A case study of a residential college devoted to the sciences provides insight on improving student success in the sciences.

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

Ryan D. Sweeder, Kathleen A. Jeffery, and Aaron M. McCright

Abstract

Michigan State University's Lyman Briggs College (LBC) is a residential, undergraduate college devoted to studying the natural sciences with an understanding of the history, philosophy, and sociology of science. LBC is the longest-running program of its kind at a large U.S. research university and offers its students the close-knit living-learning community of a liberal arts college and diverse resources and opportunities of a research university. LBC has succeeded in developing a strong residential science learning community that supports its students by creating a culture of engagement in science and employing student-centered learning techniques. This has resulted in a first-year retention rate of approximately 95% (92% in STEM) and a six-year university graduation rate of approximately 85% (more than 70% in STEM with equal retention of male and female students). LBC can therefore provide a useful case study for approaches that lead to student retention and success in STEM fields.

Keywords

STEM, Higher Education, Career Development, Student Support

Introduction

Significant research has gone into understanding student motivation in college and retention in a major. Astin examined the student experience extensively and reported that one of the most important factors influencing students' choices about remaining in college is the connection 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 choice 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… a number of interesting possibilities for how students' science interests might be strengthened" (Astin, 1993). Research specifically within the sciences has also suggested that connecting undergraduates with authentic research experiences helps maintain interest in the pursuit of a science major (Russell, Hancock, & McCullough, 2007; Seymour, Hunter, Laursen, & Deantoni, 2004). Providing all students with real undergraduate research experiences early in their careers has been a challenge; however, there are examples of success at large institutions for larger enrollment classes (Full, 2010; Weaver et al., 2006).

Concerns over the need for more graduates in science, technology, engineering, and mathematics (STEM) fields have led to national calls for reform of teaching and learning in undergraduate science education: The President's Council of Advisors on Science and Technology's (PCAST) *Engage to Excel Report* (2012), *Boyer Commission Report* (1998), and *Rising Above the Gathering Storm* (2007). Each report stresses the importance of engaging students in the authentic practice of science and improving student-faculty connections, as such out-of-class 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). These calls for reform reinforce the need to rethink the student experience especially in the early years to attempt to maintain and even strengthen student interest in the sciences (National Science Board, 2003). Even though students majoring in STEM fields are more likely to complete a bachelor's degree than are students in other majors (DesJardins, Kim, & Rzonca, 2002; Pascarella & Terenzini, 2005; National Science Board, 2012), Seymour and Hewett (1997) reported that 40 to 60% of undergraduates from a representative sample of universities leave the STEM fields—especially among women and students of color (Carnevale, Smith, & Melton, 2011).

One method to improve undergraduate science education is the creation of residential colleges or similar forms of learning communities (Bean & Kuh, 1984; Tinto, 1997; Zhao & Kuh, 2004). These residential learning communities have great impact by blurring "the boundaries between students' academic and social lives, and the evidence indicated clearly and consistently that they succeeded" (Pascarella & Terenzini, 2005). In studying three differing living-learning communities in a single institution, Stassen (2003) found that two of the three communities had statistically positive impacts on grades and retention after controlling for pre-college academic success predictor variables. These settings provide the kinds of out-of-class, student-faculty interactions that have been shown to have positive impacts on students' academic, personal, and social development (Strong, 2009) and give strong indication for how to improve undergraduate education and retention.

This article focuses on Lyman Briggs College (LBC), a residential science college, as a model for cultivating student success and retention in STEM fields. This article describes the curriculum including impacts on student retention, summarizes the students' experiences assessed via student surveys, discusses lessons learned, and provides key recommendations for developing high-impact, science-based residential colleges.

Lyman Briggs College: A Model Community

Founded in 1967 at Michigan State University (MSU) with the mission of bridging the divide between C.P. Snow's "two cultures" of the sciences and the humanities (Snow, 1959), the LBC is a residential, undergraduate college devoted to studying the natural sciences in their historical, philosophical, and social context. LBC offers its students the best of both worlds: the close-knit living-learning community of a liberal arts college and resources and opportunities of a large research university. The faculty—active and accomplished scholars focused on undergraduate education—span the sciences from astrophysics to zoology including the fields of history, philosophy, and sociology of science (HPS). For more than 40 years, LBC has educated scientists to understand both the fundamental scientific and mathematical context of their disciplines in a societal context. By interlacing academics, residential life, and student services, LBC is able to fulfill its educational philosophy that those sharing an interest in the sciences will benefit from learning and living together.

Annually, 625 first-time, first-year students enter LBC intending to earn a bachelor's of science degree in STEM or HPS. Students self-select into the college through their application for undergraduate admission to MSU with no special requirements or costs associated with the program; it is open to all entering students on a first-application priority. LBC has nearly 1,900 total students, and all first-year students are required to live in the residence hall where LBC classrooms, laboratory, faculty, staff, and administrative offices are located. LBC majors are affiliated with 17 departments across the Colleges of Natural Science, Engineering, and Agriculture and Natural Resources. The faculty of LBC consists of natural scientists (biologists, chemists, mathematicians, and physicists) and social scientists (historians, philosophers, and sociologists). The interactions between these groups provide excellent opportunities for LBC to engage students in all aspects of science and experience a wider range of potential science careers. Since each faculty member also has a joint appointment in a disciplinary department, the faculty can provide insight and advice to students regarding their academic pursuits.

The Lyman Briggs Curriculum

Nationally, 90% of students who leave the sciences cite poor teaching as one of the primary factors in their departure (Seymour & Hewitt, 1997). However, research from the field of the scholarship of teaching and learning (SoTL) has helped identify practices that can help change these discouraging patterns. "High-impact" teaching and learning strategies can greatly increase student retention in science majors (Bransford, Brown, & Cocking, 2000; Johnson, Johnson, & Smith, 1991). The LBC curriculum strives to use these learner-centered teaching techniques to provide students with a solid foundation before they focus on a specific major, see Table 1. Through active and collaborative learning, initial 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). They not only introduce field-specific concepts, theories, and methods, but also demonstrate the inter-relation of various

Table 1: Courses Typically Taken by LBC students

Student year	Usual courses taken through LBC	Courses taken outside LBC
First	Intro to HPS, Biology I, General Chemistry I & II, Mathematics (Calculus or other appropriate)	1-3 general education courses
Second	Biology II, Physics I & II	Organic Chemistry 2-6 general education courses
Third	1-2 HPS upper-level courses	4-7 major or general education courses
Fourth	0-1 HPS upper-level courses, senior seminar (Capstone Course)	5-8 major or general education courses

scientific disciplines: e.g., how chemical principles underpin biological processes. Students discuss course material with each other at a conceptual level to deepen their understanding and engage in science collaboratively through course-based research projects.

Class sizes are designed to be smaller than equivalent university courses and provide a greater level of individual attention from faculty (Kokkelenberg, Dillon, & Christy, 2008). The introductory laboratory courses employ inquiry-based experiments that focus on scientific methods and argumentation to help students understand the process of science (Bransford et al., 2000) rather than confirm pre-existing "right" answers. The laboratory courses strive to help students learn how scientists communicate through the development of the skills necessary to write journal-style lab reports that illuminate their scientific reasoning skills. Students also begin to learn scientific presentation 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.

Three courses in the HPS field strengthen the science education. In an initial HPS course, students are introduced to key questions, concepts, theories, and methods in HPS. Students then extend and apply their foundational HPS knowledge to more advanced courses in at least two substantive fields of HPS of science, technology, environment, and medicine. These courses help students gain a more complete understanding of the fields of science in which they are gaining technical proficiency by exploring the interdisciplinary, professional, and civic nature of science. HPS instructors regularly prompt students to engage with each other to confront their prior knowledge and reflect upon how and why they know what they know. By their very nature, HPS courses break down the boundaries erected in traditional disciplinary science courses (cf. Snow, 1959), illustrating, for example, sociologically that scientists have never divided neatly along the lines we draw when teaching undergraduate courses. HPS courses also expose students to the human implications of scientific research, thereby discouraging students from thinking about science as merely vocational knowledge, and instead seeing it as a professional career that demands more than the mastery of a bounded body of technicalities.

The overall curriculum is designed to engage students with learner-centered pedagogical techniques and assessment methods to impact a diverse group of learners. Science courses that include pedagogical approaches used in LBC such as active learning benefit all students, but disproportionately increase retention of underrepresented students (Herreid, 1998; Froyd, 2009). Much like the Colorado Learning Assistant model (Goertzen, Brewe, Kramer, Wells, & Jones, 2011), LBC employs undergraduate learning assistants (ULAs) to assist in teaching many of the courses. This approach builds on the long-held research model of identifying and engaging undergraduate students early in their careers 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 undertaking 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.

As a means to formatively assess each course, Lyman Briggs faculty formally adopted the research-validated Student Assessment of Learning Gains (SALG) (Seymour, Wiese, Hunter, & Daffinrud, 2000) in 2011 as the primary means for collecting student feedback about their course experience to better evaluate their own teaching. This research-validated instrument asks students to evaluate their improvement on specific skills, abilities, or knowledge, shifting assessment of the classroom from "teaching" to "learning" and better addressing the key question about the efficacy of classes: what did students learn? Similarly, the faculty employs the Reformed Teaching Observation Protocol (RTOP) (Sawada et al., 2002) as a means to assess the 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 and opportunities in promoting student learning.

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 creating a culture of science engagement with students, faculty, advisors, and staff engaging with each other around science.

The residential nature provides an environment conducive to building this science-laden culture. The inclusion of the LBC classrooms, faculty, and student services within Holmes Hall is critical to the Lyman Briggs experience, providing 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 serve as better mentors. 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).

The culture of science is further strengthened by the 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 freshman class book debates, community service, and the LBC Speaker Series as well as involvement in student groups (e.g., Briggs Multiracial Alliance, Women in Science, and STEM Alliance). Students also help shape 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.

Active research is another key component of the Lyman Briggs culture, as demonstrated through the consistent engagement of students in scientific research. The LBC Research Symposium involves more than 700 student participants annually as they present 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. LBC faculty work closely with students in their research labs, involving nearly 70 undergraduates in research and leading to between 15 and 22 students coauthoring papers and a similar number presenting at regional/national conferences each year. Many other students work with non-LBC faculty as well. These numbers testify to our efficacy in developing a culture of scientific research and investigation that reaches beyond the classroom.

Methods for Evaluation

Our students are well situated to provide information about the success of our program. With MSU Institutional Review Board approval, a standardized survey was administered anonymously online to 1,712 LBC students in spring 2012 to gauge the student experience. The survey included closed-ended questions. The measurements included usage of facilities, features of residence living, curriculum, and the general teaching and learning environment experiences in LBC. Students had three weeks to complete the survey and were requested twice via email to prompt completion. Four hundred and forty six respondents completed the survey fully, representing a 26% response rate with equal distribution across class standing. Females were statistically more likely to respond than males (34.6 versus 19.2%; $p<.05$ using z-test of proportions) consistent with previous literature (Sax, Gilmartin, & Bryant, 2003).

Results were analyzed using SPSS 20.0. To better understand the differences between the male and female experiences and potential reasons for differential retention, a z-test of proportions was used to determine the statistical significance of differences between male and female responses. Retention data was obtained from the MSU registrar.

Students were determined to qualify as a STEM graduate if they earned a degree in mathematics; natural sciences (including physical sciences and biological/agricultural science); science or math education; engineering/engineering technologies; health professions and related clinical sciences; and computer/information sciences. This broader definition of STEM tends to more accurately reflect the participation of women and minorities in STEM-capable careers (George-Jackson, 2011).

Evidence of Success

Student Survey Supports LBC's Teaching Model

The students overwhelmingly showed support for a number of the pillars of the LBC teaching model through the 2012 survey as shown in Table 2. For example, regarding the use of reformed teaching practices, 82.8% of Briggs students indicated that their LBC STEM courses had a "moderate amount" or "great deal" of influence on their success in upper-level STEM courses in their major as illustrated in Table 2. Also, 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. Students also indicated moderate or great benefit from their interactions with Briggs faculty both inside (91.5%) and outside (88.6%) of the classroom and with their peers (92.9%) as illustrated in Table 2. For both the class size and preparation items, female students were significantly more likely to indicate a greater positive response, consistent with previous literature results (Kokkelenberg et al., 2008).

Table 2: Results of 2012 Student Survey

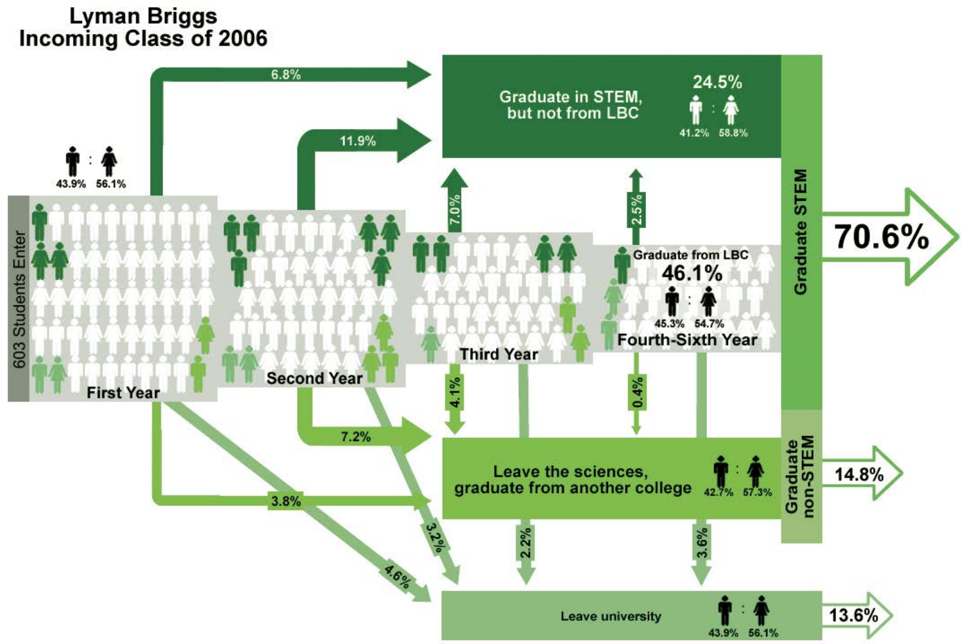
LBC characteristic	Percent of respondents indicating factor added a "great deal" or "moderate amount" of quality to their LBC experience	Percent of Males (N=137)	Percent of Females (N=309)
Smaller class sizes	96.8	83.8	98.2*
Inquiry-based labs	73.3	72.3	73.8
Intro STEM classes leading to success	82.8	77.9	85.0*
Living in Holmes Hall	88.4	85.2	89.8
Interaction with faculty in class	91.5	90.3	91.9
Interaction with faculty outside of class	88.6	85.5	90.0
Interaction with peers/classmates	92.9	91.7	93.5
Integration of HPS with science and math	67.4	63.4	69.3
Statement	**Percent of respondents who indicated they "somewhat agree" or "strongly agree"**	**Percent of Males (N=137)**	**Percent of Females (N=309)**
The Briggs curriculum has given me opportunity to do real science	84.2	82.2	85.2
The Briggs curriculum is helping me graduate timely with a BS degree	70.6	71.2	70.3
LBC promotes an inclusive science learning environment	82.1	71.9	86.7*
How much did your LBC courses help you…	**Percent of respondents who indicated a "moderate amount" or a "great deal"**	**Percent of Males (N=137)**	**Percent of Females (N=309)**
Develop scientific skills	87.0	84.9	87.9
Understand relationship between science and society	84.7	85.6	84.2
Communicate science to others	83.8	81.5	84.9
Activity	**Percent of Senior respondents who participated in activity (N=115)**	**Percent of Males (N=36)**	**Percent of Females (N=79)**
Research with professor outside a course	48.7	55.6	45.6
Study abroad	38.3	36.1	39.2
Work as learning assistant	24.3	25.0	24.1
* z-test of proportions indicates significant difference between males and females at the 0.05 level.			

The student survey also provided strong evidence that the LBC culture encourages students to participate in many high impact co-curricular activities. Of the 115 senior respondents, 48.7% had conducted research with a professor outside of a lab course, 11.3% had co-authored 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 as listed in Table 2. These percentages may be inflated by the self-selection of student respondents, yet the independently verifiable study abroad rate of the classes from 2008 to 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.

High Persistence Rates at LBC

The value of the LBC experience, which supports its students in their transition from high school to college and through to graduation, is evident in the retention and graduation rates. The first-year retention rates at MSU for LBC's incoming classes between 2003 and 2008 were consistently around 95.5%, and the six-year graduation rates at MSU for the LBC classes entering as freshmen between 2001 and 2006 were between 82% and 86%. This compares to 74-77% for MSU overall (MSU, 2012) and 57% for life science majors nationally (PCAST, 2012). Sixty percent of matriculating LBC students graduated within four years, almost double the national four-year graduation rate of 31.3% (NCES, 2012). Figure 1 shows how the incoming class of 2006 progressed through MSU in six years. It is remarkable that more than 70% of incoming LBC students persist in the STEM fields, with nearly equal retention of male and female students. This high rate helps LBC fill the expected 17% growth of STEM occupations between 2008 and 2018 (Langdon, McKittrick, Beede, Khan, & Doms, 2011). The survey results support that these high first-year retention and graduation rates are a result of the learner-centered teaching and science culture developed with LBC.

Figure 1: Six-Year Path of LBC Freshman Class of 2006



Assessment of recent student graduation trends indicate that incoming female LBC students graduate at an equivalent rate to their male counterparts (+/- 2% on the six-year graduation rate). This is evidence that LBC helps female science students pass the critical first and second years where most institutions lose females from science majors at higher rates than they lose males (Astin, 1993; Atkin, Green, & McLaughlin, 2002). Presently, minority students in LBC graduate at a slightly lower rate than the LBC average (0-12% lower), yet at a higher rate than MSU's average. These data, combined with a 95% first-year retention rate at MSU, 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, nearly 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 University has recently created a Science, Technology, and Society program which, similar to LBC, strives to bridge Snow's two cultures divide (AAC&U, 2012). The lessons taken from LBC highlight the importance of using learner-centered teaching pedagogies in combination with the creation of a strong science culture. 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 for almost 45 years by creating a setting with the 95% first-year retention and 85% six-year graduation rates. The student survey strongly indicates the importance of any designed science living-learning community to:

- Utilize learn-centered teaching techniques
- Engage students in the research culture of science
- Provide meaningful student-faculty and student-student interactions

- Employ smaller introductory science courses to create an inclusive environment for female students

Creation of programs with these key elements may help meet the demand for quality STEM graduates that all institutions of higher education must work together to fill.

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Ryan D. Sweeder, Ph.D., Michigan State University

Ryan D. Sweeder, Ph.D. *is an associate professor of chemistry in the Lyman Briggs College at Michigan State University. He earned his Ph.D. at the University of Michigan in inorganic chemistry and chemistry education. He is a member of MSU's Center for Research on College Science Teaching and Learning (CRCSTL) and is co-director of the STEM Learning Laboratory. His research group explores gender inequity in science education, retention of STEM students, and the impact of curricular interventions on learning. He can be reached at sweeder@msu.edu.*

Kathleen A. Jeffery, B.S., Michigan State University

Kathleen A. Jeffery, B.S. *is a recent graduate of Lyman Briggs College at Michigan State University. She earned a BS in biological sciences for secondary education and was a semi-finalist for the 2012 Knowles Science Teaching Fellowship. Jeffery is in the process of earning her teaching certificate. She is interested in how students understand scientific concepts and the effect of alternative pedagogical approaches on their learning. She can be reached at jeffery7@msu.edu.*

Aaron M. McCright, Ph.D., Michigan State University

Aaron M. McCright, Ph.D. *is an associate professor of sociology in Lyman Briggs College and the Department of Sociology at Michigan State University. He earned his Ph.D. in sociology at Washington State University. He examines the influence of inquiry-based learning projects on students' scientific and statistical knowledge, skills, and attitudes. He was a 2007 Kavli Frontiers Fellow in the National Academy of Sciences, and he received the 2009 Teacher-Scholar Award and the 2009 Curricular Service-Learning and Civic Engagement Award at MSU. He can be reached at mccright@msu.edu.*