CAREER: Second Chance STEM: Uncovering school policies structuring access to and engagement in high school STEM credit recovery

Project Description

Course failure is common in high school, particularly among minoritized students, a trend exacerbated by the COVID-19 pandemic with reports of high school students failing up to half of their courses in the 2020-21 school year (Belsha, 2022; Borter & O'Brien, 2021; Gross, 2021; St. George, 2020; Thompson, 2020; Viano, 2021). Credit recovery refers to courses students retake because of previous course failure. While credit recovery has traditionally been face-to-face (F2F), retaking courses virtually through online credit recovery (OCR) has become increasingly popular (*Issue Brief: Credit Recovery*, 2018; Tyner & Munyan-Penney, 2018; Viano, 2021). OCR is a potentially problematic replacement for F2F instruction if courses are low quality, particularly for STEM courses that often assume a prior sound foundation and are essential for secondary STEM learning necessary to transition into a STEM career (Allensworth & Easton, 2005; Bowen et al., 2019; Redmond-Sanogo et al., 2016). The purpose of this CAREER proposal is to develop a deeper understanding of STEM credit recovery school-level policy, particularly for minoritized students, while developing mixed methods STEM policy frameworks allowing similar analyses on other significant questions on school-level STEM policy.

This research will include a series of three studies over five years with the goal of understanding how to catalyze STEM interest, learning, and participation of students who fail STEM courses but deserve a second chance. In the first study, through a partnership with a [redacted] school district, I will identify school policies and engagement approaches for STEM credit recovery (Aim 1). The second study will translate these findings into a survey instrument that I will develop, pilot, and validate for measuring these policies in other contexts (Aim 2). In the third study, I will field the survey with a nationally representative sample of high school leaders to assess nationwide trends in STEM credit recovery policy (Aim 3). Throughout these three studies, I will develop the capacities of graduate students in each of these areas, particularly mixed methods STEM policy analysis (Aim 4). This project will revolutionize our understanding of STEM credit recovery policy, allowing for the development and testing of transformative practices for STEM OCR to increase participation in STEM for minoritized students.

Overview and Significance

One of the most consistent, concrete challenges high school administrators face is helping students to meet minimum course credit requirements to graduate high school. While F2F credit recovery has been common for decades, my research in North Carolina found OCR was just as popular as F2F credit recovery by the 2016-17 school year (Viano, 2021).

As OCR has become an increasingly popular credit recovery intervention, many have expressed a great deal of concern about OCR course quality compared to F2F courses. When the online periodical *Slate* did a series on OCR, they wrote that OCR has "a disturbing lack of quality control" with "a whole generation of students being let down by a system that prioritizes graduation over knowledge" (Kirsch, 2017; Smiley, 2017). Correlational studies confirm this suspicion, finding OCR is associated with lower test scores, lower postsecondary enrollment rates, and lower earnings (Heinrich et al., 2019; Heinrich & Cheng, 2022; Heinrich & Darling-Aduana, 2021). My research found the negative test score changes associated with OCR are particularly pronounced in Biology with OCR students scoring almost two-tenths of a standard deviation lower than F2F credit recovery students (Viano & Henry, 2020).

However, OCR has several attractive features including the ability to complete courses during non-traditional hours and skip previously mastered topics. In fact, similarly correlational research finds OCR students are more likely to earn course credit and graduate from high school (Hart et al., 2019; Heinrich et al., 2019; Heinrich & Darling-Aduana, 2021; Viano, 2021; Viano & Henry, 2020). In other words, OCR can be a "lifeline for struggling students" (Loewenberg, 2020).

We have little understanding of how to maximize the positive aspects of OCR and minimize the negative, but schools likely have policies in place for this purpose (Malkus, 2019; Sproull, 2018). My preliminary research suggests school-level policies on OCR enrollment might contain significant nuance based on the course and the student needing credits (Viano, 2021). Decisions on OCR/F2F enrollment are likely influenced by course subject since STEM courses are characterized by the sequential accumulation of knowledge and/or tactile laboratory experiences (Hofstein & Lunetta, 2004; Stevenson et al., 1994). Tradeoffs between efficiency of credit remediation and learning might be even more pronounced for minoritized students: historically denied high-quality educational opportunities, particularly in tracked mathematics and science courses, and monitored subgroups for high-stakes assessments (Lauen & Gaddis, 2012; Schneider et al., 1997).

The nascent research on online learning in secondary schools suggests schools take a variety of approaches to course administration, who has access to these tools, and the extent of student engagement in online courses (Borup et al., 2020; Burch et al., 2016; Darling-Aduana, 2019; Darling-Aduana et al., 2019; Heinrich et al., 2019; Viano, 2021). Although a deep research base addresses engagement in F2F STEM courses (e.g., Kelly & Zhang, 2016; Sinatra et al., 2015; Wang et al., 2016), it is less clear how schools are facilitating engagement in online learning (Martin, 2022; Veletsianos et al., 2022). Previous efforts to collect data on OCR were hampered by poorly defined measures that did not differentiate between OCR and F2F credit recovery or did not take into account the OCR policy context (Tyner & Munyan-Penney, 2018). Recent efforts to understand OCR policy have focused at the district-level in districts with high credit recovery participation with no similar data at the school-level (Malkus, 2019). Developing effective STEM OCR policies has the potential to benefit minoritized students failing STEM courses through increased course passing and graduation rates without the negative STEM learning outcomes.

This CAREER project using innovative mixed methods policy analysis methodologies will measure these enrollment/engagement approaches, exploring these policies' association with STEM learning and other outcomes while also attending to courses' culturally sustaining practices to increase positive outcomes for minoritized students. Better measures of STEM OCR policy will increase understanding of STEM credit recovery nationwide. This research will facilitate the discovery of potentially transformative policies and innovations to increase the likelihood that students who fail courses are truly given a second chance to address their unfinished learning, a necessary precursor to succeed in subsequent STEM courses and broaden participation for minoritized students in STEM careers.

Conceptual Framework

1. Policy Context of STEM Credit Recovery for Minoritized Students

1.1 Population of Interest: Minoritized Students Who Fail STEM Courses. STEM course failure in high school has been a consistent barrier to STEM learning and participation in STEM fields (Allensworth & Easton, 2005; Bowers, 2010; Neild et al., 2001). At the same time, course failure is very common: 21% of high school students in the Study 1 school district failed a STEM course between 2016-17 and 2020-21.

Course failure rates are not consistent across students, tending to be higher for minoritized student populations (Márquez-vera et al., 2013; Viano, 2021). I use the term *minoritized* across this narrative to reflect how certain student attributes are defined societally as outside of the norm. These classifications are context specific, and, in the US context, often includes emergent bilingual students (often referred to as English language learners), students who receive special education services, and students with racial identities of Black and Hispanic. Within the aforementioned time period in the participating school district for Study 1, all minoritized populations had higher STEM course failure rates, often 2 to 3 times the rates of the majoritized group, see Figure 1. Focusing on minoritized students is essential for understanding specific innovations that will broaden STEM participation to maximize effectiveness through supporting assets-based approaches (Gay, 2010; Ladson-Billings, 2012; Milner, 2012).

Figure 1. STEM Course Failure Rates, 2016-17 to 2020-21

1.2 Credit Recovery Assignment, Engagement, and Outcomes. Prior studies of credit recovery assignment have focused on observable characteristics using surveys or secondary data (e.g., Stevens et al., 2016). For instance, one of my recent publications explored the correlates of OCR versus F2F enrollment in the state of North Carolina using administrative data, finding Black students and students with more absences were more likely to enroll in OCR over F2F credit recovery (Viano, 2021). Prior interviews with district leaders indicate a range of approaches to credit recovery enrollment, including some who explicitly consider factors like student attendance and grade level (Viano, 2021). I will extend this work by measuring OCR assignment policies, based on interviews with school leaders on how they decide whether to assign students to OCR or F2F credit recovery, in addition to secondary data.

Much of the heterogeneity in school policies on credit recovery are related to course engagement approaches, ranging from OCR courses being in classrooms with a subject expert instructor to neither scheduled class time nor supervision (Gemin & Pape, 2017; Murin et al., 2015). Prior studies provide useful frameworks for measuring OCR engagement including observational tools for assessing engagement with online content and measures from course management software (Darling-Aduana et al., 2019; Heinrich et al., 2019; Levine et al., 2017). This study will contribute to this literature by comparing observations of OCR and F2F engagement and linking assignment policies with pedagogical approaches and course engagement.

The bulk of prior work on STEM credit recovery has attended to the effectiveness of OCR versus F2F credit recovery. Two randomized control trials (RCTs) have compared the efficacy of OCR for Algebra I in Chicago and Los Angeles, finding few differences in outcomes between those randomly assigned to OCR compared to F2F (Rickles et al., 2018, 2020). As opposed to eliminating differences caused by endogenous assignment, I seek to measure assignment to aid in developing future interventions and causal studies on the effects of credit recovery policy. For instance, it is possible that OCR is most effective when targeted at chronically absent students, and I will seek to identify the prevalence of those kinds of specific assignment decisions. Developing a greater understanding of assignment and engagement approaches will also aid future research reconciling the RCT findings with results from quasi-experimental studies that OCR led to higher graduation rates but lower end of course exam scores, ACT scores, and four year college enrollment (Hart et al., 2019; Heinrich & Darling-Aduana, 2021; Viano & Henry, 2020). This study will also complement prior literature by exploring potential relationships between enrollment and engagement policies and STEM learning outcomes.

1.3 STEM Credit Recovery and Online Learning. With the exception of the RCTs, prior literature has examined OCR enrollment monolithically. Schools potentially have different policies for STEM credit recovery, and the relative effectiveness of OCR versus F2F is likely distinct for STEM courses. The sequential nature of mathematics courses might affect assignment because schools might feel more time pressure for students to remediate mathematics courses thus preferring OCR (e.g., reports in Belsha, 2022) or, conversely, want students to have assistance from a F2F mathematics instructor who can help to explain content (Hill et al., 2008). While science courses are not necessarily sequentially aligned, schools might be more hesitant to enroll students in science OCR because of the lack of the tactile laboratory experience (Biel & Brame, 2016; Crippen et al., 2013; Faulconer et al., 2018). Schools might also be observing the relative efficacy of OCR by subject. In prior work in North Carolina, I found student end of course exam scores were up to two tenths of a standard deviation lower for Biology OCR compared to F2F, associations that were much smaller for English II and Math I (Viano & Henry, 2020). In the Study 1 school district, 43% of online course enrollments were in science or mathematics. This focus will provide specific information on understanding STEM credit recovery learning environments to help broaden STEM participation, post-credit recovery enrollment.

2. Cultural Sustaining Pedagogy in STEM and Online Learning

2.1 Culturally Sustaining Pedagogy. Culturally sustaining pedagogy (CSP), often referred to as culturally relevant pedagogy, is a set of practices and competencies supporting relevant and responsive instruction (Gay, 2010; Ladson-Billings, 1995; Paris, 2012; Paris & Alim, 2014). CSP was developed to counter deficit-oriented pedagogy, with CSP extending assets-driven educational philosophy into praxis to tightly couple high expectations for academic success with preservation of cultural identity (Gay, 2010; Ladson-Billings, 1995; Paris, 2012). Prior studies on CSP and CSP-adjacent practices have confirmed the efficacy of these approaches for minoritized student engagement and academic success (Aronson & Laughter, 2016; Clark, 2017; Dee & Penner, 2017; Hipolito-Delgado & Zion, 2017; Voight & Velez, 2018). This study is situated at the intersection of several CSP strands including CSP in STEM and online learning for minoritized students.

2.2 Culturally Sustaining Pedagogy in STEM. A rich literature explores the practices, frameworks, and training associated with effective CSP in mathematics and science (Brown et al., 2018; Brown & Crippen, 2017; Chinn, 2006; Hernandez et al., 2013; C. C. Johnson, 2011; Laughter & Adams, 2012; Mensah, 2011; Nam et al., 2013; Nasir & de Royston, 2013). One challenge in integrating CSP into OCR is successful CSP practices are often framed as experiential or inquiry based, learning modalities that do not naturally lend themselves to an asynchronous environment (Brown, 2017; Fusco, 2001; Williams et al., 2018).

2.3 Culturally Sustaining Pedagogy in Online Learning. Compared to the literature on CSP in STEM, we know little about CSP in online learning in secondary schools, especially asynchronous online learning. While studies rarely use specific terminology related to CSP (exceptions include Darling-Aduana et al., 2020; Lawrence, 2017; Scott & White, 2013), they often examine similar concepts from CSP (Gay, 2010; Ladson-Billings, 1995). For instance, studies have explored online learning integrating students' dialects, caring teaching practices, and communication approaches (Borup et al., 2014; DiPietro et al., 2008; Finkelstein et al., 2013; Velasquez et al., 2013). I build most directly on recent studies evaluating cultural responsiveness of four courses developed by a private asynchronous course provider (a different course provider than the provider in Study 1) and the CSP-related practices of secondary, online teachers in a virtual school (Darling-Aduana et al., 2020; Lawrence, 2017). I will complement this research by integrating data on teaching practices and course content. Based on this prior literature, I focus on three aspects of CSP most aligned with asynchronous courses: curriculum, instructional tasks, and assessment.

3. Relevant Theories

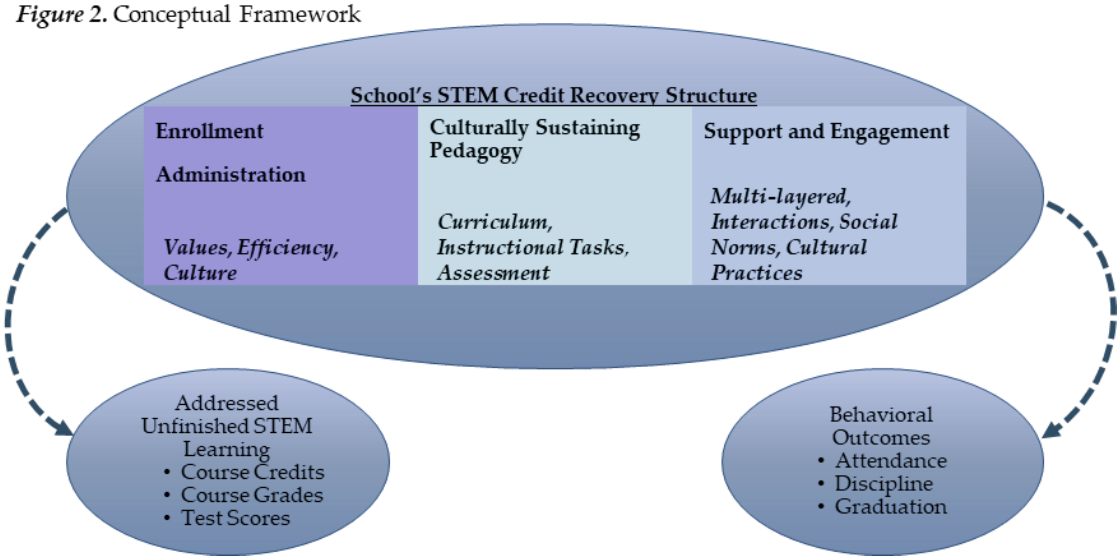
3.1 New Institutionalism in Education. Borrowing from new institutionalism in education (Burch, 2007; Meyer & Rowan, 2006), educational institutions have various configurations based on the preferences of the collective actors who guide the institution. Certain configurations are privileged over others with the empirical question of whose interests those arrangements best serve. Educational institutions have rules and procedures in place that are at least partially motivated by values and cultural beliefs. These perspectives likely inform credit recovery enrollment and administrational policies. Administrators, as institutional actors, make rules about who has access to OCR or F2F and how courses will be structured. These micro-institutional administrative decisions are informed by efficiency, values, and cultural beliefs (Burch, 2007). In this study, I will assess what administrators understand to be efficient, what values they have on how courses should be structured and who should have access, and the cultural beliefs that guide what they value and believe to be efficient.

3.2 Sociocultural Theory. A sociocultural perspective is quite informative when considering the support and engagement aspects of credit recovery, as it conceptualizes learning through interactions, social norms, and cultural practices (Rogoff, 2003; Vygotsky, 1980; Wertsch, 1998). I use sociocultural theory to explicate the multi-layered nature of STEM OCR with online instruction, in-person monitoring, and peer interactions. Sociocultural theory will help to recognize the hierarchies, structures, conventions, and norms that inform engagement and support approaches (Borup et al., 2020). While, in some ways, taking a sociocultural perspective represents a predominant framing for understanding learning contexts, applying this framing to OCR makes this study fall under a line of inquiry specifically attuned to the needs of minoritized students.

4. Integrated Conceptual Framework

The conceptual framework of this project (see Figure 2) combines each of the frameworks described above into a proposed iterative process through which schools make policy decisions on STEM courses that I hypothesize directly impacts STEM learning, participation, and other outcomes. This project is exploratory, theory building, and field building with a focus on heightening our understanding of credit recovery STEM policy structures and their potential linkages to STEM learning and other outcomes. This will allow both the development of STEM credit recovery policy interventions and future impact studies of their subsequent effectiveness.

Figure 2. Conceptual Framework



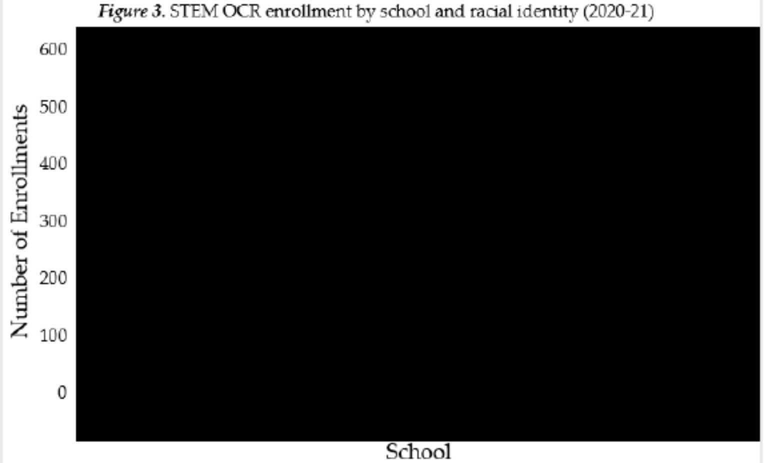
Research Plan

The research plan includes three sequential studies that each satisfy the first three aims of this proposal. (1) The study will begin with comparative, mixed methods case studies of high schools to address the research questions: How do schools structure STEM credit recovery enrollment, administration, engagement, and CSP? To what extent are OCR versus F2F enrollment, OCR engagement, and STEM credit recovery policy structures associated with differential STEM learning and behavioral outcomes? (2) Through this theory building, I will have the necessary information to develop a survey instrument to more widely measure these school-level policies at high schools to address the research question: What is the most efficient way to measure STEM OCR policy in a survey of school principals? After piloting and validating this instrument, (3) this survey will be distributed to a nationally representative sample of high school principals to address the questions: How are school principals structuring STEM credit recovery policy nationwide? To what extent is STEM credit recovery policy correlated with school demographics and indicators of educational equity? Each study will incorporate graduate research assistants with the "research team" referring to the joint work of the PI and the research assistants.

Study 1, Years 1 and 2: Building Theory on School-Level STEM Credit Recovery Policy

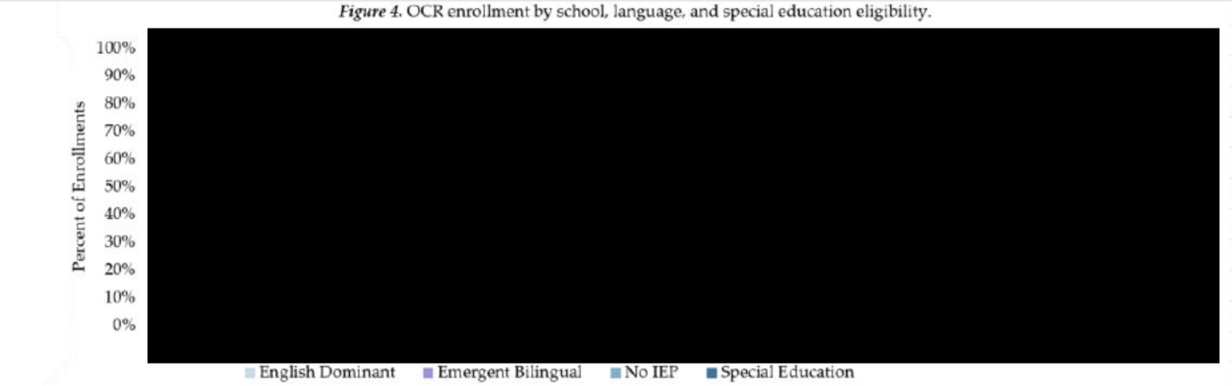
Setting. An ideal setting for this study would include schools that offer OCR and have autonomy on school-level policy decisions on OCR enrollment, administration, and engagement. At the same time, a more complete understanding of engagement would ideally be of an online class with a seat time component to observe course taking in real time. Given these criteria, the research partner is a [redacted] high schools that all offer OCR. [redacted] the district mandates is that all OCR students must at least partially complete their asynchronous online course in a physical classroom with a monitor, allowing for in-person observations of classrooms.

Figure 3. STEM OCR enrollment by school and racial identity (2020-21)



[redacted] Initial data analysis confirms schools likely take a variety of approaches to OCR enrollment. According to data on enrollment in online courses from 2020-21, the average high school had 164 online STEM course enrollments, but three schools had over 300 enrollments and half of schools had less than 100 (Figure 3). Schools tended to enroll slightly higher percentages of emergent bilingual and students qualifying for special education services in STEM OCR compared to their enrollment in each school (Figure 4, bars are OCR enrollment and the table shows overall school enrollment by student status).

Figure 4. OCR enrollment by school, language, and special education eligibility.



Total Enrollment %	[redacted]
Emergent Bilingual	
Special Education	

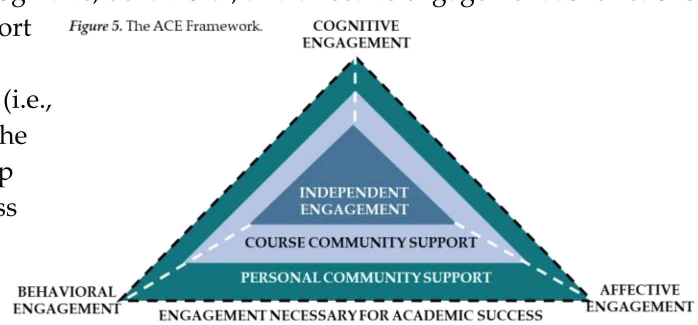
I have an established research partnership with this school district with approval from the district and university IRB to conduct interviews and classroom observations as well as access the online course management system and administrative data. In December 2020 and July 2022, I created reports for district leaders detailing online course enrollment and engagement using online course management and administrative data – with Figures 1, 3, 4, and 6 representing some of this pilot data analysis.

Design. This study design uses qualitative and quantitative data in the style of the fully integrated mixed methods research design (Burch & Heinrich, 2015). This design recognizes the complexity inherent in the interplay of OCR enrollment, administration, engagement, and outcomes. I selected this design in order to increase the relevance of the findings for school administrators, district leadership, and other education policymakers (Burch & Heinrich, 2015; R. B. Johnson & Onwuegbuzie, 2004). The mixed method design will most closely resemble the exploratory sequential mixed methods study design (Creswell & Plano Clark, 2011). The research study will begin with collection and analysis of qualitative data (interviews, observations) followed by iterative integration of quantitative data (online course management data, administrative data). The intent of this design is to focus on exploring and building up theory. While I will do some initial hypothesis testing as I integrate quantitative data, this phase will be exploratory and similarly intended to build theory on potential relationships between policy and outcomes that could then be tested in future studies using designs better suited for causal claims.

Data Collection and Measures. Data collection will occur in all [redacted] high schools. The research team will conduct interviews to measure OCR enrollment and course administration with at least one administrator at each school in charge of OCR enrollment and at least one administrator who decides on how the OCR course will be administered. These interviews will seek to assess how values, efficiency, and culture inform OCR enrollment/administration, and how minoritized status is part of decision making. All interviews will be semi-structured with interview protocols to guide the conversation.

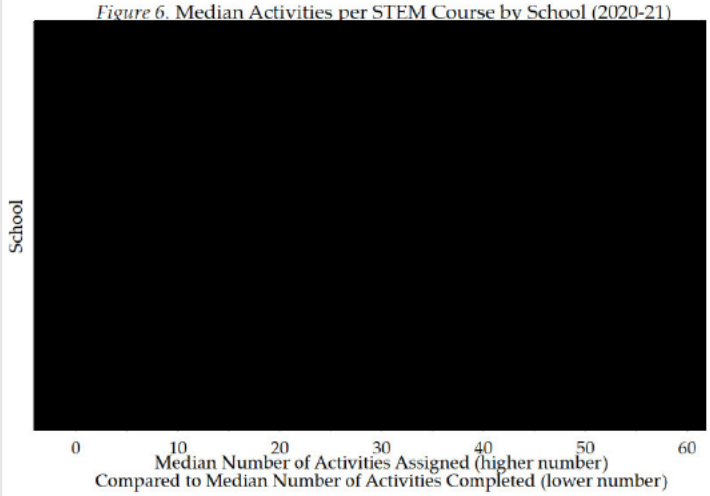
The team will conduct at least eight classroom observations of OCR classrooms at each high school and interview the OCR classroom monitors to measure support and engagement, the third element in the conceptual framework. I will develop a classroom observation protocol aligned with sociocultural theory, specifically through the Academic Communities of Engagement (ACE) framework with the assistance of the project consultant, Dr. Jered Borup. ACE is a useful heuristic for assessing support and engagement in online learning especially since it integrates a sociocultural perspective on culture and learning (Borup et al., 2020; Lokey-Vega et al., 2018; Zhang et al., 2018). ACE is designed to interpret context and culture of online learning spaces through indicators of cognitive, behavioral, and affective engagement as functions of independent, course, and community support (see Figure 5). The observation protocol will include quantitative measures of engagement (i.e., checklists, counts) and qualitative narratives the OCR classroom environment. I will co-develop the observation protocol and continually assess validity and reliability with the project consultant. Validity will be assessed through member checking with the classroom monitor and data from the course management system from that class period. The team members who conduct the pilot exercises will jointly update the protocol and training exercises for inter-rater reliability.

Figure 5. The ACE Framework.



I also assess engagement in OCR courses using data from the online course management system including how much active time students spend on the course, how often they log in, and completion of course activities. See Figure 6 for an example of course engagement data showing the median number of assigned activities in each STEM course by school compared to the median number of completed

Figure 6. Median Activities per STEM Course by School (2020-21)



activities. These measures help to define the multi-layered nature of interactions with the online course. I have continual access to these data with final data on courses available as the courses are completed.

CSP in OCR courses will be assessed using the Online Curricular Responsiveness and Relevance Protocol (OCRRP). Researchers developed OCRRP to measure online asynchronous course integration of CSP (Darling-Aduana et al., 2020). The review of lessons in STEM OCR courses using OCRRP will produce numeric scores for three CSP constructs: curriculum content, instructional tasks, and assessment (see Figure 2). To obtain similar measures for comparisons to F2F, the research team will conduct at least eight observations of STEM classrooms at each school with a significant proportion of F2F credit recovery students in the class (identified by school administrators). I will use an observation protocol aligned to CSP – the Culturally Responsive Instruction Observation Protocol (CRIOP). This tool evaluates the extent to which classrooms are integrating CSP in relationships, family collaborations, assessments, instruction, discourse, and critical consciousness (Powell et al., 2013, 2016). Others have used CRIOP to study CSP in secondary science classrooms (Brown & Crippen, 2017; Stepp & Brown, 2021). CRIOP produces a series of numeric scores for six CSP constructs, including the three from OCRRP.

Administrative data from the school district includes student covariates and outcomes for all high school students including whether the student earned course credit, attendance, disciplinary records, course grades, end of course exam scores, and graduation status. The state administers end of course exams at the completion of the associated course. These assessments are developed by the state department of education with contractors who annually assess the reliability and validity of each exam (Virginia Department of Education, n.d.). While OCR students take assessments in the courseware system, the reliability and validity of these assessments are unknown and will not be included in the study. Outcome data will also be measured for students in the sample who did not enroll in OCR as the sample includes all high school students. Measures of minoritized status will come from administrative data.

Analysis. The exploratory sequential mixed methods analysis phase begins with qualitative data analysis. The interviews and narratives from the classroom observations will be analyzed through multiple cycles of coding. First, two members of the research team will analyze transcripts/narratives using magnitude coding and structural coding techniques. Magnitude coding will help to quantify the data on administration, enrollment, support, and engagement and structural coding will break up transcripts into broad categories based on the conceptual framing (Guest et al., 2012; Miles et al., 2014; Saldaña, 2013). The structural coding is guided by new institutionalism in education perspectives on values and efficiency and the ACE framework (corresponding to sociocultural theory). The structural coding will follow the interview guide closely; the research team will develop a codebook based on the interview guide and emergent themes in the transcripts. This codebook will guide the structural coding process by defining the various constructs while being continually updated if new types of cases are found in the coding process (Guest et al., 2012). Throughout each cycle, the research team will write analytical memos detailing coding definitions and evolving themes.

The coding will result in quantitatively definable typologies of enrollment and administration approaches defined by the values, efficiency, and culture (Miles et al., 2014). I will visually orient these typologies using case-ordered meta-matrices as part of our findings on enrollment and administration choices as well as convert the resulting typologies into numeric, school-level indicator variables for quantitative analysis (Miles et al., 2014). Quantitative data on enrollment/engagement will be analyzed using k-means cluster analysis to define the typologies separately by minoritized subgroup.

I will explore the association between enrollment policies and student enrollment through descriptive tables (mean enrollment patterns by student enrollment policy typology, correlations between typologies and enrollment patterns) and regression analyses. The regression analyses will have OCR enrollment as the outcome. Student behavior (discipline, attendance), academic performance (test scores, grades), and OCR enrollment typologies will be on the right-hand side of the equation. I will perform a similar analysis comparing the typologies of support and engagement to the data from the course management system on student engagement. In the regression analyses, the outcomes are the engagement indicators including time on task, number of logins, and proportion of completed course activities as predicted by the enrollment/support typologies.

The goals of the final quantitative analysis on student outcomes are to explore whether there could potentially be relationships between school-level OCR policies, OCR enrollment, and student outcomes. I will estimate multilevel models with students (level 1) nested within schools (level 2). To build theory on potential relationships, I will fit the following reduced-form model with observations at the student level,

(1) $$\mu_{ij(t+1)} = \gamma_{00} + \beta_{1j}OCR_{ijt} + \boldsymbol{\beta_{vj}M_{ijt}} + \boldsymbol{\beta_{uj}OCR_{ijt}} \times \boldsymbol{M_{ijt}} + \boldsymbol{\beta_{wj}\alpha_{ij(t-1)}} + \boldsymbol{\gamma_{0y}\vartheta_{jt}} + \boldsymbol{\beta_{xj}\delta_{ijt}} + \boldsymbol{\gamma_{0z}\pi_{jt}} + u_{0j} + e_{ij}$$

where bold font indicates vectors. The outcomes, $\mu_{ij(t+1)}$, for student *i* in school *j* include earning STEM course credit, attendance, subsequent higher-level STEM course enrollment and completion, STEM standardized end of course exam scores, and graduation. All outcomes are measured after OCR enrollment (*t+1*). The coefficient β_{1j} will indicate the association between enrolling in OCR and the subsequent outcomes. Being part of a minoritized group is represented by the vector $\boldsymbol{M_{ijt}}$. The interaction of OCR with minoritized status is represented by $\boldsymbol{\beta_{uj}OCR_{ijt}} \times \boldsymbol{M_{ijt}}$**.** The vector $\boldsymbol{\alpha_{ij(t-1)}}$ represents baseline behavioral and academic covariates the year before OCR enrollment (*t-1*). This vector will include a variety of variables from administrative data including whether the student never failed a course, student disciplinary data, and prior test scores. The first variable is especially noteworthy such that its inclusion makes the comparison group students who failed courses, thus making them eligible for OCR, such that β_{1j} is the adjusted difference in the outcome for students in OCR who failed a course versus students who failed courses not in OCR. The vector $\boldsymbol{\vartheta_{jt}}$ represents school-level characteristics in the 2023-24 school year (*t*) including demographics, test scores, online course enrollment, and attendance. The vector $\boldsymbol{\delta_{ijt}}$ represents student-level engagement indicators from the course management system like time on task and number of logins. The last vector, $\boldsymbol{\pi_{jt}}$, represents the school-level typologies of enrollment and engagement approaches from the interviews and observations. This model will be fit first to the full sample and second limiting the sample to only OCR students (eliminating β_{1j}) to examine the association between enrollment approaches for all students and then only OCR students. The model includes student (e_{ij}) and school level (u_{0j}) random effects. If I find little variation in OCR policy across schools (despite preliminary evidence of variation in Figures 3, 4, and 6), the model will still be helpful for assessing relations between OCR course taking, OCR engagement, and the outcomes.

Study 2, Year 3: Developing a Survey Instrument Measuring School-Level STEM Credit Recovery Policy

Survey Design. This design corresponds to a seven-step questionnaire development model with the first three steps being accomplished through Study 1 (see Artino et al., 2014). The initial survey design will include items aligned with the theoretical framework with high correspondence with the data collection instruments. The previously developed instruments, aligned with the theoretical framework, will naturally transition into question stems for the survey items. This will include items on (a) how schools assign students to OCR or F2F credit recovery, (b) administration of OCR courses, (c) how they engage OCR students, (d) how students are supervised in OCR, (e) interest in/knowledge about CSP, and (f) related items on beliefs/values aligned with the theoretical framework. The findings from Study 1 will inform how the items are structured including the response options and type (e.g., multiple choice, free response). The previous results will also be used to explore other potential item stems for unanticipated school-level STEM OCR policy structures discovered during data collection and to identify potential anticipated structures that were part of data collection that can be deleted from the second study (e.g., if schools had no articulation of policy related to that area).

Expert Review. After this initial development of the survey items, I will complete two stages of expert review of the survey to assess content validity. First, I will recruit district-level and school-based leaders to be part of an expert panel reviewing the questionnaire. I will share with the panel findings from Study 1, give them space to reflect on these findings, and share ideas for continuing this research. This will help to prime the panel to provide feedback. I will then share the questionnaire with the panel for their review and discussion. I will then make updates suggested by the panel. Second, I will consult with both the scientific and practitioner-policymaker advisory boards (see below) for feedback on the instrument, and I will integrate their feedback they provide based on their areas of expertise.

Cognitive Interviews. The final step in the initial design process will be cognitive interviews with practicing school-based administrators. I will recruit a sample of school-based administrators who are neither working in the case study school district nor part of the expert panel consulted previously. A member of the research team will individually interview each school-based leader. The interview protocol will specify that the survey respondent is to read each item aloud, offer feedback on wording, and ask clarifying questions. In responding to each item, the facilitator will ask probing questions to assess whether the respondent is interpreting the item as intended (Desimone & Le Floch, 2004). After the first few interviews, I will reflect on feedback from participants and make adjustments to the survey instrument that were noted by at least two respondents. I will continue this survey adjustment process after every 2 to 3 interviews are completed until the pace of consensus feedback slows – anticipated to be at about 10 interviews.

Survey Pilot. I will pilot the instrument to collect initial data for survey validation. The pilot sample will be a convenience sample. I will send the survey to the listserv for over 2,000 alumni of the Master's in Educational Leadership program at my university, encouraging them to complete the survey and forward the survey to others in their networks. I will distribute the survey via social media, and ask others in my network and the practitioner-policymaker advisory board to distribute the survey. My goal will be to have at least 200 responses in order to allow for the calculations that are part of the validation process (although if I receive fewer than 200 responses, a smaller sample size will still allow the validation to proceed, see de Winter et al., 2009). While the pilot will be a convenience sample, the goal is to validate a survey for use with a national sample. To assess generalizability and appropriately weight the pilot sample for validation, I will use The Generalizer tool to compare the pilot sample to population estimates (Tipton & Miller, n.d.). By asking in the survey which school the participant is working in, The Generalizer provides an index indicating how similar the sample is to the target population, in this case public schools containing high school grades. This generalizability index ranges from 0 to 1 with a score of 1 indicating a perfect approximation of a random sample using the specified criteria (e.g., demographics, urbanicity) with 0 indicating vast differences between the sample and target population (Tipton, 2014). I will assess generalizability based on urbanicity, demographics, school size, and state. If the generalizability index is at least 0.5, statistical adjustments can reweight the sample to produce generalizable estimates, with these adjustments unnecessary for indices above 0.9 (Tipton & Olsen, 2018). If the generalizability index is below 0.5, I will seek additional survey responses to meet this threshold. With a sample with an index between 0.50 and 0.90, I will use inverse-probability weights to reweight the sample to reproduce the composition of the target population based on observable variables noted previously (Tipton & Olsen, 2018).

Survey Validation. The survey validation process will include several psychometric tests typically used to assess reliability and validity of survey items/scales. I will begin by assessing missingness in the pilot data to see if there are missing patterns that could be indicative of an error or misunderstanding in the survey. I will then examine the measures of central tendency of each item (range, variance, mean), Cronbach's alpha to assess scale reliability (reliability threshold of greater than or equal to 0.70), and correlations between items on the survey. I will assess these values to see if they correlate with expected relationships based on theory and survey development. I will assess evidence of satisficing where respondents selected the same option each time or "do not know" options (Vriesema & Gehlbach, 2021).

The correlations will also be helpful as part of an item reduction and internal consistency exercise. After examining correlations, I will perform exploratory factor analysis (EFA) using principal-component factor analysis followed by orthogonal varimax rotation. The EFA will assess the number of constructs (eigenvalues greater than one) represented by each scale and across the survey – to see if the survey is measuring distinct constructs or one underlying construct. In scales with more than three items, the correlations and EFA will facilitate an item reduction exercise, examining correlations and factor loadings to identify if any items can be deleted without loss of information. The goal will be to create a survey that take a maximum of 15 minutes to complete.

Study 3, Year 4: Nationwide Trends in School-Level STEM Credit Recovery Policy

Sample. The RAND American School Leader Panel (ASLP) is a nationally representative sample of public school principals, including approximately 2,500 principals at schools containing high school grades. The sampling frame is compiled through a variety of tools, including API and web scraping, designed to identify all public school principals in the United States. As public school principals are public employees, names and email addresses are publicly available, although complicated to compile nationwide. RAND contracts with MDR Education, which compiles this list four times a year. In comparisons between the list from MDR Education and actual data on principals in schools from select state longitudinal data systems, representatives from the RAND ASLP confirm these lists are very accurate for principals who have been in their positions for at least a year. The RAND ASLP team selects principals randomly with each principal having a known probability of selection. This probability varies between principals, as certain groups of principals are oversampled based on their state, school level, or other covariates. Surveys begin with a screener question to ensure the respondents meet the sample criteria. The survey will go to field in January of the fourth year of this grant. The survey will be sent electronically to principals. They will receive an invitation and follow up reminders weekly via email if they do not respond. After two weeks, we will mail hard copy reminder letters including a QR code link to the survey to non-respondents. For completing the survey, the survey software immediately directs completers to a link where they receive a $15 gift card with a selection of gift card vendors. Based on previous ASLP surveys with financial incentives and hard copy reminders, we can expect about a 40% completion rate, which would result in about 1,000 responses.

The RAND ASLP team calculates survey weights to account for probability of selection and to generalize results to the target population (i.e., principals at schools containing high school grades). The final weight will be a product of several weights including a weight to account for the stratified sampling strategy where principals did not have equal probability of selection based on school characteristics (by design), an inverse probability of selection weight, an inverse modeled probability of completing the survey, and (if applicable) a non-response weight to account for differences between the target population and the respondents based on observable school characteristics. These weights allow weighted estimates to be interpreted as nationally representative. Results from previous ASLP surveys are published in top-tier, peer-reviewed educational journals (e.g., Kaufman et al., 2022) and are part of at least one previous NSF award (DGE-2039612).

Data Analysis. Upon conclusion of the survey fielding stage, RAND will send me the full survey results that includes weights and the National Center for Education Statistics (NCES) ID of each school. With the NCES ID, I will merge in covariates from the Common Core of Data (CCD) as well as data from the Civil Rights Data Collection (CRDC). The CCD and CRDC are census surveys of all public schools. The CCD will provide covariates related to enrollment, demographics, and urbanicity. While the exact nature of CRDC data collection in the future is unknown, the goal of the CRDC is to help enforce civil rights statutes and therefore contains many indicators related to educational equity. Recent CRDC school surveys have included items on key STEM outcomes like enrollment in advanced mathematics and science courses (*Civil Rights Data Collection (CRDC)*, 2021).

I will perform a similar set of survey validation exercises as I conducted with the pilot instrument. I will assess missingness, measures of central tendency, scale reliability, response variability, correlations, and EFA. If the survey had significant patterns of missing data, I will explore the utility of multiple imputation to increase statistical power based on rates of missingness and other considerations (Graham et al., 2007; Jakobsen et al., 2017; Rubin, 2004).

The final stage will address the two research questions for this aim (see page 5). I will address the first research question on how principals are structuring STEM credit recovery policy through reporting descriptive statistics on and graphical displays of the survey items and scales. The second question on correlations between the school STEM credit recovery policy and covariates from the CCD and CRDC will be addressed first through an iterative series of linear regressions where the STEM credit recovery policies can be either predictors of the covariates or the covariates predictors of the policies. As these are cross-sectional data, the goal is to explore relationships, not establish causality.

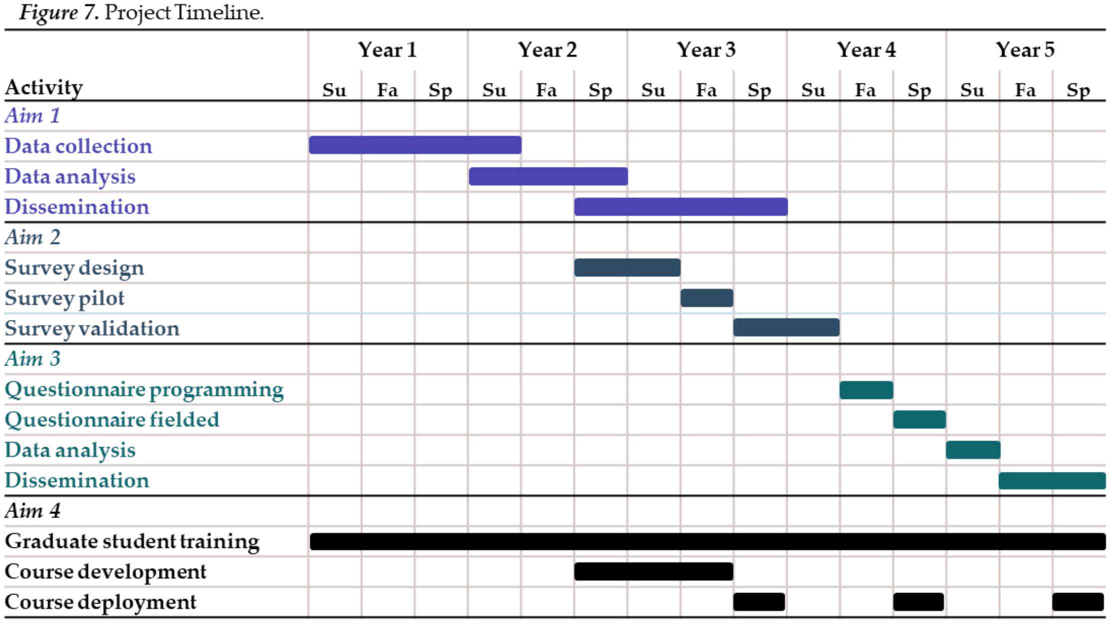
Feasibility and Potential Limitations

My relationship building and preliminary research activities with the Study 1 site, strong relationships with practicing school leaders, and confirmed support from RAND greatly improve the feasibility of this study. I am aware of and planning to address several potential limitations. First, mixed methods data collection is a complex endeavor with many potential pitfalls along the way to be cognizant of including participant interest and scheduling challenges. My experience with prior mixed methods data collection projects will help to ensure the success of the project. Second, Study 2 will involve recruiting school and district leaders to assist with survey development and piloting. To ensure sufficient participation at this stage, I will be able to call upon the expertise and connections of the practitioner-policymaker advisory board (described below). I also have a network of connections to aspiring and practicing school administrators having taught over 200 students enrolled in my university's Master's in Educational Leadership program and strong connections with neighboring school districts outside of the case study school district that will be part of outreach for survey development and piloting. Third, Study 3 requires working with an external partner, the RAND Corporation, which will require consistent communication structures that I will work to establish with their staff to facilitate survey administration that gathers the info necessary to meet study goals.

Education Plan

Graduate student researchers are integral and authentic partners throughout this project, developing their skills in mixed methods research while we co-develop specific tools for mixed methods STEM policy analysis (MM-STEM-PA). Each study integrates doctoral-level graduate research assistants. The development of graduate student research assistants' skills during Study 1 will then inform the development of a doctoral level course on MM-STEM-PA and the creation of a de-identified dataset for educational purposes. This course and dataset will seek to give emerging researchers tools to conduct similar studies, and I will purposefully integrate MM-STEM-PA design development and experiences conducting this type of research synergistically by having students in the course analyzing the de-identified dataset created from Study 1 data. The goals of the course are not only to help students apply these methods to a course-specific project, but also to consider ways to develop this methodology to extend beyond this study into a central method for those wishing to research STEM policy more generally. Each of the times this course is offered during this project (see Figure 7) will push the MM-STEM-PA methodology further to create a reciprocal relationship between the educational and research aspects of this project. Students enrolled in this course and I will be able to publish materials during the final dissemination period meant to spread the use of the MM-STEM-PA.

Figure 7. Project Timeline.



Note. Su stands for summer, Fa is fall, Sp is spring.

Dissemination

The dissemination efforts will primarily take place during Years 3 and 5 and will focus on communicating findings/recommendations to practitioners and local policymakers while making substantive contributions to academic research. The first priority will be the partnering school district which will receive at least two presentations and reports.

Policymakers, District Leaders, School Leaders, and Teachers

As this project seeks to inform STEM credit recovery enrollment and administration policies nationally, final dissemination efforts will focus on outreach to school/district policymakers and educators. I will compile a list of contacts for central office leaders at the 500 largest school districts and distribute policy briefs as hard copies, through email, and social media with specific recommendations based on the findings. I will distribute the policy briefs to communities of online learning professionals (e.g., Association for the Advancement of Computing in Education), education leaders (e.g., ASCD), mathematics educators (e.g., Association of Mathematics Teacher Educators), and science educators (e.g., Association for Science Teacher Educators). I will seek out opportunities to present findings at statewide conferences for district policymakers. I will write policy-oriented publications for educational professionals in outlets such as *Educational Leadership*. I will also write articles and/or blog posts for organizations with readerships of online learning professional (e.g., *Educause Review)*, mathematics educators (e.g., *Mathematics Teacher*), and science educators (e.g., *The Science Teacher*).

Researchers

I will take a similarly broad approach to disseminating the findings from this research to the education research community including the specific sub-specialties of education policy, education leadership, online learning, mathematics education, and science education. I will present findings at national education policy, education leadership, learning technology, and STEM research conferences including the American Educational Research Association annual meeting, the University Council for Educational Administrators annual convention, Society for Information Technology & Teacher Education International Conference, and NCTM Research Conference. I will develop these conference presentations into manuscripts that will be submitted to high-impact, peer-reviewed educational research journals like the *American Educational Research Journal*, *Educational Researcher*, *Computers & Education*, *Journal of Research in Science Teaching*, and *Journal of Research in Mathematics Education*. I will also pursue opportunities to disseminate the advancements on mixed methods STEM policy research methods through similar journals and book chapters in methodology textbooks.

Qualifications and Career Development

Topically and methodologically, I am qualified to complete the proposed study because my dissertation focused on OCR and included quantitative analysis of administrative data. I have experience conducting mixed methods research in partnership with school districts, widely disseminating this research, and publishing findings in top-tier education research journals (e.g., Curran, Viano, et al., 2021; Viano et al., 2021). I have experience developing, piloting, and fielding survey instruments intended for school-based employees (Viano et al., 2021). For several years, I integrated graduate students in a Master's level course on program evaluation at Vanderbilt University into research projects, including in the aforementioned mixed methods project. At the same time, this project will be transformative for my career development in several ways. First, I will integrate a focus on STEM policy as a natural and important extension of my general work on credit recovery (e.g., Viano, 2018). Second, I will transition from a user of mixed methodologies to a developer of research methodology in my focus on mixed methods STEM policy analysis. Third, by combining the research studies with course development and deployment, I will develop my mentoring capacity for future STEM policy and mixed methods policy researchers. Fourth, the findings from this research will be leveraged to design either interventions to test causal impact of different approaches to school-level STEM OCR policy or quasi-experimental studies that measure school policies, attempting to isolate the effect of these policy differences on STEM learning. This project will launch a career understanding STEM policy adoption and implementation, particularly focusing on the success of minoritized students in STEM, as a mixed methods researcher.

I have not received any NSF support to date and therefore do not have any "Results from Prior NSF Support" to include with this submission.

Advisory Board

Scientific Advisory Board

The scientific advisory board includes experts in the fields of study spanning the breadth of this project, including the fields of organizational theory, STEM policy implementation, STEM learning and technology, and culturally responsive STEM including [redacted]. I will confer with this advisory board 1-2 times a year throughout the five-year span of the project.

Practitioner-Policymaker Advisory Board

This project will also incorporate an advisory board with members spanning policy/practice as central office leaders in a diverse array of school districts. This Practitioner-Policymaker Advisory Board will greatly heighten the relevance of the methodologies and findings for implementation in schools and assist with recruiting for Study 2. I will confer with this advisory board 1 to 2 times a year throughout the five-year span of the project. This advisory board includes [redacted].

Intellectual Merit

Through the three studies and the development of the MM-STEM-PA course and associated dataset, this work will contribute to the research literature on credit recovery policy, secondary STEM online learning environments, CSP in STEM, and the intersection of these previously siloed areas. The policy structures around secondary online learning environments have rarely been studied (see Martin, 2022; Veletsianos et al., 2022), and almost no attention has been paid to how these structures result in differences in enrollment, engagement, course administration, and integration of CSP. Since minoritized students are more likely to fail courses and enroll in OCR (see Figures 1, 3, and 4), building out theory on the intersection of these fields will allow for the development of more advanced understanding school-level STEM policies targeted at students most underserved by our educational system. Further assessing the generalizability of these structures through the development and administration of a nationally representative survey will both exhibit the potential of these frameworks and provide an unprecedented understanding of STEM credit recovery policy in schools. Beyond this one policy space, MM-STEM-PA will allow future studies to integrate knowledge from disparate fields including education policy, learning sciences, and STEM instruction among others.

Broader Impacts

Impacts on Policy

COVID-19 has greatly exacerbated a persistent challenge in secondary education – STEM course failure derailing high school graduation, STEM learning, and subsequent STEM careers. High schools have increasingly turned to OCR over the last decade because existing solutions to course failure were not able to keep up with the pace of course failure or the needs of students failing courses (Viano, 2021). However, OCR will do little to address STEM learning and participation if students are not learning STEM content or failing to receive the credits necessary for graduation and post-secondary enrollment. This project seeks to build theory that can then be leveraged to transform STEM OCR to potentially (a) enroll students most likely to benefit from OCR, (b) engage students effectively to learn STEM content, and (c) integrate CSP to broaden STEM participation to effectively include minoritized students. The nationally representative survey of principals will not only provide an unprecedented level of information on credit recovery policy but also allow for a greater understanding of credit recovery policy structures to maximize the utility of potential subsequent interventions assessing the effects of different policies on students' outcomes.

Impacts on Education

The support of a Practitioner-Policymaker Advisory Board will accelerate the impact of this project on STEM credit recovery nationwide. STEM pipelines struggle to keep up with demand for STEM professionals with especially high attrition of minoritized students – partially because students struggling with STEM content drop out of these fields. Our society has an urgent need to understand the most effective and efficient ways to address STEM course failure to broaden participation from students more likely to fail STEM courses initially. District and school leaders in addition to STEM and OCR teachers will be more equipped to more purposefully implement STEM OCR policies and practices because of the findings of this project. This project will catalyze STEM interest, education, learning, and participation of students who have failed to learn STEM content, but deserve a second chance.