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Understanding the Impact of Learning Community Support for STEM students with Low Mathematics Placement

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Abstract

As a residential college within Michigan State University that focuses on STEM fields, Lyman Briggs College developed a STEM learning community to support students with low mathematics placement test scores, the Instilling Quantitative and Integrative Reasoning program (INQUIRE). INQUIRE serves some of those students considered historically at-risk based on STEM retention and graduation rates. INQUIRE was developed as learning community using curricular design, cohort-building activities, and academic resources to assist students' transition to college. Participating students were surveyed to understand the student experience of INQUIRE. Students' responses indicated that the program helped them adjust to college, prepare for introductory STEM courses, collaborate with other students and faculty, and experience academic and personal growth. A few students (4%) stated that the program put them behind their peers. Quantitatively, four-year STEM retention showed an increase from 43 to 56% for students starting in college-level algebra but remained statistically unchanged for those beginning in pre-college algebra (moving from 31 to 37%). The six-year graduation rates for both groups remained unchanged. These results indicate the difficulty in improving the graduation rates of students with low mathematics placement but indicate that INQUIRE made a positive and meaningful impact on students' experience.

Keywords

College transition, Graduation rate, Low mathematics preparation, Program assessment, STEM retention

Cover Page Footnote

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Improving persistence in undergraduate STEM degree programs has been a challenge for decades (Seymour & Hewitt, 1997). While some trends in STEM participation have shown improvement over time (Miller & Wai, 2015), recent gains still fall short of the overall projected need for STEM graduates in order for the United States to remain economically competitive (National Academies of Sciences, 2018; President's Council of Advisors on Science and Technology [PCAST], 2012). Improving undergraduate persistence in and graduation from STEM degree programs remains an active area of both research and funding.

Given the vast array of colleges and universities that are motivated to improve pathways through STEM programs, an enormous body of both foundational and applied literature has been generated that addresses persistence factors (Xie, Fang, & Shauman, 2015). Seminal work by Tinto (1993) describes three principles for retaining students: prioritizing institutional commitment to students, committing to the education of all students, and committing to integrating students within social and intellectual communities. Specifically, with respect to STEM majors, the PCAST (2012) report summarizes mechanisms for improving persistence within three categories: greater student engagement in classrooms and challenging co-curricular activities like undergraduate student research, altering motivational factors such as financial support and the availability of role models, and supporting STEM identity, a relatively new term that involves developing connections to STEM faculty, peers, and fields in general (Williams & George-Jackson, 2014).

Encouraging student persistence requires a constellation of social, financial, and academic support although arguments have been made that the academic is the most crucial of these supports (Adelman, 2007). Indeed, the current proportion of students who need access to developmental instruction in one or more subjects in order to be ready for college-level coursework is estimated at roughly 29% of the college-going population (Chen, 2016). Across the nation, students tend to demonstrate the most need for developmental instruction in mathematics, reading, and writing (Tinto, 2012). Further, as the socioeconomic racial and ethnic diversity of students pursuing degrees in higher education continues to expand (U.S. Department of Education, 2016), so too expand the number and types of supports required since many students will come from less well-resourced schools and so have lower levels of preparation.

Grouping cohorts of students within learning communities is a widely recognized strategy for addressing persistence issues (Allen & Bir, 2012; Smith, MacGregor, Matthews, & Gabelnick, 2009). Although learning communities exhibit wide variation in their implementation, they tend to incorporate both academic connections and some level of social integration, an important consideration for retention (Wilcox, Winn, & Fyvie-Gauld, 2005). Learning communities, with all other factors being ostensibly equal, have been linked to

improved student grades in courses across a range of disciplines (Friedman & Alexander, 2007). Through social membership, students are often able to form relationships with new friends, a positive indicator for making a smooth adjustment to college (Swenson, Nordstrom, & Hiester, 2008). Much evidence shows that learning communities have been specifically beneficial for academically underprepared students with peer interactions, pedagogy, and support services all being influential (Dagley, Georgiopoulos, Reece, & Young, 2016; Engstrom & Tinto, 2007; Scrivener et al., 2008; Zhao & Kuh, 2004).

Some evidence shows that, in addition to benefiting underprepared students, learning communities are an effective mechanism for promoting retention, specifically in STEM degree programs. Evidence from a Rutgers University learning community program focused on math and science showed improved STEM retention over time with major program elements including linked course enrollments, common housing assignments for residential students, and peer mentorship (Khan, 2015). A similar residential program for women in STEM also showed overall improvement in STEM retention and post-graduate degree obtainment (Maltby, Brooks, Horton, & Morgan, 2016). A recent analysis that estimates the causal effects of a learning community for biology students entering college below a threshold SAT score in mathematics shows that students improved with respect to both academic performance and their sense of belonging to the major (Xu, Solanki, McPartlan, & Sato, 2018). Programs integrated across the curricular and co-curricular domains have demonstrated success as well (Kezar & Holcombe, 2018). These positive results on STEM students appear to be driven by the social interactions that are generated through the learning communities (Carrino & Gerace, 2016).

Research Questions

The guiding research question for this study was "How can a learning community be used as an intervention to increase the success of STEM students with lower incoming mathematics skills?" Answering this question requires a definition of success. Clear quantitative measures of success include graduation and STEM retention rates. Similarly, student performance in subsequent science courses helps indicate whether the program is helping students successfully advance in their undergraduate career. Success can also be recognized in non-quantitative outcomes such as providing students greater confidence, building their self-image as a scientist, and developing a network with peers and faculty. Many of these factors can help to build a sense of belonging and connectedness to the institution that have been shown to be connected to higher graduation rates (Astin, 1997). Generating evidence for success on these two scales involves collecting different types of data and using multiple methods to triangulate results.

Our research focuses on a STEM learning community for students with low

math placement scores. This ten-year-old learning community was developed within Lyman Briggs College, a larger, fifty-year-old STEM living-learning community (Sweeder, Jeffery, & McCright, 2012). This newer learning community program has shown moderate success with improved student grades in chemistry courses, improved STEM retention for a subset of students, and the participants strongly valuing it, but it has not statistically improved graduation rates.

Theoretical Framework

The development of the new learning community, the Instilling Quantitative and Integrative Reasoning program (INQUIRE), has been shaped by several theories about student retention and learning. Most prominently, we are guided by Astin's Involvement Theory, which maintains that student engagement with the university is one of the core markers critical for student success (1984). Astin's work (1997) also describes how the sense of community that an individual has developed toward their college is one of the most influential factors on students' choices about remaining in college. INQUIRE has been further shaped by Tinto's Departure Theory (1994) and Theory of Student Persistence (2017). Tinto's work recognizes that a disconnect between students' perceived attributes and the expectations of the institution is what causes them to depart an institution, perhaps to continue pursuing their goal of earning a degree elsewhere. These theories indicate the critical role that a learning community can play in connecting students deeply with peers, faculty, and the institution.

Within the classroom, situated learning guides our approach to teaching and learning (Lave & Wenger, 1991). This theory states that learning is "situated" in a community or culture and is a social experience and construct; thus, students are naturally part of it and engaged. For these reasons, meaningful learning occurs most often when individuals engage in social activities in collaboration with their peers (McMahon, 1997). Recognizing that peers and teachers contribute to learning concepts in the classroom through scaffolding, tutoring, and cooperative learning (Rogoff, 1998), intentionally designed learning communities provide an opportunity for helping retain students in STEM fields. Together these theories support a classroom environment in which students work collaboratively to construct their knowledge through inquiry and problem-solving. The instructors act as guides, helping students create meaningful mental models for scientific processes.

Context

Michigan State University (MSU) is a large, land-grant public university with very high research activity and a primarily residential student body. Within

MSU, Lyman Briggs College (LBC) provides a living-learning experience for some students focused on STEM degree pathways. The LBC experience includes LBC-specific versions of the typical introductory biology, chemistry, physics, and mathematics sequences and a focus on the history, philosophy, and sociology of science. INQUIRE was created as a cohort-based student support program for incoming students within LBC and has been running continuously since Fall 2009. Each year, about 60 students enter INQUIRE, which accounts for approximately 10% of the entire LBC matriculating class. These students are drawn from the set of students whose math placement score indicates that they should initially enroll in pre-college algebra (PCA) or college algebra (CA) and are thus ineligible to take General Chemistry 1 in their first semester.

INQUIRE was designed to help these students develop a sense of belonging to the LBC learning community and develop an identity as "Briggsies." The students are supported during their transition into college with the assistance of a faculty team and various program-related activities. The primary academic element of INQUIRE is a 3-credit introductory science course (INQ101) with both lecture and laboratory components. Several former INQUIRE students are employed as undergraduate learning assistants to support student learning in both the lecture and laboratory setting. INQ 101 focuses on developing quantitative problem-solving skills in the context of chemistry and biology. Academically, the INQ101 course develops problem-solving skills through inquiry-based labs, a problem-solving workbook, and weekly workshops. Students also engage in community-building events such as field trips and seminars that focus on promoting college success (e.g. study skills, academic resources). These additional activities were designed to provide opportunities for students to build connections with others in the program and with faculty. Like all first year members of the broader LBC living-learning community, the INQUIRE students live in the same building that houses their LBC classes, laboratories, and faculty offices. This proximity further helps students build connections with other members of the community through informal evening study groups. Although fundamental components of INQUIRE have remained consistent from year to year, as is typical (Khan, 2015), regular feedback from faculty, staff, and students has supported occasional program changes. For example, prior to Fall 2012, students were advised to opt into the program. Starting this semester, students were automatically enrolled in INQUIRE but could opt out.

Although most programmatic changes have been small, one more significant change impacts how student outcomes data are analyzed and interpreted here. Since the prerequisite course for General Chemistry 1 is the completion of college algebra, students enrolled in INQUIRE are eligible to enroll in General Chemistry 1 in the spring term of their freshman year at the earliest. However, until the 2013-2014 academic year, LBC offered General Chemistry 1 only in fall

semesters and General Chemistry 2 (which requires passing General Chemistry 1 as a prerequisite) only in spring semesters. Thus, prior to 2013, INQUIRE students who completed INQ101 during their first fall term had no natural general chemistry course to take within the college during their first spring term. Thus, INQUIRE students would generally pursue one of three options: (a) enroll in the university's general chemistry course, which followed a different curriculum and was offered in sections of approximately 400 students each; (b) enroll in general chemistry over the summer at a local college or university; or (c) wait until the fall of their sophomore year to begin the LBC version of general chemistry, generally adding at least one year to any four-year degree program. All of these options were suboptimal and forced students within the cohort to essentially disperse after only one semester of building community.

Beginning with the 2013-2014 academic year, LBC began offering "off-sequence" general chemistry courses, ensuring that INQUIRE students could continue in cohort-based general chemistry courses during the spring of their first year and fall of their second year. Because this structural change significantly impacted student course-taking patterns, it was necessary to analyze INQUIRE data separately using this change as a boundary; thus, the students are grouped by cohorts beginning 2009-2012 (four cohorts) or 2013-2017 (five cohorts). Additionally, the 2009-2012 cohorts have all had six or more academic years to complete a degree, the standard time used by the Integrated Postsecondary Education Data System and many other organizations to record graduation rates. We note that some analyses additionally include comparisons to historically similar cohorts of students who began in 2007-2008 (two cohorts).

Table 1
Typical Early Science and Math Course Enrollment Pattern for Different Student Groups

	Pre-INQUIRE	INQUIRE 09-12	INQUIRE 13-17	INQUIRE 13-17	Non-INQUIRE
Initial Math	PCA or CA	PCA or CA	PCA or CA	CA	Calculus 1 or higher
Fall 1	Bio 1	INQ 101	INQ 101	INQ 101	Gen Chem 1
Spring 1		Bio 1		Gen Chem 1	Gen Chem 2
Fall 2	Gen Chem 1	Gen Chem 1	Gen Chem 1	Gen Chem 2	
Spring 2	Gen Chem 2	Gen Chem 2	Gen Chem 2		

One final contextual note concerns the relationship between student performance on the mathematics placement exam and their ability to enroll in particular mathematics courses during their freshman year. To be eligible for

INQUIRE, students had to earn a score of 12 or less on MSU's mathematics placement exam or have no score at all. Within this range of scores, students were either routed to a college algebra (CA) course (scores 10-12) or a developmental, intermediate algebra course (scores 0-9) considered to be pre-college algebra (PCA). Given that completing PCA is a prerequisite to enrolling in CA, students who tested into PCA were never eligible to enroll in General Chemistry 1 in the spring of their first year (see Table 1). That is, the addition of off-sequence general chemistry courses did not directly impact the population of students who placed into PCA. Because these two groups of students were routed to meaningfully different sets of courses, they are considered separately in some analyses.

Methods

Data collection and analysis

Given the desire for a holistic assessment of the impacts of INQUIRE, a mixed methods approach was used for this research, integrating both quantitative and qualitative data (Creswell & Creswell, 2018). This approach recognizes the broad potential manifestations of success, including those both for individual students and statistically across the overall learning community population. We collected qualitative data from student surveys and quantitative data from MSU's Office of the Registrar and Residential and Hospitality Services to explore how a learning community can be used as an intervention to increase the success of STEM students with low mathematics placement exam scores. A concurrent triangulation design was used to corroborate findings within a single study (Greene, Caracelli, & Graham, 1989). Within this design, quantitative and qualitative data were used separately to offset their individual strengths and weaknesses. Equal priority was given between the two methods, and their results were integrated. This work was approved and deemed exempt by our Institutional Review Board (IRB# X10-543).

Quantitative Data

Data from MSU's Student Information System was requested from our Office of the Registrar. The requested data pertained to undergraduate students who met the following three criteria: they (a) matriculated between Fall 2007 and Fall 2017, (b) were enrolled in Lyman Briggs College, and (c) had taken INQ101, general chemistry, introductory biology, or organic chemistry courses (N=6864). For all such students, we requested pre-college data such as SAT and ACT scores and mathematics placement exam scores; course grades for INQ101, general chemistry, introductory biology, organic chemistry, and the student's first mathematics course at MSU; and semester-by-semester data about major. Majors

were categorized as either STEM or non-STEM according to the Department of Homeland Security STEM Designated Degree Program List (U.S. Department of Homeland Security, 2016).

Several adjustments were made to the initial data set to account for the variety of student paths. First, all students who did not have a first-semester enrollment in a fall term were removed from the data set; given that these students would not be able to take INQ101 in their initial semester, their course-taking pattern would already be inherently different from the students who begin during a fall semester. Second, when students took a temporary leave of absence, we backfilled those semesters with the major code associated with the semester that they returned. Further, the few students who earned an advanced degree such as a Doctorate in Veterinary Medicine (DVM) at MSU without first completing their undergraduate degree were counted as having graduated upon attaining their advanced degree, and their field of study was categorized as either STEM or non-STEM based on the category of their advanced degree. Thus, a student who earned a DVM would count as having graduated but not toward retention in a STEM field. Finally, given that MSU has three terms each year (Fall, Spring, and Summer), we counted each semester as one-third of a year when calculating time-to-degree, which is consistent with the National Student Clearinghouse Research Center methodology (Shapiro et al., 2016). Therefore, a student graduating in the spring of their fourth year is reported to have graduated in 3.7 years whereas a student graduating the following summer is reported as graduating in 4.0 years.

Information about the students' on-campus housing arrangements was obtained from Residential and Hospitality Services databases for all students identified as being part of INQUIRE. Students were classified as living together if at any time during a given year they shared a room with another INQUIRE student. Comprehensive and reliable information about students' off-campus housing arrangements was not available.

Analyses of the quantitative data was completed using IBM SPSS Statistics Version 25 (IBM SPSS, 2017). Although the data are not normally distributed, analysis of variance (ANOVA) comparisons was used to identify statistical differences between groups in course grades and time-to-degree given their robustness to non-normal distributions (Glass, Peckham, & Sanders, 1972; Lix, Keselman, & Keselman, 1996).

Qualitative Data

To understand the impact of INQUIRE on the student experience, we developed a survey that asked students to reflect on and evaluate their experience. This initial survey was administered using Qualtrics (Qualtrics, 2018) for the 2017 INQUIRE cohort outside of class toward the end of their General Chemistry 1 course in Spring 2018 with extra credit offered as an incentive. In total, 61 out

of 71 (86%) students completed the survey. After the first data collection, the students' responses were analyzed, and several prompts were revised to better focus the student responses. A question branch was also added asking students why they left the college or MSU as appropriate. The revised survey (Appendix A) was administered with solicitations of students via campus email to all INQUIRE students who began from 2014-2016 plus those who began in 2017 and had not completed the original survey. Respondents were entered into a drawing with the chance to receive one of four cash awards. In this second administration, 63 out of 231 (27%) students completed the survey, providing a total response rate of 40%, although this is heavily skewed toward first-year respondents.

Student responses were analyzed using open coding to identify common themes. We used the constant comparative approach to ensure that the codes encompassed all student responses (Strauss & Corbin, 1990). Half the data from the first survey administration were used to develop common themes, and then two raters independently coded all the data. This resulted in interrater reliability (Cohen's Kappa) of between .87-.95 on individual questions. Responses on which the coders disagreed were then coded via consensus coding between the two raters. No new themes emerged from a single coder evaluating the student responses to the second survey administration.

Limitations

The survey data are heavily biased toward the 2017 INQUIRE cohort because these students were the most readily accessible at the time of the study and could be more effectively incentivized to participate. All other cohorts were solicited by their email address; as such, we expect that most students who left MSU (N=43) were unlikely to have received the survey.

For the purpose of analysis, we divided the INQUIRE cohorts into two groups (2009-2012 and 2013-2017) based on our perception of one of the most significant changes to the program, the addition of off-sequence general chemistry courses. However, these analyses do not account for the incremental programmatic changes made each year, such as the addition of evening seminar that began with the 2016 cohort or any minor variations in the academic profile of incoming students. We also note that, although the incoming average composite ACT for students between 2007 and 2017 increased by about one point, there was no statistical change with the PCA or CA groups between the 07-08, 09-12, and 13-17 cohorts for either their composite or any subscores of the ACT.

Results and Discussion

Overview

Using the quantitative and qualitative data to triangulate the results, we identified four areas that these data could provide insight into getting through college, success in courses, making connections, and personal growth. These areas align well with the primary goals of the program (helping students' adjustment to college, preparation for introductory STEM courses, interaction/collaboration with others, and academic and personal growth). Here, we discuss how these two streams of data reveal the successes of INQUIRE. In general, the common theme from the quantitative data is that there is little evidence of meaningful success. The qualitative data, however, provide stronger evidence for the program having positive impacts on students.

Table 2
Comparison Groups by INQUIRE Participation

Group	Years (20XX)	N	Description
INQUIRE	09-12 13-17	170 361	Students considered to be part of INQUIRE based on enrolling in INQ101 during their first semester. These students placed at the intermediate or college algebra levels
Eligible	07-08 09-12 13-17	141 191 66	Students who otherwise would have been in INQUIRE but were not because it did not exist (07-08), they did not opt in to INQUIRE (09-11), or they opted out of INQUIRE (12-17).
Ineligible	07-08 09-12 13-17	1032 2144 2759	Students who placed above college algebra and so were eligible to enroll in General Chemistry 1 during their first fall semester.

Table 3
Comparison Groups by Mathematics Course Placement

Group	Years (20XX)	N	Description
PCA	07-08 09-12 13-16	49 135 123	All students placed at the intermediate algebra level regardless of INQUIRE status. Intermediate algebra was replaced in 2017 by an enhanced college algebra.
CA	07-08 09-12 13-16 17	94 216 247 69	All students placed at the college algebra level regardless of INQUIRE status. The 2017 cohort includes students who would have previously been enrolled in intermediate algebra, and so represents a different student population.

The quantitative analyses draw on several useful comparative groups. One natural comparison group is the students who entered the college and took PCA or CA as their first mathematics class in 2007 and 2008, prior to the existence of INQUIRE. A second comparative group is those whose first mathematics classes were above CA since they provide a "target" outcome (Tables 2 and 3). Several common themes were noted across the four main survey questions (Table 4). These themes suggest that INQUIRE is helping students adjust to college, interact and collaborate with others, prepare for introductory STEM courses, and grow personally and academically. Each core theme is prevalent in the responses to each question (see Figure 1; for all themes and percentages see Appendices B and C) Each of the themes was present at notable rates on at least three of the four questions, and these themes encapsulate a large percentage of all responses. In responding to the most useful part of the INQUIRE, 36% of the responses fell outside of these primary themes, with these students mostly citing specific resources or experiences (such as field trips) as the most useful part.

Table 4
Common Themes Spanning the Four Main Questions

Survey Questions	• In what ways did INQUIRE help your transition to college? • In what ways did INQUIRE help with your non-INQUIRE courses? • Ignoring the impact on classes, in what ways did INQUIRE help your college experience? • Reflecting, what was the most useful part of the INQUIRE?

Common Themes	Exemplar Quote
Adjustment: • Helped or eased the transition to the college/course/college life/major, • Helped to get used to bigger classroom settings, • Provided a slower start, OR • Helped adjust to the balance between social life and classes	INQUIRE helped my college experience because it gave me an intro into future classes in my first semester of college and it eased the transition from high school to college.
Preparation for Introductory STEM Courses: • Helped for chemistry, biology or any specific content topic, OR • Introduced layout the college coursework	INQUIRE helped refresh my skills and knowledge in biology and chemistry courses, so when it was time for me to begin chemistry, I felt more confident about knowing that material.

Interaction/Collaboration with Others: • Helped to interact/ communicate/ collaborate/ meet professors, TAs, professionals, friends, classmates, etc. • Created community	The group of people I have interacted with. I made many close friends that made Michigan State feel like home. The people in the initial class ended up being in many more of my classes so you could get study groups and just friends to hang out with when you were busy. The instructors were also amazing they made you feel very conformable. They made you feel like if you needed help with anything you could go and talk to them even if you weren't in their class anymore.
Academic and Personal Growth: (select samples shown) • Improved/ gained study skills • Discovered career path • Gained confidence/ encouragement	INQUIRE gave me get a feel for how college is and helped me build confidence. When I bombed the mathematics placement test and got into [PCA] and INQUIRE, I felt discouraged because I had to begin with these classes. I came to find out that this program was really a blessing in disguise. It was a confidence booster because I excelled my freshman year, which was a great way to begin my undergraduate career because it only gets more challenging going forward.

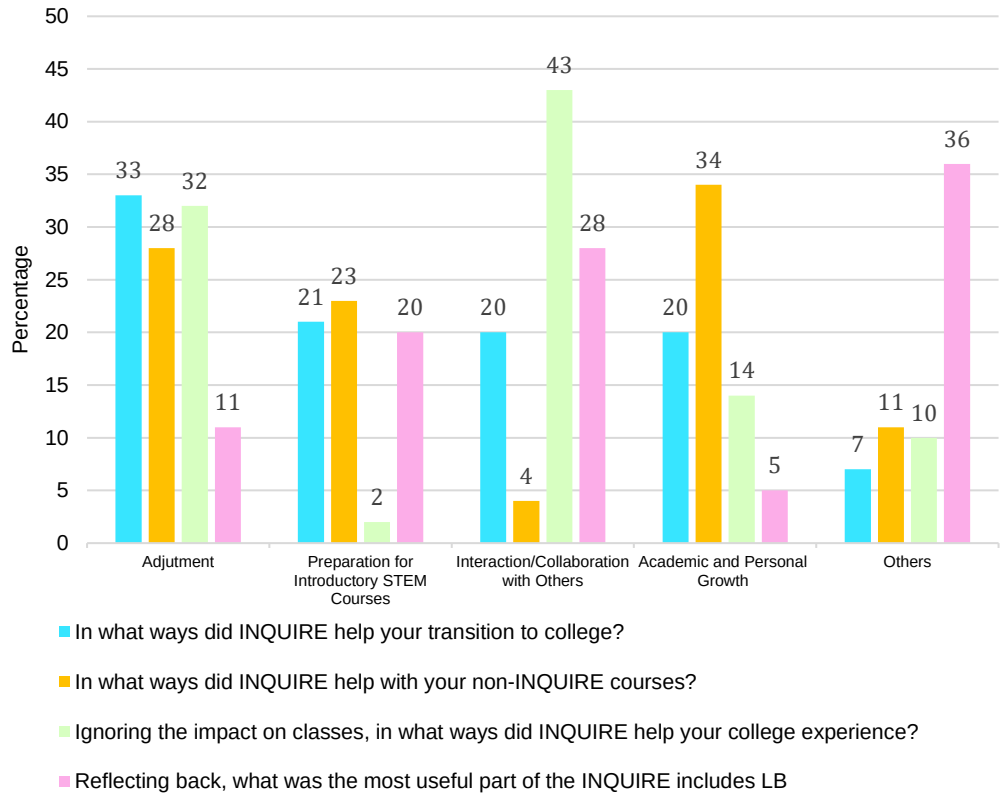


Figure 1. Percent of student responses in each theme by question on a reflective survey

Getting through college

Graduation rate

One of INQUIRE's primary goals is to increase the graduation rate for students who placed into PCA or CA. The baseline six-year graduation rate for similar students placed in these mathematics courses was 70% for the 2007-2008 matriculating classes (Table 2, eligible 07-08). For the incoming cohorts in 2009-2012, the six-year graduation rate for PCA or CA students was 68%. As a comparison, the ineligible students' graduation rate was 87%, reflecting that the students placed in PCA or CA are more at risk of not graduating within six years. Interestingly, INQUIRE students had a graduation rate of 57%, fluctuating from 50-60% depending on the cohort, whereas those who were eligible but elected not to complete the program graduated at a rate of 78%. This could be interpreted that participation in INQUIRE resulted in a lower graduation rate; however, a more likely scenario is that the decision to forego participation in INQUIRE is an indicator of the motivation and drive of the student, which is correlated to the likelihood of completing a degree (Pintrich & Schunk, 2002). For the cohorts starting after 2012, not enough time has yet passed to determine a meaningful six-year graduation rate.

Time-to-degree

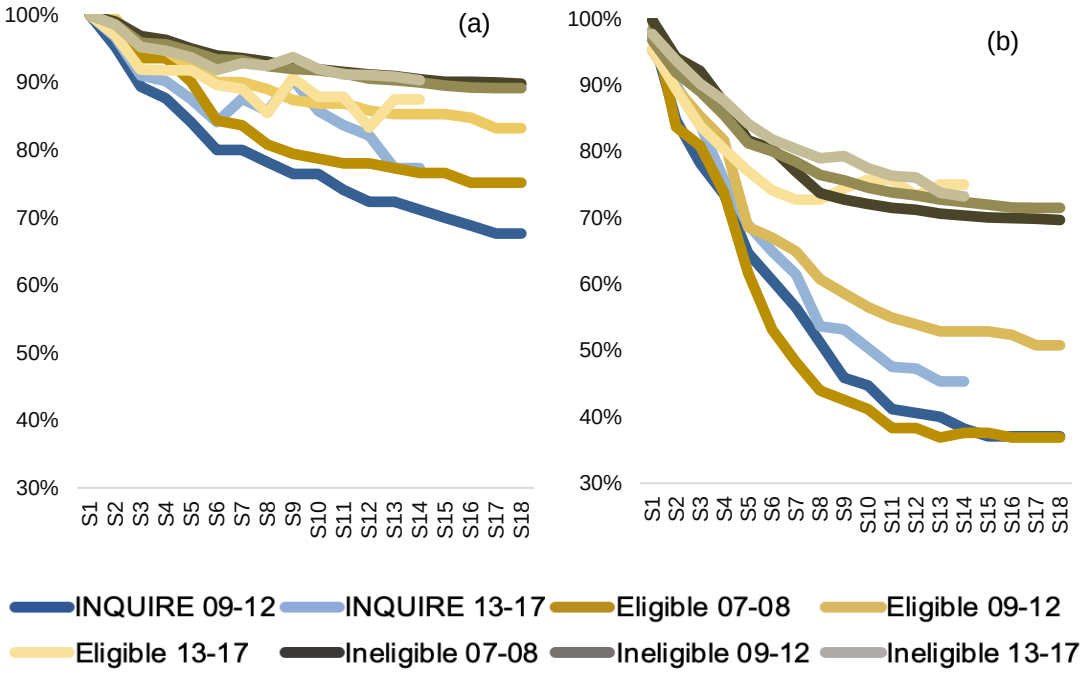
For students who graduated, we additionally considered time-to-degree. Students ineligible for INQUIRE graduated in 4.0 (+/- .7) years whereas low mathematics placement students graduated in 4.5 (+/- .8) years, showing that students placing at the intermediate and college algebra levels average an additional 1.5 semesters to graduate. The 2007-2008 cohorts who would have been eligible for INQUIRE, had it existed, averaged a statistically equivalent time-to-degree of 4.3 (+/- .6, $p = .109$) years. On the survey, four of the 41 junior and senior survey respondents (10%) indicated that they perceived INQUIRE to have added time to their degree completion, saying for example that "INQ101 set me back a semester from everyone else in Lyman Briggs, as well as the classes required for my major and stressing about graduating in 4 years. Because I don't know if I could afford to NOT graduate in 4 years." This concern about time-to-degree is real and provides a strong argument for bridge programs. Indeed, one student even suggested this possibility: "I wish that the INQ101 course could have been offered before freshman fall semester even started. I would not be behind in all of my other courses and would be even more prepared."

Retention rate at MSU and STEM persistence

At this time, the graduation rate and time-to-degree metrics reflect only the early years of INQUIRE (2009-2012). To better understand the outcomes from more recent iterations of the program, we compare retention rates at MSU and in

STEM degree programs by group. Figure 2a shows the percent of students who remain at MSU or have earned a degree by semester, indicating that the students who participate in INQUIRE leave MSU at a higher rate than those who had similar mathematics placement exam scores but did not participate in the program (listed as "eligible"). Given the opt-out nature of the program, this is not surprising. Students who have the confidence to opt-out of this recommended program are making that decision based on some information likely not captured by their mathematics placement exam score. This may be a belief that the mathematics placement exam does not reflect their true level of mathematical knowledge and skills or that they have a level of personal drive and commitment which they believe will allow them to succeed; either way, their decision appears to be well founded.

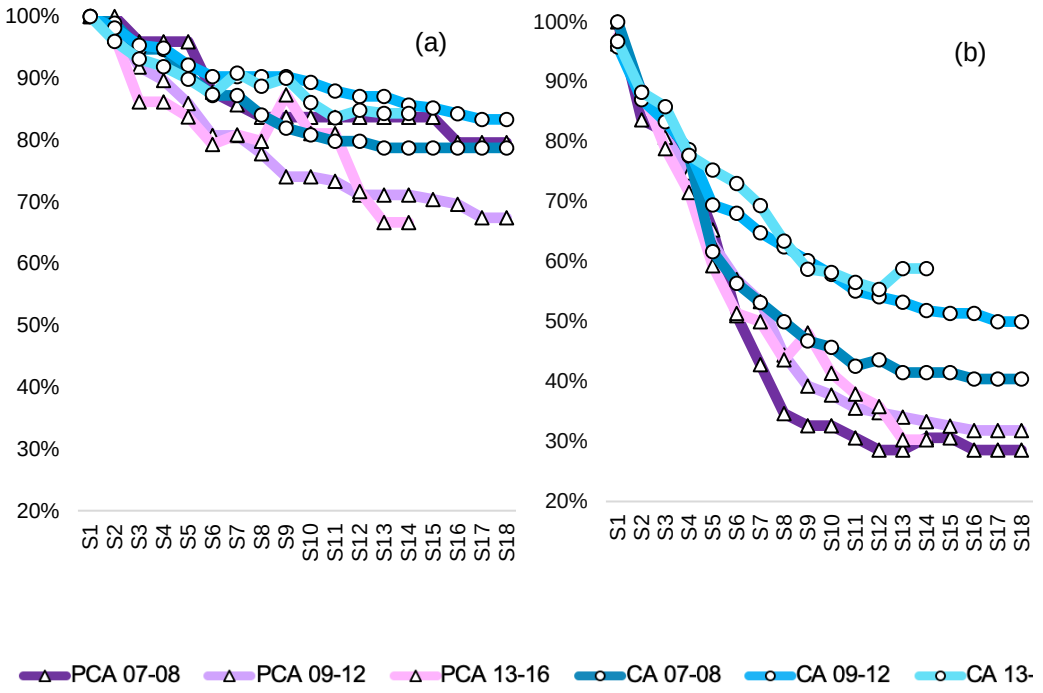
The eligible 2007-2008 group is an equivalent set of students based on mathematics placement exam scores, but without separating them based on their INQUIRE participation. Thus, this group would be expected to be an average of the students who would have participated and opted out had INQUIRE been available. From a resources standpoint, it is important to recognize that students who opt out are likely to have positive outcomes and may not require as much additional support.



Figures 2a and 2b. Percent of students in each comparison group who (a) remained enrolled at MSU or earned a degree and (b) were enrolled in a STEM degree program or earned a STEM degree, within 18 semesters (six years) of matriculation. Note that the lines for the 13-17 cohort reflects all students who could have reached that timepoint. This change in the number of

represented students from semester to semester allows the line to potentially increase.

However, INQUIRE is focused on not only graduation rates, but also retention in STEM degree programs (Figure 2b). Here, we see a positive impact of INQUIRE. The eligible 07-08 line provides a reference to identify the success of the program in terms of retaining students in STEM degree programs. Here both the INQUIRE participants and those who are eligible but not participating show equal or improved likelihood to remain within STEM compared to the 07-08 baseline.



Figures 3a and 3b: Percent of students in each comparison group by mathematics placement group who (a) remain at MSU or graduate with a degree and (b) graduated from or remain at MSU in a STEM degree program, both within 18 semesters (six years) of matriculation. Note that the lines for the 13-17 cohort reflects all students who could have reached that timepoint. This change in the number of students represented from semester to semester allows the line to potentially increase.

Retention rate at MSU and in STEM degree programs by mathematics placement

It is important to recognize that not all lower mathematics preparation students enter with the same level of background experiences and mathematics competencies and that their level of preparation is related to their outcomes. Figures 3a and 3b shows outcomes for students based on their initial mathematics course combining both INQUIRE and non-INQUIRE students. This analysis

eliminates bias based on a shifting proportion of students in the two mathematics courses or on the decision to opt in or out of the program; however, this also diminishes the observable impact that INQUIRE may be having. Students who begin in CA notably stay or graduate from MSU at a nearly 15% higher rate than PCA students (Figure 3a). A comparison of CA students to their pre-INQUIRE equivalents (CA 07-08) shows an increase in the probability of remaining in a STEM field four years later (from 43% to 56%; odds ratio (OR) = 1.7; 95% CI 1.11, 2.70). Indeed, they are matching the national average for students matriculating with an interest in STEM (Chen & Soldner, 2013) (Figure 3b).

For PCA students the data shows fewer positive outcomes, corroborating other work showing that higher mathematics placement scores tend to correlate with better outcomes (Khan, 2015). Although the STEM retention rates are equivalent, the six-year graduation rate of 58% for the cohorts of student after INQUIRE started are lower than the 07-08 baseline of 73% (OR = 0.36; 95% CI 0.16, 0.80). This combination indicates that a larger percentage of the 07-08 cohort left STEM fields but still obtained a degree from MSU. These differences in outcomes could have multiple explanations including the natural fluctuations in student population or that the barrier to STEM was initially viewed as so high that students quickly fled STEM fields and found success elsewhere or that the INQUIRE experience actively drove away these students. The fact that 16% of the 07-08 cohort transferred to non-STEM fields by the beginning of their second semester is weak but consistent evidence, with the idea that the students simply perceive the barrier to STEM as too high. This compares to 9% of PCA students who have made that same jump since INQUIRE began. However, it is important to recognize that the 07-08 cohort is not a true negative control since the student population and external pressures (such as the Great Recession that struck this state particularly hard) change from year to year.

The fact that students are leaving a STEM field is, of course, not inherently a negative result if they find success elsewhere on campus. However, the goal is that all students who wish to pursue a STEM field have the support to make that possible. Many students enter college with an expected future in a STEM field and subsequently discover other passions. This seems to be the consensus of our survey respondents who left STEM through comments such as “I left LBC ONLY because of the lack of interest in natural sciences. I figured out that I really enjoyed social sciences” and “I decided to leave LBC because I no longer want to pursue a major in the scientific path. I used to want to do medical, but I found myself really falling in love with business majors, so with that being said, I left LBC for the business college.” It should be noted that the voices of those students who left the university completely are missing and that they might express different reasoning.

Together the above results provide some glimmers that INQUIRE is

succeeding. There is clear evidence that the outcomes for PCA students tend to be worse than for CA placed students. Yet there are other potential measures of the program that may hold better evidence for success. One of the goals of the introduction to quantitative reasoning course is to provide the foundation for students to succeed in their chemistry and biology courses.

Course grades in subsequent science courses

The INQ101 course is designed to help students gain an initial college level chemistry and biology experience. Given this, it is reasonable to imagine that this course would result in higher grades by these students in subsequent chemistry and biology courses. A comparison of students with the opportunity to move directly from INQ101to General Chemistry 1 and those previous to INQUIRE via an ANOVA (Table 5, CA13-17 vs. CA07-08; see Appendix D for full ANOVA results) shows that there is indeed a statistically significant improvement in General Chemistry 1 grades ($F(1, 292) = 14$, $p < .01$). These improvements continue in both General Chemistry 2 ($F(1, 145) = 6.4$, $p = .01$) and Organic Chemistry 1 ($F(1, 150) = 7.2$, $p = .21$), although for these latter courses the difference may simply reflect a greater understanding (as measured by grade) of the prerequisite course.

Table 5
Average Grades Earned in Subsequent Chemistry and Biology Courses in 2007-2008 and 2013-2017

Math Class	Course	2007-2008 Ave (N)	2013-2017 Ave (N)	*df*	*F*	*η*	*p*
CA	Gen Chem 1	2.0 (83)	2.6 (211)	1	14.0	.21	<.01
	Gen Chem 2	2.0 (44)	2.5 (103)	1	6.4	.20	.01
	Organic Chem	2.3 (33)	2.9 (108)	1	7.2	.21	<.01
	Cellular Bio	2.4 (56)	2.6 (148)	1	1.9	.10	.17
	Organismal Bio	2.9 (77)	2.9 (179	1	.47	.04	.49
PCA	Gen Chem 1	1.7 (33)	1.7 (85)	1	0.01	.01	.92

Gen Chem 2	1.9 (17)	1.9 (37_	1	0.02	.02	.90
Organic Chem	2.1 (16)	2.6 (32)	1	1.9	.20	.17
Cellular Bio	1.8 (25)	2.2 (61)	1	1.5	.13	.23
Organismal Bio	2.3 (44)	2.6 (101)	1	3.7	.16	.06

By contrast, the students placed in PCA, who are not eligible to move directly into the LBC chemistry due to the mathematics restrictions, show no improvement in grades (Table 5). Interestingly, neither set of students shows any statistical differences in their biology course grades. This suggests that the temporal connection between the courses may be important; moving from the chemistry half of the INQ101 course directly into chemistry resulted in improved grades. Supporting this interpretation is that there is no statistical difference in grades between the 07-08 (pre-INQUIRE) and 09-12 students in any of the courses (See Appendix D).

During these years, there was no spring General Chemistry 1 offered in the college, and as a result 62% waited at least one semester complete General Chemistry 1 whereas only 20% of students waited at least a semester to take the class in the 13-17 cohort. This idea of the temporal importance is supported by the lack of any difference in grades in biology courses, which always suffer from at least a two-month delay between INQ101 and the next biology course since the biology content is the focus of the first half INQ 101.

The idea that INQ101 helps prepare students for subsequent courses is corroborated by the student survey responses. More than one in five students included preparation for subsequent courses in their responses to each of three questions focusing on how the program helped the students transition to college, how it helped for other classes, and the most lasting impact of the INQUIRE (Figure 1), with nearly half of respondents having at least one such response.

Making connections

One of the goals of INQUIRE is to help the students develop a strong sense of community and belonging. This is a very important predictor of student retention and graduation (Astin, 1997; Tinto, 1994, 2012) and something that had been lacking for these students. The student survey provides strong evidence that INQUIRE made progress toward this goal. Nearly half of the students provided answers indicating that the connections and interactions with others were the biggest non-course related benefit. As one junior said,

> I met most of my current friends in INQUIRE. It created an even smaller community within Briggs that made it easy to connect with other students going through the same challenges. Most of us would study together for the exams and homework. It also allowed me to get closer to professors with the small class sizes.

In this quotation she highlights the common themes expressed by the students, including connections with other students, both personally and professionally, and connections to faculty and the general residential college community. These strong connections help provide the support network that most students occasionally rely on to thrive in college (Swenson et al., 2008). Overall, three-quarters of students gave one or more responses that reinforced the importance of making connections with others as a benefit of the program. Given the overwhelming body of literature supporting the positive impacts of learning communities (Engstrom & Tinto, 2007; Minkler, 2002; Zhao & Kuh, 2004), these results are not surprising.

Table 6
The Observed Rate of INQUIRE Students Living Together

		INQUIRE students living on campus (2009-2017)		INQUIRE students with INQUIRE roommate on campus	
Year (FS, SS, US)	Total Students	#	%	#	%
First Year	533	526	99	87	17
Second Year	533	327	61	52	16
Third Year	533	111	21	7	6
Fourth Year	533	97	18	2	2

Beyond simply making connections, one student's comment jumped out: “I met future colleagues, friends, and roommates all within this program.” This aligned with anecdotal evidence that many INQUIRE students live together. Given the critical role that roommates can play in student support and success (Sacerdote, 2001; Stinebrickner & Stinebrickner, 2006; Zimmerman, 2003), we examined the number of students who lived on campus with a roommate from INQUIRE. Initial roommate selection occurs prior to the students being identified for INQUIRE, meaning that the percent of students living together in their first year is random with respect to participation in INQUIRE. Given the typical entering LBC cohort size of ~625 and an assumed INQUIRE cohort size of 72 (the average cohort size over from 2013-2017), we would expect about 12% of INQUIRE students to be paired as roommates in a completely random process,

although the observed rate of INQUIRE students living together during their first year is actually 17% (Table 6).

This increased rate is likely due to some students opting to live with a roommate that they knew from before college, meaning that it is not a fully random process. In the students' second year, roughly the same percent of on-campus INQUIRE students live with another INQUIRE student as during the first year; thus, the data we have does not support the hypothesis that the INQUIRE students live together preferentially. The total number of students living on campus drops precipitously in the third year, and our institutional data does not follow off-campus living arrangements efficiently, so it is not possible to determine the impact that INQUIRE may have on student roommate selection beyond the second year or for those living off campus.

Personal development

One of the goals of the INQUIRE is to "develop the skills needed for a successful transition to college which will lead academic and lifelong success." There are no direct quantitative data streams that can help determine the success of the program in helping students successfully transition to college. However, the student responses very clearly illuminate two manners in which INQUIRE impacted students' transitions to college: content review and academic/personal growth (Figure 1). Fifty six percent of first-year students, 36% of second-year students, 27% of third-year students, and 6% of fourth-year students cited the review of chemical and biological content as being critical to their success in college level science courses, which indeed was reflected in the improved course grades discussed above.

Students also cited academic or personal growth as an outcome of INQUIRE, but how this benefit manifested varied. Many students stated that they gained confidence and developed self-esteem. This also materialized as a greater comfort level with asking questions and communicating with faculty. Others cited that the program helped them develop their academic skills by developing study skills, a barrier for at-risk students (Ye, Shuniak, Oueini, Robert, & Lewis, 2016). One student nicely listed both of these themes, writing, "I was able to develop study skills and motivation that was able to fuel me through courses outside of STEM. I also was more confident connecting with other students and faculty within the 'larger university'." It seems that the focus on study skills and resources available resonated with students in a manner that they recognized.

Conclusions and Implications

The results of this intervention to assist STEM students placed into PCA and CA has shown mixed results, but its evaluation provides several important lessons

for the creation of learning communities focused on this subset of students. INQUIRE has shown success in helping these at-risk students transition to college. They recognize that the program has helped them develop social connections with peers and faculty. The students also indicated that the program helped them in their academic and personal growth by improving their study skills and enhancing their self-confidence. The academic outcomes, however, provide mixed signals. Students in recent years show improvements in their chemistry grades. These gains were only observed after an introduction of an off-sequence chemistry course that allowed the students to enroll in general chemistry immediately after completing INQ101. For the PCA placed students who were required to wait at least a semester, no course grade gains were observed. Although the introductory course also included biology content, no impact on the student grades in biology were observed. Together, this suggest the critical temporal aspects that need to be considered for academic based interventions. The implication may be that a summer "bridge" program prior to the semester or an enhanced version of the introductory course may offer a better option for serving these students by keeping their time-to-degree lower.

The graduation and retention results offer a mixed measure of success of the program. For the students who are initially placed into CA, the program has led to a statistically significant increase in the percent of students pursuing STEM majors but a non-significant change in the graduation rate. For the students starting from PCA, there is a statistical decrease in graduation rates while maintaining equivalent STEM retention rates. This suggests that this style of learning community has differential impacts depending on the initial math preparation of the students and that it is critically important to examine the overall impact on population subsets to ensure efficacy of the program.

Yet perhaps the biggest take away from this work is the importance of ongoing student support. Initially the program was developed as a one-semester intervention (INQ101) with the intent to support students during their critical transition to college. However, it became evident that a subsequent barrier existed since students could not immediately begin their science course sequence (with General Chemistry 1). For the students in CA, offering an off-sequence chemistry course then both alleviated this hurdle and effectively extended the INQUIRE intervention to three semesters, leading to improved performance in their chemistry courses and enhanced STEM retention. Indeed, it is important to provide students with the continued support to be successful and not assume that a one-time intervention will fully create the desired results.

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Appendix A

Student Survey

Student Survey

1. The INQUIRE Program has involved a variety of different activities. For each of the following indicate if they should be kept, modified, or ended.

	Kept	Modified	Ended	Don't remember/ didn't participate
Future Design Studio (during orientation)	o	o	o	o
Evening Problem-Solving Workshops	o	o	o	o
Evening Workshops with faculty/staff Presentations	o	o	o	o
Study Skills Workshops	o	o	o	o
Field Trips	o	o	o	o
INQ101 Biology Coursework	o	o	o	o
INQ101 Chemistry Coursework	o	o	o	o

2. What role did INQUIRE (INQ101 and Spring General Chemistry 1) play in your first year?
3. How did INQUIRE help you with your coursework?
4. What impact did INQUIRE have on your outside of the classroom experiences?
5. In your opinion, what was the most beneficial part of the INQUIRE program? Please explain.
6. In your opinion, what was the least beneficial part of the INQUIRE program? Please explain.
7. What did you struggle with this year? How might the INQUIRE program help with this?
8. What would you tell someone who was about to begin the INQUIRE program?
9. What would you most like to see in future incarnations of INQUIRE?

The survey was administered through Qualtrics. Students were provided with open ended text boxes. In the revised version, on question 2-4 students were asked if INQUIRE had a positive, negative, or non-impact on their first year, coursework, or outside of classroom experiences respectively. Display logic was then used to request a further explanation for how it had the positive/negative/non-impact (as appropriate) effect.

Appendix B

Survey of Student Experiences and Coding Guidelines

Questions (Q's) / Categories:

Q.1: In what ways did INQUIRE help your transition to college?
Categories for Q.1: Adjustment, Preparation for the Introductory STEM courses, Interaction/Collaboration with Others, Academic and Personal Growth, and Others

Q.2: In what ways did INQUIRE help with your non-INQUIRE courses?
Categories for Q.2: Adjustment, Preparation for the Introductory STEM courses, Interaction/Collaboration with Others, Academic and Personal Growth, Others, Resources, and NA

Q.3: Ignoring the impact on classes, in what ways did INQUIRE help your college experience?
Categories for Q.3: Adjustment, Preparation for the Introductory STEM courses, Interaction/Collaboration with Others, Academic and Personal Growth, Others, and Resources

Q.4: Reflecting back, what was the most useful part of the INQUIRE includes LB?
Categories for Q.4: Adjustment, Preparation for the Introductory STEM courses, Interaction/ Collaboration with Others, Academic and Personal Growth, Others, Resources, and Class add-on activities

Q.5: Reflecting back, what was the least useful part of the INQUIRE
Categories for Q.5: Preparation for the Introductory STEM courses, Interaction/Collaboration with others, Others, Class add-on activities, Specific Academic Content/ Concerns/Course Structure, NA and None

Theme: Definition	Exemplar Quote(s)
Adjustment: Helped or eased the transition to the college/course/college life/major, Helped to get used to bigger classroom settings, Provided a slower start, OR Helped adjust to the balance between social life and classes	*It was a very **easy transition from a small high school class to a little larger class,** then to a full lecture in LB 171. INQUIRE allowed me to get to know the people in our class, rather than sitting next to strangers in a larger lecture.* *INQUIRE **helped my college experience** because it **gave me an intro into future classes** in my first semester of college and it **eased the transition from high school to college.***
Preparation for Introductory STEM Courses: Helped for chemistry, biology or any specific content topic, OR Introduced layout the college coursework Refresher	*INQUIRE **helped refresh my skills and knowledge in biology and chemistry courses**, so when it was time for me to begin chemistry, I felt more confident about knowing that material.* *Taking INQ101 was a really great **"prep class" to get me ready for general chemistry and LB 144/145.** General chemistry isn't an easy course and INQ101 gave me some knowledge that was seen in LB 171/172. There were also many ideas in the biology section of the semester seen in organismal & cell/molecular biology. Taking that first semester strengthened those core chemistry and biology ideas.*

Appendix B (continued)

Interaction/Collaboration with Others: Helped to interact/ communicate/ collaborate/ meet professors, TAs, professionals, friends, classmates, etc. Created community Provided network	*It **helped me find a group of people** that were in the same spot I was, and the class was more personal, so you **could connect with the teacher and the students.** It does not feel intimidating walking into a classroom size you are used to because some of the big classrooms are very overwhelming as a freshman just starting out in a huge university. I **made a lot of friends from this class** that I have kept through my college experience.* ***The group of people I have interacted with**. I **made many close friends** that made Michigan state feel like home. The people in the initial class ended up being in many more of my classes so you could **get study groups** and j**ust friends to hang out with** when you were busy. The **instructors** were also amazing they made you feel very conformable. They made you feel like if you needed help with anything **y**ou could go and talk to them even if you weren't in their class anymore.*
Academic and Personal Growth: (select samples shown) Improved/ gained study skills Discovered career path Gained confidence/ encouragement	***Skills necessary for me to succeed academically** in my courses. This is with greater emphasis on my science courses. Being able to participate in INQUIRE **not only gave me the study/learning skills and confidence** I needed to be a successful student, it allowed me to build relationships with faculty who have a strong desire to see me learn and grow into the scholar I was meant to become.* *INQUIRE **gave me get a feel for how college** is and **helped me build confidence**. When I bombed the mathematics placement test and got into MTH 1825 and INQUIRE, I felt discouraged because I had to begin with these classes. I came to find out that this program was really a blessing in disguise. It was **a confidence booster** because I excelled my freshman year, which was a great way to begin my undergraduate career because it only gets more challenging going forward.*
Resources: any opportunity which has been provided or allowed by INQUIRE. Location, materials, the professors, the office hours, work materials, scholarship opportunities, and etc.	*It allowed me to look at things differently and **reach out to the leading faculty for study tips**.* *I **ended up receiving a scholarship** through the program which is potentially one of the greatest ways it helped outside of course work. I think it also **introduced me to a lot of great classmates and professors** which helped me realize the impact of networking.*
Class Add-on Activities: field trips, workshops, online homework, nightly presentations, and papers that they have to do problem-solving workshop that has been or can be added to an existing object or arrangement.	*I personally enjoyed **the field trip**, it helped me get to know other kids and that is how I like to network.* *The **workshops by professors** and other individuals helped me the most, I think. I learned how to better study, that I didn't even know how to study, that I needed to go to office hours, how college worked, and they inspired me to do better.*

Appendix B (continued)

Specific Academic Content Concerns/Course Structure: a specific part of the INQUIRE course should be restructured/ redesigned/ modified/ changed/ improved (e.g., chemistry lab work portion and biology part of the course work should be restructured, the monotony of the assignments should be changed, or extra mathematics classes should be added)	*The least useful part of the INQUIRE was by far the lab portion. Since we only were able to use water to practice using the lab equipment, I felt like I wasn't really learning anything. I think the INQUIRE* ***should modify the lab to allow students to practice lab skills with actual experiments.*** *The f****ield trip*** *would probably be the least useful due to the fact I didn't really learn much.*
NA's and None	*N/A* *Everything was useful in some way.*
Others: when students' answers do not respond to the questions and cannot be categorized under a common theme	*I was set back. I was behind in my coursework and that ultimately pushed a lot of my planned courses back a semester for all of college.* *I loved all the professors*

Appendix C

Frequency of Student Responses for Each Code by Question

	Adjustment	Prepare for introductory STEM courses	Interaction with others	Academic and Personal Growth	Resources	Class add-on activities	Others	Course Structure	None/NA
In what ways did INQUIRE help your transition to college?	33 %	21%	20%	20%	NA	2%	5%	NA	NA
In what ways did INQUIRE help with your non-INQUIRE courses?	28%	23%	4%	34%	2%	NA%	9%	NA	NA
Ignoring the impact on classes, in what ways did INQUIRE help your college experience?	27%	2%	46%	15%	2%	NA%	9%	NA	NA
Reflecting back, what was the most useful part of the INQUIRE includes LB	12%	20%	28%	2%	13%	13%	12%	NA	NA
Reflecting back, what was the least useful part of the INQUIRE program?	NA	NA	2%	NA	NA	22%	14%	41.2%	22%

Appendix D

ANOVA Comparing Course Grades for all PCA and CA students

Average Grades Earned in Subsequent Chemistry and Biology Courses in 2007-2008, 2009-2012, and 2013-2017

Math Class	Course	2007-2008 Ave (N)	2009-2012 Ave (N)	2013-2017 Ave (N)	*df*	*F*	*η*	*p*
CA	Gen Chem 1	2.0 (83)	2.0 (179)	2.6 (211)	2	13.1	.23	<.01
	Gen Chem 2	2.0 (44)	2.1 (107)	2.5 (103)	2	4.6	.19	.01
	Organic Chem	2.3 (33)	2.5 (112)	2.9 (108)	2	4.4	.18	.01
	Cellular Bio	2.4 (56)	2.5 (146)	2.6 (148)	2	.95	.07	.39
	Organismal Bio	2.9 (77)	2.9 (191)	2.9 (179	2	.40	.04	.67
PCA	Gen Chem 1	1.7 (33)	1.5 (93)	1.7 (85)	2	1.3	.11	.29
	Gen Chem 2	1.9 (17)	1.9 (35)	1.9 (37)	2	.01	.02	.99
	Organic Chem	2.1 (16)	2.1 (48)	2.6 (32)	2	2.1	.21	.13
	Cellular Bio	1.8 (25)	2.2 (73)	2.2 (61)	2	.08	.10	.45
	Organismal Bio	2.3 (44)	2.4 (116)	2.6 (101)	2	2.1	.13	.13