

Lyman Briggs College: an Innovative Living-Learning Community for STEM Education

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ABSTRACT

Founded in 1967 with the mission of bridging the divide between C.P. Snow's "two cultures" of the sciences and the humanities, Michigan State University's Lyman Briggs College (LBC) is a residential undergraduate college devoted to studying the natural sciences in their historical, philosophical, and social context. LBC is the longest-running program of its kind at a large U.S. research university. Lyman Briggs offers its students the best of both worlds: the close-knit living-learning community of a liberal arts science college and resources and opportunities of a great research university. The faculty—active and accomplished scholars focused on undergraduate education—span the sciences from astrophysics to zoology and also the fields of history, philosophy, and sociology of science (HPS). For almost 45 years, LBC has helped to liberally educate scientists to understand both the fundamental *scientific and mathematical* context of their disciplines and the *societal context* of science.

LBC creates a learning environment that helps students develop into high achieving, science graduates. We use research-validated instructional methods to actively engage students in the process of science in introductory science courses and in context of science through our introductory HPS course. Our students then take their upper-level science courses in our partner colleges and continue to gain a better understanding of the nature of science through our upper-level HPS courses. The students finish their program with their capstone senior seminar, an interdisciplinary course that bridges their science, technology, engineering, and mathematics (STEM) and HPS coursework.

We discuss the key components of the LBC model for science education and provide evidence of student learning and engagement. These data identify some of the most impactful aspects of the living-learning community and highlight the important components that should be incorporated into other living-learning models.

Keywords: STEM, Conference Proceedings, Higher Education, Career Development

INTRODUCTION

Significant research has gone into understanding student motivation in college and their retention in a major. Astin extensively examined the student experience and reported a wide range of ways in which students connect to a college or university and found that one of the most important factors influencing students' choices about remaining in college is the connection that they feel with the institution and their fellow students (Astin, 1984, 1993). Considering further Lave and Wenger's (1991) view of learning as a social construct, the environment that incoming potential science majors experience has a huge impact on their choices to remain in the sciences. Astin additionally identified that a student's desire to make a theoretical contribution to a scientific field was positively associated with "the hours per week spent talking to faculty outside of class, enrolling in an honors program, tutoring other students, working on an independent research project, assisting faculty in teaching a course.... we have here a number of interesting possibilities for how students' science interests might be strengthened" (Astin, 1993). Specifically within the sciences, research also

has suggested that connecting undergraduates with authentic research experiences helps maintain interest in the pursuit of a science major (Russell et al., 2007; E. Seymour et al., 2004). Providing all introductory students with real undergraduate research experiences early in their career has been a challenge; however, there are examples of success at large institutions for larger enrollment classes (Full, 2010; D. B. Luckie et al., 2004; Weaver et al., 2006).

These types of studies have led to many national calls for reform of teaching and learning in undergraduate science education: PCAST's *Engage to Excel* report (2012), *Boyer Commission Report on Undergraduate Education* (1998), the National Research Council's *BIO2010 Report* (2003), and *Rising Above the Gathering Storm (Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, 2008)*. Each report stresses the importance of engaging students in the authentic practice of science and improving connections between faculty and students, as out-of-class student-faculty interaction has been found to be extremely impactful for undergraduate students (Strong, 2009). Similarly, they recognize that science students must be prepared for authentic problem solving in real-world, interdisciplinary settings, which requires that students better understand the connections between science and society (Goldey, 2008; King, 2008). These calls for reform have captured the attention of many university faculty who recognize the need to rethink the student experience especially in the early years to attempt to maintain and even strengthen student interest in the sciences (Ebert-May, 1997). One of the reasons behind the need for change comes from the loss of students. Even though students majoring in STEM fields are more likely to complete a bachelors degree than are students in other majors (DesJardins et al., 2002; Leppel, 2001; Pascarella & Terenzini, 1991; Pascarella & Terenzini, 2005), Seymour and Hewett (1997) reported that 40 to 60 percent of undergraduates from a representative sample of universities leave the STEM fields. This loss of talent and creativity occurs among the most highly qualified college entrants (Bhattacharjee, 2009), especially among women and students of color.

Many colleges and universities have taken steps to modify the undergraduate science experience to help students better engage in their collegiate experience. One method is through the creation of residential colleges or other forms of learning communities. Although simply living on campus provides educational benefits (Pascarella, et al., 1991), living-learning communities tended to have the most significant benefit for living on campus (Pascarella, et al., 2005). These residential learning communities "blurred the boundaries between students' academic and social lives, and the evidence indicated clearly and consistently that they succeeded" (Pascarella, et al., 2005). In studying three differing living-learning communities in a single institution, Stassen found that two of the three communities had statistically positive impacts on grades and retention after controlling for pre-college academic success predictor variables (2003). These settings provide the kinds of out-of-class student-faculty interactions that have been shown to have positive impacts on students in their academic, personal, and social development (Strong, 2007). In particular, African-Americans may benefit from residential learning environments. Maton and Hrabowski, in their report on increasing the numbers of African-American PhD in the sciences, specifically identify academic and social integration, knowledge and skill development, support and motivation, and monitoring and advising as key components in the success of the Meyerhoff Scholars program (Maton & Hrabowski, 2004).

LYMAN BRIGGS COLLEGE DESCRIPTION

Founded in 1967 with the mission of bridging the divide between C.P. Snow's "two cultures" of the sciences and the humanities (Snow, 1959), Michigan State University's Lyman Briggs College (LBC) is a residential undergraduate college devoted to studying the natural sciences

in their historical, philosophical, and social context. LBC is the longest-running program of its kind at a large U.S. research university. Lyman Briggs offers its students the best of both worlds: the close-knit living-learning community of a liberal arts science college and resources and opportunities of a great research university. The faculty—active and accomplished scholars focused on undergraduate education—span the sciences from astrophysics to zoology and also the fields of history, philosophy, and sociology of science (HPS). For over 40 years, LBC has helped to liberally educate scientists to understand both the fundamental *scientific and mathematical* context of their disciplines and the *societal context* of science. By interlacing academics, residential life, and student services, LBC is able to fulfill its educational philosophy that is based on the belief that those sharing an interest in the sciences will benefit from learning and living together.

Annually, 625 first-time, first-year students enter LBC to study one of approximately three dozen coordinate majors in the life, physical, and computational sciences, or a major in the history, philosophy, and sociology (HPS) of science as part of their bachelor of science degree program. Students self-select into the college through their application for undergraduate admission to MSU. There are no special requirements or costs associated with the program; it is open to all entering students on a first-application priority. LBC has nearly 1900 total students in the program, and all first-year students are required to live in the residence hall where LBC classrooms, laboratory, faculty, staff, and administrative offices are also located. The core curriculum is comprised of calculus, general chemistry, physics, biology (all with instructional laboratory components), a three-course sequence in HPS, and a senior seminar capstone course. LBC students then continue with their majors which are affiliated with 17 departments across campus, or can complete one of six majors fully within LBC. These majors connect LBC students and faculty to other departments in the Colleges of Natural Science, Engineering, and Agriculture and Natural Resources. To offer both the science and the HPS classes, the faculty of LBC consists of natural scientists (biologists, chemists, mathematicians, and physicists) and social scientists (historians, philosophers, and sociologists). The regular interactions between these groups provide excellent opportunity for LBC to engage students in all aspects of science and experience a wider range of potential science careers. Since each of the faculty members also has a joint appointment in a disciplinary department, the faculty can provide insight and advice to students regarding their academic pursuits. MSU courses in general education and the student’s selected major round out the students’ curriculum.

Table 1: Courses Typically Taken by LBC Students

Student year	Usual Courses taken through LBC	Courses taken outside LBC
1st	Intro to HPS, Biology I, Gen Chem I&II, Mathematics (Calculus or other appropriate)	1-3 General education courses
2nd	Biology II, Physics I&II	Organic chemistry 2-6 general education
3rd	1-2 HPS upper level courses	4-7 major or general education courses
4th	0-1 HPS upper level courses, senior seminar (Capstone Course)	5-8 major or general education courses

THE LYMAN BRIGGS CURRICULUM

The LBC curriculum helps students build a core science foundation through courses in biology, chemistry, math, and physics before they focus on a specific major (Table 1). The initial courses in these disciplines not only introduce field-specific concepts, theories, and

methods but also demonstrate the inter-relation of various scientific disciplines: e.g., how chemical principles underpin biological processes or how mathematical models can make sense of physical behaviors. These courses help students understand the nature of scientific reasoning, evidence, and knowledge, and instructors strive to demonstrate the relevance of course material to real world issues (Gutwill-Wise, 2001; Holman & Pilling, 2004). Students discuss course material with each other at a conceptual and theoretical level to deepen their understanding and then engage in science together to generate new knowledge through course-based research projects. These introductory science courses strive to provide students with a solid foundation upon which to build further understanding by utilizing research-validated teaching practices including active and collaborative learning (Bransford et al., 2000). Class sizes are designed to be smaller than the typical equivalent university course and to provide a greater level of individual attention from the faculty members (Kokkelenberg et al., 2008). Most exams are predominantly open-ended, giving students the opportunity to explain their understanding. The introductory laboratory courses intentionally employ inquiry-based experiments to help students to understand the process of science (Bransford, et al., 2000). These experiments focus on the methods of science and scientific argumentation and not on pre-existing “right” answers that students are seeking to confirm. The laboratory courses strive to help the students learn how scientists communicate their work through the development of the skills necessary to write journal style lab reports that illuminate the thought process and scientific reasoning skills of the students. Students also begin to learn scientific presentations skills through the creation and display of research-based scientific posters. This highly diverse range of pedagogies helps reach all types of students and engage them in learning the basic skills essential for all scientists.

To further strengthen their scientific education, LBC’s curriculum includes three courses in the history, philosophy, and sociology of science: an introduction to HPS course in their freshman year and two upper-level, substantive HPS courses in their junior and senior years. In their initial HPS course, students are introduced to key questions, concepts, theories, and methods in HPS. After this, students extend and apply their foundational HPS knowledge to more advanced courses in the diverse substantive fields of HPS of science, technology, environment, and medicine. This cluster of courses aims to help students gain a more complete understanding of the fields of science in which they are gaining technical proficiency (e.g., learning history of physics in an HPS course while they are learning key facts, theories, and methods in their physics course). Lyman Briggs’s HPS requirement plays a crucial role in helping students understand the interdisciplinary, professional, and civic nature of science. By their very nature, HPS courses break down the boundaries erected in traditional disciplinary science courses (Snow, 1959). The HPS courses illustrate that historically science has developed through complicated processes of intellectual cross-fertilization; that philosophically scientific disciplines share basic epistemological assumptions; and that sociologically scientists have never divided neatly along the lines we draw when teaching undergraduate courses (particularly at the introductory level). The HPS courses also expose the students to the human implications of scientific research, so they come to see science as much more than just a body of technical information and skill. Lyman Briggs’s HPS offerings, in other words, discourage students from thinking about science as merely disunified vocational knowledge, and instead see it as a professional career that demands more than the mastery of a bounded body of technicalities.

Across all three HPS courses, instructors manage student-centered classrooms in which students confront their prior knowledge and reflect upon how and why they know what they know. HPS instructors regularly use an array of active learning techniques that span from a single class meeting to an entire semester. Facilitated by the instructor, students engage with each other to discuss and apply the course material to real-world issues of importance. Often

doing so collaboratively, students perform inquiry-based learning projects and service learning projects, all while honing their written and oral communication skills. After completing the cluster of HPS courses, not only should LBC graduates have a better historical, philosophical, and sociological understanding of science, but they should be more capable intellectuals with basic theoretical and substantive understanding, have more marketable career skills, such as analytical reasoning and critical thinking (AAMC-HHMI, 2009), and be more empowered citizens who may be more active and effective participants in relevant public debates of the 21st century.

When completing their HPS coursework and their STEM-based coursework for their major, LBC students take their capstone senior seminar. This capstone experience—often an intensive, student-led, discussion-based seminar—formally integrates their STEM coursework and their HPS coursework and provides them with one last opportunity for independent inquiry during their college experience.

The overall curriculum is designed to engage students with an array of pedagogical techniques and assessment methods to appeal to a diverse group of learners. Research suggests that science courses which include pedagogical approaches used in LBC such as active learning benefit all students, but disproportionately increase retention of underrepresented students (Herreid, 1998). Much like the Colorado Learning Assistant model (Goertzen et al., 2011; Otero et al., 2010), LBC employs Undergraduate Learning Assistants (ULAs) to assist in the teaching of many of the courses. This approach builds on the long-held research model of identifying and engaging undergraduate students early in their career in a core aspect of the science disciplines. Highly talented students are introduced into the culture of teaching science and work closely with faculty members in instruction as early as in their second year. Much like those students first discovering research, some of the ULAs use this as an opportunity not only to improve their understanding of the core science, but also to explore teaching as a potential career option.

THE LYMAN BRIGGS EXPERIENCE

The Lyman Briggs experience profoundly influences how students critically think about science and the world around them. More than just a set of classes, it involves engagement in a community of students, faculty, advisors, and staff and includes individual and shared educational experiences.

A major aspect of the LBC experience is the formal curriculum discussed above. Yet, the Lyman Briggs experience is much richer than just coursework. The residential college provides essential cohort-building experiences for LBC students. Housing the first year students in a single residence hall provides opportunities for students to develop strong relationships with colleagues that will last throughout their entire MSU career and likely beyond. These students form relationships with older ULAs or other LBC students still residing in Holmes Hall. These ties help foster a sense of community as the older students share their experiences and knowledge with younger students (Astin, 1993). This type of cross-cohort mentorship, which has long been a staple in bench science laboratories, is integral to the Lyman Briggs experience.

LBC's living-learning community has additional features that promote student engagement. The inclusion of the LBC classrooms, faculty, and student services within Holmes Hall is critical to the Lyman Briggs experience, facilitating out-of-the-classroom interaction between community members. These informal interactions humanize the faculty and staff in the minds of the students and allow them to better mentor students. Significant discussions take place during class times, advising appointments, office and walk-in hours, as well as informally in hallways, the cafeteria, and elsewhere throughout Holmes Hall (Strong, 2009). Similarly, the proximity of faculty from different disciplines within Holmes Hall also

has a profound impact on the faculty-faculty relationships. The informal interactions that arise among scholars in close proximity have led to many new teaching and research collaborations such as the Diversity in Science Senior Seminar developed by a historian, two biologists, and a social scientist.

Many Lyman Briggs students participate in a wide range of co-curricular opportunities that help foster learning and engagement in the Lyman Briggs community and beyond. Such activities include the LBC Research Symposium, the class book debates, community service, and LBC Speaker Series as well as involvement in primarily Lyman Briggs student groups (Briggs Multiracial Alliance, Women in Science, STEM Alliance, etc.). Students also take part in shaping the future of LBC and MSU through their involvement in governance (on all LBC standing committees and many university student groups) and in their participation in the faculty hiring process. The students' well-rounded experiences have led US News and World Report to cite LBC as an outstanding example of an academic program that fosters student success each year since 2005. In both 2008 and 2009, this organization recognized LBC as a "Program to Look for."

Active research is a key component of the Lyman Briggs experience. This is demonstrated through the consistent engagement of our students in scientific research. The annual LBC Research Symposium (initiated in 2007) has regularly involved over 700 student participants presenting research from faculty-led research labs, coursework, and honors option projects. Each year more than 70 LBC students participate in the University Undergraduate Research and Arts Forum. The culture of research has been strengthened within the LBC student body, with the number of Professorial Assistants (facilitated by the Honors College) increasing from 37 in 2007 to 94 in 2010. LBC faculty also work closely with students in their research labs, involving nearly 70 undergraduates in research and leading to between 15 and 22 students yearly coauthoring papers and a similar number presenting at regional/national conferences. These numbers testify to our efficacy in developing a culture of scientific research and investigation that reaches beyond the classroom.

The LBC mathematics faculty have carried this research focus into the summer through their Summer Undergraduate Research Institute in Experimental Mathematics program (SURIEM). The NSF and the National Security Agency in partnership with the University's Louis Stokes Alliance for Minority Participation (LSAMP) and the National Research Experience for Undergraduates Program (NREUP) of the Mathematical Association of America support this 6-week research program for an intentionally diverse cohort of undergraduate students from MSU and other universities. Such experiences greatly encourage undergraduates to persist in completing degrees in STEM fields and pursue graduate studies or careers in science.

SCHOLARSHIP OF TEACHING AND LEARNING

Nationally, 90% of students who leave the sciences cite bad teaching as one of the primary factors in their departure (Elaine Seymour, et al., 1997). However, research from the field of the Scholarship of Teaching and Learning (SoTL) has helped identify practices that can help us change these discouraging patterns. "High impact" teaching and learning strategies can greatly increase student retention in science majors (Beichner et al., 1999; Bransford, et al., 2000; Johnson et al., 1998). Unlike some science faculty elsewhere, the LBC faculty have strongly embraced SoTL as a means for developing and engaging students in the culture of science. The Lyman Briggs faculty consistently employ many of these high impact, student-centered learning strategies, such as student-led discussions, inquiry driven laboratories, and active lectures with student response pads as a means of engaging students in making

predictions and practicing newly learned skills. Our students increasingly recognize the benefit of these practices in their own learning (see Evidence of Success below.)

Interdisciplinarity has been highlighted in many calls for reform of teaching and learning in science as mentioned above. LBC faculty implement our integrated interdisciplinary curriculum using research-validated pedagogical techniques and technologies that make students active participants in the classroom. One example is the BRAID project (Bringing Relationships Alive through Interdisciplinary Discourse), which has facilitated the implementation of interdisciplinary experiences for students throughout their introductory courses (D. Luckie et al., 2012) and has spawned the annual LBC Research Symposium. LBC also promotes undergraduate research experiences through faculty mentoring, competitive research grants, inquiry-based classroom labs, and an emphasis on the acquisition of science process skills.

The culture of SoTL runs much deeper than simply influencing the design and execution of LBC courses. The Lyman Briggs faculty now employ research-validated instruments to better assess and evaluate our own teaching. LBC formally adopted the Student Assessment of Learning Gains (SALG) (Elaine Seymour et al., 2000) in 2011 as the primary means for collecting student feedback about their course experiences. This research-validated instrument asks students to evaluate their improvement on specific skills, abilities, or knowledge. This shifts the assessment of the classroom from “teaching” to “learning” and better addresses the key question about the efficacy of classes: what did students learn? Similarly, the faculty employ the Reformed Teaching Observation Protocol (RTOP) (Sawada et al., 2002) as a means to assess the kind of learning environment that an instructor fosters within the classroom. This instrument provides a resource for mentoring committees and strengthens a culture that openly discusses challenges in promoting student learning.

Further, many of the faculty within Lyman Briggs College have become active contributors to SoTL scholarship [for example: (Bray Speth et al., 2009; Cruz et al., 2010; Fata-Hartley, 2011; Kortemeyer, 2009; D. Luckie, et al., 2012; Rauschenberger & Sweeder, 2010; Smith & Cheruvilil, 2009; Sweeder & Strong, 2012)]. The very nature of LBC means that it is an excellent laboratory for educational experiments. The students are highly engaged, they have close relationships with the faculty, they are a closed community where many students are taking the same classes, and the wide range of disciplines represented allow LBC to be a unique and, in many ways, ideal setting for SoTL research.

EVIDENCE OF SUCCESS

Our students are also well situated to provide us information about the success of our program. A spring 2012 survey was administered anonymously to 1712 LBC students to gauge the student experience. Of the 446 respondents (26% response rate), the students overwhelmingly showed support for a number of the pillars of the LBC teaching model. 96.8% indicated that class size and 73.3% indicated that the inquiry-based nature of the LBC’s labs added either “a great deal” or “a moderate amount” to their LBC experience (Table 2). Due to the use of SoTL reformed teaching practices, the Lyman Briggs students’ experience in introductory science courses may be expected to lead to subsequent stronger academic success; 92.8% indicated that their LBC STEM courses had a “moderate amount” or “great deal” of influence on their performance in upper-level STEM courses in their major (Table 2). For both the class size and preparation questions, female students were significantly more likely to indicate a greater positive response (consistent with previous literature results (Kokkelenberg, et al., 2008)). If we compare the performances of the Lyman Briggs students to that of other MSU students across a variety of upper-level science courses, we find that the ratio of the median grades in organic chemistry, biochemistry, physiology, microbiology, and genetics for LBC students to median grade of their non-LBC

Table 2: Results of 2012 Student Survey

LBC characteristic	% respondents indicating factor added a "great deal" or "moderate amount" of quality to their LBC experience	% of Male (N=137)	% of Female (N=309)
Smaller class sizes	96.8	83.8	98.2
Inquiry-based labs	73.3	72.3	73.8
Intro STEM classes leading to success	82.8	77.9	85
Of Senior Responders			
Activity	% of students who participated (N=115)	% of Male (N=36)	% of Female (N=79)
Research with prof. outside a course	48.7	55.6	45.6
Study Abroad	38.3	36.1	39.2
Work as Learning Assistant	24.3	25	24.1

counterparts varies from 1.05:1 to 1.18:1, with LBC students consistently earning higher grades (*Internal Statistics*). Most dramatic is the difference between LBC and non-LBC students in organic chemistry. After controlling for incoming GPA and general chemistry class grades, Lyman Briggs students who took LBC chemistry typically earn a grade 0.22 points higher than university students with equivalent predictors (Creech & Sweeder). This improvement likely is due to a small organic chemistry module included in the Lyman Briggs introductory course.

The student survey also provided strong evidence that the culture of LBC encourages students to participate in many high impact co-curricular activities. Of the 115 senior level respondents, 48.7% had conducted research with a professor outside of a lab course, 11.3% had coauthored a publication with a faculty member, 38.3% had participated in a study abroad program, and 24.3% had worked as an undergraduate learning assistant. These percentages may be inflated by the self-selection of student respondents, yet the study abroad rate of the classes from 2008-2010 ranged from 31% to 41%. Interestingly, 67% of non-freshman respondents still felt that greater opportunities for research would significantly enhance their experience, suggesting an unmet demand for authentic research opportunities.

The value of the LBC experience, which supports its students in their transition from high school to college and through to graduation and beyond, can be seen in the retention and graduation rates. The second-year retention rates for the incoming classes between 2003 and 2008 were consistently around 95.5% and our 6-year graduation rate for the LBC classes entering as freshmen between 2001 and 2006 were between 82% and 86% (compared to 74-76% for MSU overall) (Figure 1). Although fewer than 50% of incoming college students interested in science actually graduate with a college degree in the sciences (PCAST, 2012), it is remarkable that nearly 70% of incoming LBC students graduate with a STEM major. Given our incoming class of 625 students, this equates to approximately 120 additional science graduates above an "average" institution helping to fill the expected 17% growth of STEM occupations between 2008 and 2018 (Langdon et al., 2011). LBC thus helps MSU meet the AAU's call to increase the number of STEM majors (AAU, 2011).

Assessment of recent student graduation trends suggests that incoming female LBC students graduate at an equivalent rate to their male counterparts (+/- 2% on the six year

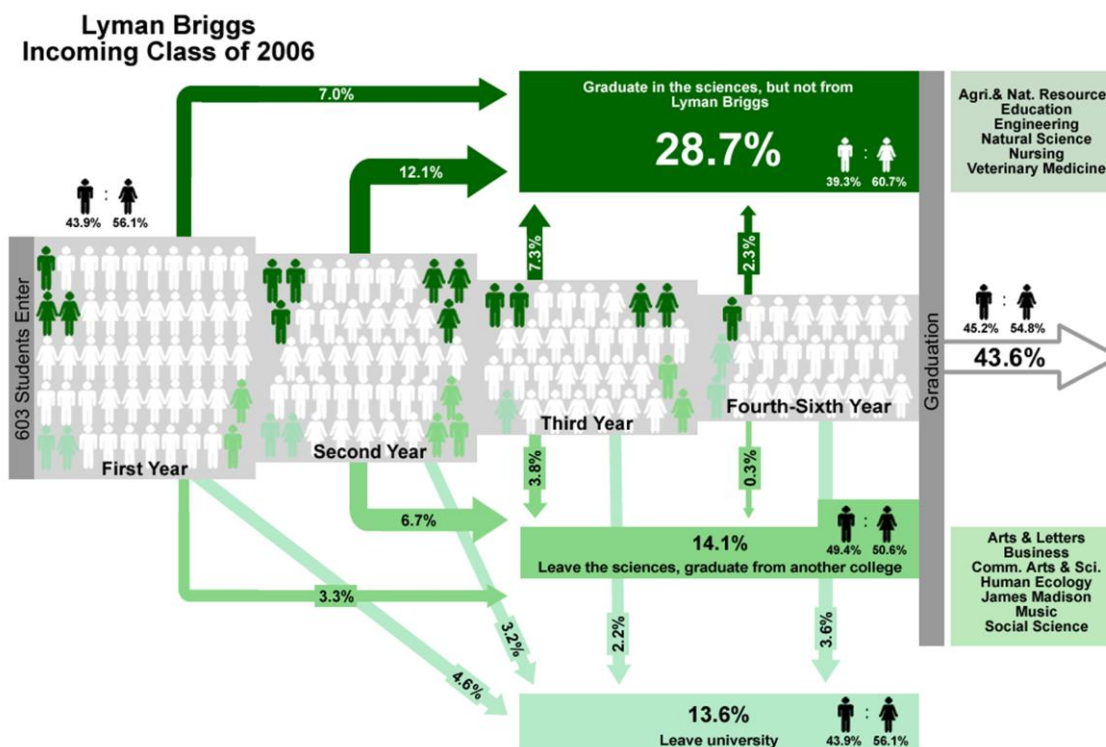


Figure 1: Path of LBC Class of 2006

graduation rate; see Figure 1 (*Internal Statistics*)). This is evidence that we are able to help female science students pass the critical first and second years where most institutions lose female students from science majors at higher rates than they lose males. Presently, minority students in LBC graduate at a slightly lower rate than the LBC average (0-12% lower), yet at a higher rate than the MSU's average. These data, combined with a 95-97% second year retention rate, suggest that LBC is providing a broadly supportive environment that leads to success across the demographic diversity of incoming students. For each of the graduating classes of 2008 to 2010, approximately 80% of LBC graduates have continued on to some form of post-baccalaureate education. This is indicative that a large number of our students have fostered an interest in continuing their education and have achieved a sufficient level of academic success to be accepted by a subsequent institution.

CONCLUSIONS

Many institutions are recognizing the benefits of an educational setting such as LBC. Stanford has recently created a Science, Technology, and Society program which, similar to LBC, strives to bridge C.P. Snow's two cultures divide (AAC&U, 2012). Thus, LBC can provide a model for the creation of such intensive residential colleges or learning communities which can then be adjusted to the individual culture and setting at each institution. LBC has partnered recently with Duhok University in Iraq and Monterrey Tech (Tec de Monterrey) in Mexico to share our approach to undergraduate science education. Similarly, LBC also has been a model investigated by Fukuoka Institute of Technology in Japan and Can Tho University in Vietnam. Although the creation of a robust residential college such as LBC can be an extensive undertaking, in the case of MSU, it has been a strong investment that has continued to pay dividends over almost 45 years in attracting quality students and creating quality STEM graduates. However, like any program, there are still areas which can and must be improved to meet the demand of quality STEM graduates that all institutions of higher education must work together to fill.

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