOSI visits for a first-generation student is the strongest predictor of ICMB course GPA. Further, the R^2 value for the first-generation regression model shows the highest correlation among all cohorts. This is not surprising given that most first-generation students may not have opportunities at home to engage in group learning-based scientific inquiry. Providing this experience on campus increases these opportunities and further involves the student in academics on campus (Orbe, 2004).

Demographic and Environmental variables -MOSI attendance and Credit Load

The environmental variables of number of MOSI sessions attended and credit load were chosen for this study because these are readily available statistics and they both measure a student's level of involvement on campus. As a reminder, a student's level of involvement is a predictor of student success and persistence (Astin, 1984; Tinto, 1997). The data generated suggests significance and a moderate R^2 value for the overall regressions model. In this overall model, only the number of MOSI visits and the student's age range are significant. The number of visits to MOSI is further indicated in this model to be the strongest predictor of student success in ICMB. When the data is disaggregated among cohorts, we see that the number of OSI visits is the strongest predictor of student success in ICMB for all but one of the cohorts – males. This suggests that MOSI is helping students succeed in ICMB relative to the number of sessions attended. This observation is also made in traditional SI programs (Lyle & Robinson, 2003; Stanich *et al.,* 2018; Congos, 2002; Ning & Downing, 2010; Malm, 2012M; Raitboy, 2012).

Research Question Three

Research question three asked if MOSI had any impact on D/F/W rates. Previous literature has argued that traditional SI lowers the DWF rate in STEM courses. This has been shown in many different courses reflecting various STEM disciplines (Stanich *et al.,* 2018, Blanc et al., 1983; Congos, 2002; Ning & Downing, 2010; Martin & Arendale, 1992; Malm, 2012; Raitboy, 2012). Here, the application on OSI in a mandatory format did not result in the observation of a significant relationship between MOSI attendance and lowered DWF rates. The reason for this is likely the small sample sizes associated with specific cohorts in the study. It is hypothesized that a larger sample size could return a significant result.

While not statistically significant, the withdraw rate for students not enrolled in sections which used MOSI was more than double that of students in MOSI sections. This observation touches on the foundations of both Vincent Tinto's departure theory and Steve Astin's theory of student involvement. Among other components of Tinto's theory, it is suggested that students integrating into the campus culture is a feature which promotes student persistence and retention. Tinto suggests that informal academic environments (e.g. office hours, tutoring, SI) are ways to integrate students. MOSI represents an informal academic environment which, theoretically, should reduce the rate of withdraw via integration (Tinto, 1997). While the results presented are not statistically significant, they do suggest that students who attend MOSI withdraw at a lower rate as compared to those who do not. Further, Astin's theory of student involvement states that outcomes are directly proportional to the quantity and quality of student involvement in their academics (Astin, 1984). MOSI represents involvement. In its simplest form, it reflects quantity. When stakeholders apply best practices in SI to a program, it represents quality. It would be interesting to see if the results of question 3 would become significant with a larger sample size.

Limitations of the Study

The data collected in this study were collected over a two-semester period during which time the COVID-19 pandemic forced much of higher education online. The online formats established for MOSI, sections of ICMB which used MOSI, and the control sections, were dynamic over this period as faculty and students found what worked best for them. This likely exacerbated the differences between instructors as defined in the results. This may have resulted in a larger number of variables which could not be controlled for. Further, the lack of a formal exam policy for online learning within the academic department in which this study took place might have influenced the data. While summative exam scores in all sections counted towards the majority of a student's grade, this ranged anywhere from 50% to 80%. The COVID-19 pandemic may also impact the demographic data as more males than females have shunned higher education in the online environment (Note, 2020).

Further impacts to this study related to the COVID-19 pandemic resulted from a grading policy CCNV adopted over the Fall 2020 and Spring 2021 semesters. CCNV allowed all students during the COVID-19 pandemic to have their letter grade changed to an "S" or "U" grade if desired. These grades identified students as passing or not passing a course but gave little insight into what letter grade students earned. Because the "S" and "U" grading scheme does not conform to the research questions of this study, these students were excluded. In total, n=9 students were excluded from the experimental MOSI cohort while n=37 students were excluded from the control cohort.

Students in this study were exclusively students who self-selected into sections of ICMB which either offered MOSI or did not. Therefore, the sample was not randomly selected. Further, true equivalency could not be drawn between the groups due to a lack of prior academic records. Moreover, sample sizes for ethnicity and age-ranges were very small for some cohorts and the results may not reflect those populations accurately.

While nine instructors taught sections which included students in the control cohort, a single instructor (InstructorEXP) developed and implemented MOSI in their sections. All MOSI attending students were drawn from this single instructor's sections. No consistency in pedagogy was established or observed in course syllabi other than the ICMB course learning objectives, the mandate for at least four exams, and course work being delivered online via the learning management system Canvas. Instructor quality, grading schemes, and pedagogical philosophies may all have influenced the results.

An unintended limitation was a direct consequence of making OSI mandatory. Student participation in SI is historically low. Further, students were resistant to signing up for MOSI sections of ICMB which were taught online in a synchronous format and required 3-metings per week. During the registration period, asynchronous ICMB section filled before the MOSI sections filled. This led the MOSI sections instructor to include MOSI attendance in the grading policy for the course and accounted for 10% of the overall grade. While this incentivized students to attend weekly sessions, it also deviated from the grading schemes of instructors who did not use MOSI. It is relevant to note, however, that the impact of adding a grading component to the MOSI sections likely had little effect on the overall GPA for students in MOSI sections. This is because not all students attended all sections, while others did. Therefore, it was just as likely for a given student's grade to be negatively impacted by not attending MOSI as it was for a grade to improve for MOSI attendance.

Recommendations

The most pressing recommendation would be to repeat this study. Since Spring of 2021, the final semester this study took place in, many policies and standardized procedures for online instruction have been implemented at CCNV. Many of these policies would reduce some of the discussed limitations and help generate equivalency among cohorts.

Follow-up studies are also recommended. This study explored the quantitative nature of MOSI, however, the qualitative nature of MOSI was beyond the scope of this work. In this study, it was demonstrated which cohorts of students benefitted from MOSI and to what degree. It would be interesting to examine which features of MOSI have the greatest impact on students' success. For example, the theoretical framework for this study suggests that the quantity and quality of both formal and informal peer-to-peer interactions are a leading predictor of a student's decision to persist. MOSI represents an informal peer-to-peer interaction opportunity, however, there are no studies which deliberately assess if this – or other features – are what lead to the improved student success we see with MOSI or other SI models. A mixed-methods study using MOSI observation and a student questionnaire is suggested to examine the impact of peer interactions.

Further, there are several variables which could be considered either demographic or environmental which could be added to this model. For example, it has been shown that STEM students perform better and persist at higher rates when a course is taught by an instructor who reflects their ethnic identity (Fairlie, Hoffmann, & Oreopoulos, 2014). It would be interesting to see if this effect extends to MOSI. While student ethnicity is a demographic variable, instructor ethnicity represents an environmental variable which institutions have some control over. As stated, the greatest predictive variable for student success in ICMB was the environmental variable of number of MOSI sessions attended. Additional studies should aim to quantify the impact of MOSI across STEM.

A persistent issue with traditional SI is faculty and student buy-in (Freeman, et al., 2014). At CCNV, the use of traditional SI among faculty and students has been low. For faculty, running SI in any format takes extra time and resources. And the students who would benefit the most from SI rarely attend. A mixed-methods study investigating avenues to incentivize MOSI use for faculty and administrators could be carried out to increase buy-in among these cohorts. At the University of Kansas Missouri-City, SI leaders, SI trainers, and faculty are all provided income for the extra work they put into the systems' students (UKMC, 2021). The University of Washington also pays their faculty and administrators for developing, implementing, managing, and sustaining an on-campus SI program (Freeman, 2014). Further, students at these institutions are incentivized through SI education at the beginning of the semester. This is done either in-person by a trained SI leader or through a professionally developed video shown on the first day of class. Here, students are educated about the benefits of SI and told what they can expect to get out of SI from a student achievement and study skills development perspective (UKMC, 2021).

Community college system leaders could look at implementing strategies to market MOSI to students and faculty. The college where this research took place is an HSI. The Hispanic student population is heavily involved in clubs and school sports. Targeting events held by these clubs would help target one of the populations that stands to benefit most from MOSI. Further, faculty at this campus are very engaged with issues of diversity, equity, and inclusion (DEI). Establishing a marketing presence for MOSI at faculty lead events which celebrate DEI would be another option for directed marketing to increase buy-in.

References

ACT. (2018). The condition of college and career readiness: National 2018.

Awidi, I. T., & Paynter, M. (2019). The impact of a flipped classroom approach on student learning experience. *Computers & Education*, *128*, 269-283.

Astin, A. (1993). What matters in college: Four critical years revisited. *San Fran.*

Avalos, J. (1996). *The effects of time-to-degree completion, stopping out, transferring, and reasons for leaving college on long-term retention, educational aspirations, occupational prestige, and income*. University of California, Los Angeles.

Arne Duncan. (2009). *The Race to the Top Begins—Remarks by Secretary Arne Duncan*.

Arvizu, D., & Bowen, R. (2014). National Science Board. *Science and Engineering Indicators 2014.*

Bailey, T., Jenkins, D., & Leinbach, T. (2005). What We Know about Community College Low-Income and Minority Student Outcomes: Descriptive Statistics from National Surveys. *Community College Research Center*.

Barack Obama. (2013). *Third Annual White House Science Fair*.

Blanc, R. A., DeBuhr, L. E., & Martin, D. C. (1983). Breaking the Attrition Cycle: The effects of supplemental instruction on undergraduate performance and attrition *The Journal of Higher Education*, *54*(1), 80-90

Boulton, C. A., Hughes, E., Kent, C., Smith, J. R., & Williams, H. T. (2019). Student engagement and wellbeing over time at a higher education institution. *Plos One*, *14*(11), e0225770.

Brakke, D. F., & Halpern, L. C. (2014). Improving success of students in introductory mathematics and statistics courses. *Peer Review*, *16*(3), 13-17.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. *Colorado Springs, Co: BSCS*, *5*, 88-98.

Congos, D. H. (2002). How supplemental instruction stacks up against Arthur Chickering's 7 principles for good practice in undergraduate education. *Research and Teaching in Developmental Education*, *19*(1), 75-83.

Dawson, P., van der Meer, J., Skalicky, J., & Cowley, K. (2014). On the effectiveness of supplemental instruction: A systematic review of supplemental instruction and peer-assisted study sessions literature between 2001 and 2010. *Review of educational research*, *84*(4), 609-639.

Eddy, P. L. (2014). Book Review: The American community college by Cohen, AM, Brawer, FB, & Kisker, CB.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior research methods*, *39*(2), 175-191.

Field, K. (2018). A third of your freshmen disappear. How can you keep them. *The Chronicle of Higher Education*, *8*.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410-8415.

Ginder, S. A., Kelly-Reid, J. E., & Mann, F. B. (2015). Enrollment and Employees in Postsecondary Institutions, Fall 2014; and Financial Statistics and Academic Libraries, Fiscal Year 2014. First Look (Provisional Data). NCES 2016-005. *National Center for Education Statistics*.

Goldstein, J., Sauer, P., & O'Donnell, J. (2012). Supplemental Instruction, Collegiate Integration and Intent to Persist. *The BRC Academy Journal of Education*, *2*(1), 1-36.

Guiffrida, D. A. (2006). Toward a cultural advancement of Tinto's theory. *The Review of Higher Education*, *29*(4), 451-472.

Gupta, T., & Hartwell, S. K. (2019). Enhancing Student Retention in General and Organic Chemistry: An Introduction. In *From General to Organic Chemistry: Courses and Curricula to Enhance Student Retention* (pp. 1-12). American Chemical Society.

Hayes, R. T., & Randall, D. W. (2019). Low DWF rate general chemistry course: it is possible. In *From General to Organic Chemistry: Courses and Curricula to Enhance Student Retention* (pp. 33-46). American Chemical Society.

Hernandez, P. R., Schultz, P. W., Estrada, M., Woodcock, A., & Chance, R. C. (2013). Sustaining optimal motivation: A longitudinal analysis of interventions to broaden participation of underrepresented students in STEM. *Journal of Educational Psychology*, *105*(1), 89.

Hinton, A. O., Termini, C. M., Spencer, E. C., Rutaganira, F. U. N., Chery, D., Roby, R., Vue, Z., Pack, A. D., Brady, L. J., Garza-Lopez, E., Marshall, A. G., Lewis, S. C., Shuler, H. D., Taylor, B. L., McReynolds, M. R., & Palavicino-Maggio, C. B. (2020). Patching the Leaks: Revitalizing and Reimagining the STEM Pipeline. *Cell*, *183*(3), 568-575.

Hizer, S. E., Schultz, P. W., & Bray, R. (2017). Supplemental instruction online: as effective as the traditional face-to-face model?. *Journal of Science Education and Technology*, *26*(1), 100-115.

Horn, L., & Skomsvold, P. (2011). Community college student outcomes: 1994-2009. *Washington, DC: National Center for Education Statistics*.

Augustine, N. R. (2007). Is America falling off the flat earth? National Academies Press.

Kahu, E. R., & Nelson, K. (2018). Student engagement in the educational interface: understanding the mechanisms of student success. *Higher education research & development*, *37*(1), 58-71.

Kampelmann, S., Rycx, F., Saks, Y., & Tojerow, I. (2018). Does education raise productivity and wages equally? The moderating role of age and gender. *IZA Journal of Labor Economics*, *7*(1), 1-37.

Kim, M. M. (2015). Peer tutoring at colleges and universities. *College and University*, *90*(4), 2.

Krishnan, P. (2019). A review of the non-equivalent control group post-test-only design. *Nurse Researcher*, *26*(2).

Luy, M., Zannella, M., Wegner-Siegmundt, C., Minagawa, Y., Lutz, W., & Caselli, G. (2019). The impact of increasing education levels on rising life expectancy: a decomposition analysis for Italy, Denmark, and the USA. *Genus*, *75*(1), 1-21

Ma, Y., & Liu, Y. (2017). Entry and Degree Attainment in STEM: The Intersection of Gender and Race/Ethnicity. *Social Sciences*, *6*(3), 89

Malm, J., Bryngfors, L., & Mörner, L.-L. (2012). Supplemental instruction for improving first year results in engineering studies. *Studies in Higher Education*, *37*(6), 2.

Martin, D. C., & Arendale, D. R. (1992). Supplemental Instruction: Improving First-Year Student Success in High-Risk Courses. The Freshman Year Experience: Monograph Series Number 7.

Mervis, J. (2011). Weed-out courses hamper diversity.

McKinney, L., Burridge, A. B., Lee, M. M., Bourdeau, G. V., & Miller-Waters, M. (2022). Incentivizing Full-Time Enrollment at Community Colleges: What Influences Students' Decision to Take More Courses? *Community College Review*, *50*(2), 144-170.

Milem, J. F., & Berger, J. B. (1997). A modified model of college student persistence: Exploring the relationship between Astin's theory of involvement and Tinto's theory of student departure. *Journal of college student development*, *38*(4), 387.

Mooney, G. M., & Foley, D. J. (2011). Community colleges: Playing an important role in the education of science, engineering, and health graduates. *See http://www. nsf. gov/statistics/infbrief/nsf11317/(accessed 23 October 2015)*.

Morris, N. P., Ivancheva, M., Coop, T., Mogliacci, R., & Swinnerton, B. (2020). Negotiating growth of online education in higher education. *International Journal of Educational Technology in Higher Education*, *17*(1), 1-16.

Ning, H. K., & Downing, K. (2010). The impact of supplemental instruction on learning competence and academic performance. *Studies in Higher Education*, *35*(8), 929-931.

O'Keeffe, P. (2013). A sense of belonging: Improving student retention. *College Student Journal*, *47*(4), 605-613.

Paloyo, A. R. (2015). A note on evaluating supplemental instruction. *Journal of Peer Learning*, *8*(1), 1-4.

Pascarella, E., Edison, M., Nora, A., Hagedorn, L & Terezini, P. (1996). Influences on students' openness to diversity and challenge in the first year of college. The Journal of Higher Education, *67*, 174-195.

Peter Riley Bahr, Grant Jackson, Jon McNaughtan, Meghan Oster & Jillian Gross (2017) Unrealized Potential: Community College Pathways to STEM Baccalaureate Degrees, The Journal of Higher Education, *889*(3), 430-478.

Rabitoy, E. R., Hoffman, J. L., & Person, D. R. (2015). Supplemental instruction: the effect of demographic and academic preparation variables on community college student academic achievement in stem-related fields. *Journal of Hispanic Higher Education*, *14*(3), 240-255.

Rath, K. A., Peterfreund, A. R., Xenos, S. P., Bayliss, F., & Carnal, N. (2007). Supplemental instruction in introductory biology I: Enhancing the performance and retention of underrepresented minority students. *CBE—Life Sciences Education*, *6*(3), 203-216.

Riegle-Crumb, C., King, B., & Irizarry, Y. (2019). Does STEM Stand Out? Examining Racial/Ethnic Gaps in Persistence Across Postsecondary Fields. *Educational Researcher*, *48*(3), 133–144.

Rouse, C. E. (1995). Democratization or diversion? The effect of community colleges on educational attainment. *Journal of Business & Economic Statistics*, *13*(2), 217-224.

Schleicher, A. (2019). PISA 2018: Insights and Interpretations. *oecd Publishing*

Spaniol-Mathews, P., Letourneau, L. E., & Rice, E. (2016). The Impact of Online Supplemental Instruction on Academic Performance and Persistence in Undergraduate STEM Courses. *Grantee Submission*, *2*(1), 19-32.

Stanich, C. A., Pelch, M. A., Theobald, E. J., & Freeman, S. (2018). A new approach to supplementary instruction narrows achievement and affect gaps for underrepresented minorities, first-generation students, and women. *Chemistry Education Research and Practice*, *19*(3), 846-866.

Starobin, S., & Laanan, F. S. (2005). Influence of precollege experience on self-concept among community college students in science, mathematics, and engineering. *Journal of Women and Minorities in Science and Engineering*, *11*(3).

STATISTICS, U. B. O. L. (2015). Women in the labor force: A databook. *Retrieved from*.

Terrion, J. L., & Daoust, J. L. (2011). Assessing the impact of supplemental instruction on the retention of undergraduate students after controlling for motivation. *Journal of College Student Retention: Research, Theory & Practice*, *13*(3), 311-327.

Thompson, M. E. (2021). Grade Expectations: The Role of First-Year Grades in Predicting the Pursuit of STEM Majors for First- and Continuing-Generation Students. *The Journal of Higher Education*, *92*(6), 961-985.

Tinto, V. (1986). Theories of student departure revisited. *Higher education: Handbook of theory and research*, *2*(359-384).

Tinto, V. (1987). *Leaving college: Rethinking the causes and cures of student attrition*. University of Chicago Press, 5801 S. Ellis Avenue, Chicago, IL 60637.

Tinto, V. (1993). Building community. *Liberal education*, *79*(4), 16-21.

Tinto, V. (1997). Classrooms as communities: Exploring the educational character of student persistence. The Journal of Higher Education, *68*(6), 599-623.

Tinto, V. (1998). Colleges as communities: Taking research on student persistence seriously. *The review of higher education*, *21*(2), 167-177.

Tinto, V. (2005). *College student retention: Formula for student success*. Greenwood publishing grouP.

Tinto, V. (2017). Through the eyes of students. *Journal of College Student Retention: Research, Theory & Practice*, *19*(3), 254-269.

Townsend, B. K. (2008). Feeling like a freshman again": The transfer student transition. New Directions for Higher Education, *2008*(144), 69–77.

Vance, L. K. (2016). *Best practices in tutoring services and the impact of required tutoring on high-risk students* (Doctoral dissertation, Eastern Kentucky University).

Yue, H., Rico, R. S., Vang, M. K., & Giuffrida, T. A. (2018). Supplemental instruction: Helping disadvantaged students reduce performance gap. *Journal of Developmental Education*, 18-25.

Wang, X. (2015). Pathway to a baccalaureate in STEM fields: Are community colleges a viable route and does early STEM momentum matter? *Educational Evaluation and Policy Analysis*, *37*(3), 376-393.

Wang, X. (2017). Toward a holistic theoretical model of momentum for community college student success. *Higher education: Handbook of theory and research*, 259-308.

Weston, T. J., Seymour, E., Koch, A. K., & Drake, B. M. (2019). Weed-out classes and their consequences. In *Talking about leaving revisited* (pp. 197-243). Springer, Cham.

Zaritsky, J. S., & Toce, A. (2006). Supplemental instruction at a community college: The four pillars. *New Directions for Teaching and Learning*, *2006*(106), 23-31.

Zhang, Y. L. (2019). Early Academic Momentum: Factors Contributing to Community College Transfer Students' STEM Degree Attainment. *Journal of College Student Retention: Research, Theory & Practice*, *23*(4), 873-902.