AC 2009-1342: BEYOND MATH ENRICHMENT: APPLIED PRACTICE WITH LIFE- AND CAREER-SKILLS INTERVENTION AND RETENTION APPLICATIONS MATTER IN EDUCATING NEW MINORITY FRESHMEN

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Beyond Math Enrichment: Applied Practice with Life and Career Skills Intervention and Retention Applications Matter in Educating New Minority Freshmen

Abstract

STEM and urban education along with educational psychology scholarship established four critical research areas that needed judicious exploration to systematically increase the exercise of effective instructional programming for minorities: 1) Early access to and sustained engagement with salient concepts (e.g., logical reasoning, managing complexity) that practically apply classroom theories, 2) Curriculum that supports cognitive development in proportion to students' learning styles, 3) Peer and expert-model pedagogical agents as learning companions and social models, and 4) Considering sociocultural and gender issues in the other three areas. The research design for this study expected promising outcomes with broader applications for similar activities at other institutions based on the assumption that salient tenets of a statistically proven method, the Information Technology Life Skills Career Development (IT-LSCD) model, would transfer to a modified engineering and computer science (E/CS) learning system.

Efforts in the University of Wisconsin-Milwaukee College of Engineering & Applied Science to infuse technical education with practical application, life skills counseling, career development instruction, and financial support made a difference in the preparation of new minority freshmen. Developing and testing the feasibility of the comprehensive quasi-bridge instructional system, Engineering & Computer Science Explorations III (ECSE III aka ex-see 3), through mixed methodology showed that the approach in this pilot significantly advanced all 10 participants (three mentors, seven mentees). Comparisons between pre- and post-program test scores showed significant aptitude improvement. Among mentees, five attained calculus with analytical geometry status and became scholarship worthy. Of the remaining three mentees, one tested out of trigonometry (not algebra) while the other two tested into both courses.

Broad fundamentals helped expand students' experiences beyond math enrichment. All participants reported to have developed investigative responsiveness, increased their technical reflection abilities, formed presentation skills, established durable academic relationships, and gained networking confidence. Besides classroom and field instruction, the ECSE III strategy used multilevel mentoring, residential clustering in a Living Learning Community (LLC), professional associations, and enhancement activities during the ensuing academic semester. The goal was to improve student population diversity by increasing the number of minorities in E/CS disciplines through early access and preparation that concurrently addressed recruitment, matriculation, retention, and sustained support issues.

This paper depicts results that derived from examining ECSE III through the abovementioned lenses. The paper informs about participants' traits, pre-program expectations, and post-program self-reported experiences. As well, the paper discloses gradations observed within ECSE III pre-post-program test scores, outcomes of tracking participants' development during the ensuing fall semester, and suggestions for component modifications within ECSE III.

Preface

Scholarship shows four fundamentally important research areas that require more investigation to increase effective instructional programming that helps develop engineering and computer science (E/CS) talent from among minority (African American, Hispanic, Native American, Women, Southeast Asian, and first generation college student) populations. To explain, STEM educators[12] support early access to and continual engagement with fundamental E/CS concepts (e.g., logical reasoning, arithmetical constructs, analytical transfer, spatial cognition, and managing complexity) and subsequent practical applications of classroom theories over an extended period, preferably in a continuum.

Urban educators[1] advocate for the presence of multiculturalism in instructional design, finding that curriculum supportive of cognitive development in proportion to students' learning styles produces outcomes with greater long term value. These educators strongly suggest that young adults are 'high-risk' when educators do not make advancement realistically meaningful as such. Besides, the educators add that instructors place learners at risk when sizeable disparity occurs between students' circumstances and needs, and the willingness of their teachers to acknowledge, accommodate, and react in a manner that enables maximum social, emotional, and intellectual growth and development. This matters in E/CS when considering the viability of a pipeline that begins with intervention.[1] The absence of mutual respect diffuses the possibility of forming synergistic relationships as the analogical transmission-line system model[2] of engineering education supports.

As well, studies by educational psychologists[3] find a need for both peer and expert-model pedagogical agents as learning companions (PALs) and social models. To them, peer modeling supports 'self-efficacy beliefs' when interaction involves openness to aid a more dynamic exchange. As such, these educators consider peer partners more effective than experts for learning and motivation. However, these scholars concede that expert agents are more ready to provide superior competency that better demonstrate skills. Still, both bring unique advantages that can concurrently benefit a recipient. Considering sociocultural and gender issues in the preceding paragraphs, psychologists[4] suggest designing competency (low/high) and interaction type (proactive/responsive) of PALs according to preferable learning and motivational objectives. The goal is to clarify what does or does not work for minorities.

This paper responds to the need for disseminating information about learning systems designed to help equip more minorities to pursue Science, Technology, Engineering, and Mathematics (STEM) degrees. At present, all minorities remain significantly under-represented in all STEM fields and more effort is necessary to resolve concern.[5] This state exists due to decreasing interest (especially among African-American and Hispanic males) in technical fields, a smaller college-age population, falling retention rates, scarce pre-college mathematics preparation specific to E/CS fields, and shifting demographics in major urban areas.[678]

The mixed-methodology research design for this study expected promising outcomes with broader applications for similar activities at other institutions. The premises derived from the assumption that salient tenets of a statistically proven method, the Information Technology Life Skills Career Development (IT-LSCD) model, would transfer to a modified E/CS learning

system. Scholars[1] advocate for research-proven learning systems that fuse technical education, conventional teaching, and counseling that nurtures abilities to make successful life choices.

Adapting a Proven IT Model to E/CS

The Office of Diversity/Gender Initiatives (ODGI) in the University of Wisconsin-Milwaukee (UWM) College of Engineering & Applied Science (CEAS) assumed that significant principles of the Information Technology Life Skills Career Development[9] (IT-LSCD) model for young adults could transfer to educational aspects of another technical discipline. IT-LSCD, as the model operated from 1998 – 2003 in the UWM School of Information Studies, primarily served the learning needs of urban minority high school students. The intent was to help these learners make sense of emerging fields and learn how to overcome obstacles between them and society's technical fabric. Model fundamentals comprised education, training, mentoring, counseling, subsidy, tutoring, evaluation, recommendations for revision(s) as necessary, and other support in synergistic modules to form a comprehensive learning system. Some 758 participants completed IT-LSCD during the timeframe with mostly positive results, such as pursuing their expectations to matriculate into higher education.[9]

IT-LSCD was research driven to gain a greater understanding of what was effective. The model assumed that the personal relevance of content and methods held potential to help users understand that positive skills and outcomes were attainable. The method focused on helping young adults identify their interests, assess personal values, trust in their relevant a priori knowledge, and evaluate skills in a nonthreatening environment. Beyond encouraging technical literacy, the model engaged participants in global awareness, role-playing, team building, and creativity. IT-LSCD advocated leadership development, knowledge of social protocol, and understanding the value of constructive life choices. The system supported multiple formal reasoning for decision-making, analyses, and problem solving. Exposure to information about employment trends, employer expectations, and employee rights provided minority young adults with an additional access level. The method expected minority young adults to learn to dress for success, understand the interview process, and network with what they had learned. As such, IT-LSCD consistently employed the talents of leaders who reflected the service population.

The presumption existed in the IT-LSCD method that minority young adults' worldviews influenced their learning and they needed to be equipped to function effectively in the new workforce, economy, and social system. IT-LSCD curriculum and instruction consisted of three learning levels (beginner, intermediate, and advanced) designed to stimulate higher order thinking, creativity, decision making, and critical thinking. As such, the approach advocated a variety of learning goals that made flexible knowledge possible. In that context, the curriculum incorporated textbooks and tutorials written to support non-traditional learning styles where progression depended on participants' abilities to continue knowledgeably.

Moreover, IT-LSCD considered certain life skills essential while others were not expedient. To illustrate, life principles potentially guided young adults in their choices relative to academic goals or chemical dependency. As such, IT-LSCD incorporated the Iowa State University's Targeting Life Skills[10] model into its curriculum to promote developmentally appropriate opportunities to experience and practice the life principles in need over a lifetime.

Unlike most E/CS interventions, learning theory supported curriculum development specific to the cognitive developmental stages that minority young adults experienced based on content unique to their needs. That is, the curriculum included learning theory that supported using concrete operations to acquire Piagetian[11] symbolic logic. For example, participants in a formal operational stage developed problem solving and ordering by calculating spreadsheet formulas. They engaged other problem solving and ordering by designing technical slide presentations. Navigating the computer file structure demonstrated location concepts. Customizing documents, while learning design requirements, depicted strategizing and creative design concepts as concrete objects. Multimedia supported visualization strategies through mental imagery—a process central to problem solving. As in Figure 1, educational psychology finds that video and picture media stimulate the occipital lobe, sound moves the temporal lobe to activate hearing, while text stimulates the parietal lobes for reading and frontal lobes to sustain memory.[13]

Figure 1. Sound and Brain Activity.
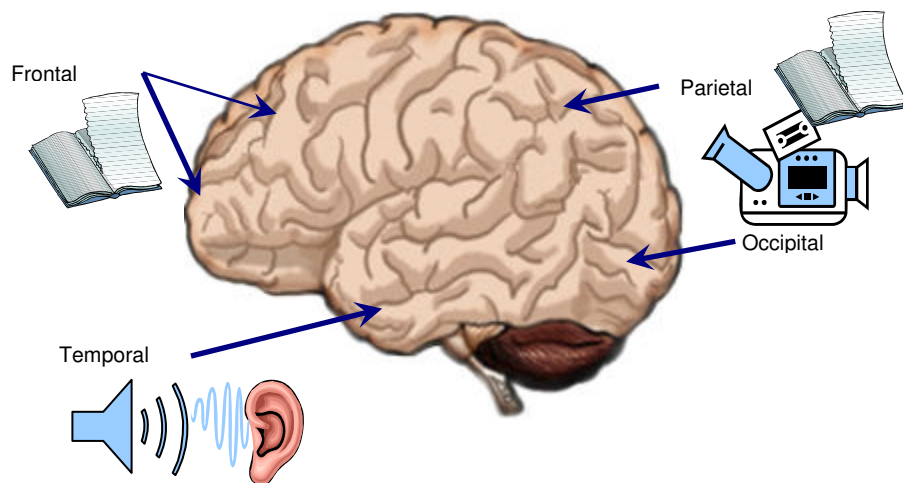
Also, IT-LSCD employed the tool approach where technical equipment facilitated teaching and learning. Studies comprised at least 24 hours of technical training and 24 added hours of personal management and professional improvement activities. Multicultural guest speakers provided information to help participants conceptualize the technical world and its potential benefits. Each individual pretested, which identified explicit learning needs. After IT-LSCD experiences, each person post-tested and completed exit surveys. A sample of IT-LSCD participants completed telephone or personal interviews, as well. Results revealed that participants achieved in ways that reflected the paradigm's synthesis between technical, daily living, and employability principles.

Additionally, multiple levels of collaboration (e.g., community, corporate, government, education) provided opportunities for a variety of realistic experiences. An orientation introduced minority young adults to valuable services available during and after their IT-LSCD experience. Participants toured the host institution and area industries to acquaint themselves with resources accessible for current and future uses. One disadvantage to the IT-LSCD method was that service population needs, physical space, funding, and other logistics influenced the number of students

admitted each semester. Still, adapting the method for the Engineering & Computer Science Explorations III (ECSE III) learning system seemed plausible.

Engineering & Computer Science Explorations III

Conceived as the third level of a continuum, an ECSE III pilot launched June 22, 2008. The first stage of ECSE III comprised a six-week residential quasi-bridge summer experience for incoming freshmen. The National Science Foundation's Louis B. Stokes [Wisconsin] Alliance for Minority Participation (WiscAMP) program and the John Deere Foundation partially funded ($22,700 and $3,000, respectively) ECSE III. The program allowed students to concentrate on E/CS concepts and practically apply those ideas in and out of the classroom.

Unlike the IT-LSCD model, ECSE III did not assume hands-on training led to knowledge regardless of the starting point. Rather, the need for understanding analytical concepts and aforementioned strategies mattered more in E/CS education. As such, the infusion of constructs into a quasi-bridge system was more complex. Besides classroom and field instruction, the ECSE III strategy used multilevel mentoring, residential clustering in a Living Learning Community (LLC), professional associations, and enhancement activities during the ensuing academic semester. The goal was to improve student population diversity by increasing the number of minorities in E/CS disciplines through early access and preparation that concurrently addressed recruitment, matriculation, retention, and sustained support issues.

Recruitment involved creating awareness through marketing and outreach. The ultimate goal was to help increase enrollment, retention, and graduation rates by targeting minorities that showed potential for latent E/CS talent. Recruitment activities helped:

- Educate the general public
- Create awareness within UWM and the community at large
- Promote the program as a valuable commodity to be sought by potential students, their parents, high school teachers (mathematics, science) and guidance counselors, and community members who could influence minority students to consider studying E/CS

Several approaches facilitated marketing, including:

- Media relations and promotions
- Campus and community communications and literature distributions
- Career fairs at high schools and other venues
- UWM minority recruitment events and community meetings
- Presentations at high schools with advanced mathematics and/or pre-engineering courses through Project Lead the Way

ECSE used existing avenues within the college to promote, as well, by:

- Highlighting the project on the Internet
- Creating new materials (e.g., fax cover page, brochures)
- Involving incoming freshmen early in student groups, mentoring, and tutoring

- Planning a newsletter to address diversity issues in education
- Connecting upper class students with ECSE III students

After orientation, students explored topics common to nine E/CS disciplines (Civil, Computer, Materials, Mechanical, Electrical, Environmental, Industrial, and Transportation Engineering plus Computer Science). They worked with nanotechnology and chemical engineering. The program also exposed them to new biomedical engineering developments. ECSE III students gained college research awareness and toured companies to explore E/CS in industry. As well, they networked with industry leaders, mostly minorities, to form present contacts with future advantages. Students also received a stipend ($1,700) besides a campus Gold Card ($300) to prevent them from having to divide time between work and study. Some students carried over portions of their stipends the following semester to defray tuition.

ECSE III students also:

- Obtained instruction and tutoring from minority adjunct instructors and informed mentors
- Applied classroom concepts in labs and designed projects to aid skills development
- Used online resources to support self-practicing and testing

Computer lab access was effortless since students and mentors shared housing in a residential LLC. ECSE III mentors served as LLC residential assistants. The LLC housed live-in peer mentors of similar ages as mentees. Peer mentors had excelled in advanced mathematics and other high school subjects yet needed non-mathematical remediation. As well, Check-In Day included LLC orientation, a campus tour, reception, and a closing recreation activity.

As in Table 1, courses began the following week and comprised at least two hours per day of math preparation on Mondays – Thursdays with weekly assessments. Co-curricular activities occurred on Fridays (industry tours) and Saturdays (academic excursions) to study and journal distinguished engineering or computing marvels. An eLife course addressed E/CS career issues, E/CS in lifelong learning, life skills training, discussion of pedagogical agents, developing professional presentations, and spreadsheet uses to reflect E/CS information. Students wrote individual weekly reflection papers based on their journal entries, also. ECSE III students presented group research reports with posters and slide presentations, as well.

Table 1. ECSE III Residential Bridge for Incoming Freshmen.

ECSE III Quasi-Bridge Schedule					
Mondays	Tuesdays	Wednesdays	Thursdays	Fridays	Saturdays
• Math Prep[a] • Project • Assessment • eLife	• Math Prep • Project • Math Lab • eLife	• Math Prep • Project • Math Lab • eLife	• Math Prep • Project • Math Lab • eLife	• Industry tour	• Academic Excursion
Recreational activities until 11:00 PM					

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[a] Polynomials, Rational Expressions, Graphing Equations and Inequalities, Systems of Linear Equations, Exponents and Logarithms, Analytic Geometry, and Trigonometry.

ECSE III students participated in a research seminar, as in Table 2, to help reinforce the terminal end of the pipeline. Graduate school faculty, coordinators, and students assisted ECSE III with scholarly writing, research protocol, and analytical co-curricular activities (e.g., scavenger hunt throughout UWM libraries, tour of an industrial research facility). That effort helped ECSE III students prepare a year earlier for the Sophomore Research Experience[b] (SRE) program. Ronald E. McNair Post Baccalaureate Achievement Program interns shared their projects with ECSE III students in a mutual learning exchange, also. The Committee on Institutional Cooperation Summer Research Opportunity Program (CIC/SROP) participants explained to ECSE III students how to prepare for graduate education while pursing an undergraduate degree, as well.

Table 2. ECSE III Research Awareness.

ECSE III Research Awareness Seminar Schedule		
Day 1		
AM Activities	PM Activities	Participants
• Academic Research Protocol • Presentation Forms	• Library Tour/Scavenger Hunt • Sociocultural Event • Ethics in Research Seminar	• Faculty & Staff • Graduate Student Mentors • Volunteers

ECSE III students participated in standard campus activities (e.g., academic advising, diversity initiatives, cultural recreation events). The purpose was to acquaint them with their campus and local surroundings while they experienced what E/CS professionals are and do.

Additionally, meeting ECSE III completers' academic and career advising needs during the ensuing fall semester transferred from ODGI to the traditional CEAS Student Services and Career Services departments. The transfer resulted in differences in approaches to providing services, ones without diversity emphases. However, ODGI continued contact with ECSE III students by mentoring, advising, and exposing them to local (sySTEM NOW!), regional (American Multicultural Student Leadership Conference), and national (National Society of Black Engineers) professional development and leadership conferences.

Moreover, ECSE III students practiced and demonstrated E/CS principles during conference presentations with the animated pedagogical agent PowerUp.[14] That agent featured expert-model lifelike minority engineer characters to facilitate the learning process. ECSE III students learned the various levels of the game and used that knowledge to attract and communicate engineering principles to other conference attendees. However, a peer-model agent was not available to ECSE III students from which to draw a comparison of effect on teaching and learning E/CS. Even so, overall, results of ECSE III students' experiences showed promise for the model.

ECSE III Results

Nine students from Wisconsin and one from Minnesota participated in ECSE III. They comprised mentors (one biracial [Native-American, White], two African-American, and one Asian) and Mentees (one Latina, one multiracial [African-American, Native, Asian, White], one

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[b] The Sophomore Research Experience is an eight-week summer internship of the UWM Graduate School that precedes and feeds into the Ronald E. McNair Post-Baccalaureate Program.

white first generation college immigrant, one African-American, and two Asian). Mentors 1 and 4 in Table 3 entered with deficits (e.g., Adv Alg, college writing) that required remediation but not a mathematics post-test. Mentors 2 and 3 pretested at UWM Math 105 level but did not satisfy the general education requirement (GER). Their post-test scores increased over pretest though neither tested into Calc 1 (Math 231). Still, they post-tested out of Trig (Math 117) and satisfied GER but did not test out of Alg (Math 116). Mentors 2 and 3 passed Alg and Trig in the ALEKS online artificial intelligent assessment and learning system final exam with letter grades "A" and "B", respectively.

Mentee 1's Alg post-test score was lower than the pretest though Trig increased. However, Mentee 1 passed Alg and Trig in the ALEKS final with a "B" grade. Being the only female, Mentee 1 did not have a peer mentor. Mentee 2 increased the Alg post-test score over pretest though Trig decreased. Mentee 2 pretested out of Trig but not Alg and post-tested out of the latter but not the former, one of many ambiguities seen in Table 3 data. Mentee 3's Alg and Trig post-test scores increased over pretest but not well enough to test out of either. Mentee 4 pretested out of Alg, not Trig, but post-tested into Calc 1. Mentee 5 pretested at the Math 105 level and post-tested out of Trig but not Alg. Mentee 6 overcame deficiencies and advanced in the third week to become a peer mentor. Overall, six of the eight (75%) post-testers significantly increased their test scores.

Table 3. Math Placement Scores: ACT Compared with UWM Pre/Post-Test and Milestone Levels.

	ACT MATH SCORE	PRE-TEST UW MILE[c] LEVEL	POST-TEST UW MILE LEVEL	PRE-TEST ALG PLACE[d] SCORE	POST-TEST ALG PLACE SCORE	PRE-TEST TRIG PLACE SCORE	POST-TEST TRIG PLACE SCORE	PRE-TEST CALC PLACE	POST-TEST CALC PLACE
MENTOR 1	29	45	N/A	770	N/A	700	N/A	YES	N/A
MENTOR 2	29	26	36	530	590	520	660	NO	NO
MENTOR 3	30	26	36	530	610	590	640	NO	NO
MENTOR 4	33	45	N/A	850	N/A	750	N/A	YES	N/A
MENTEE 1	24	30	20	560	520	420	460	NO	NO
MENTEE 2	25	36	35	580	640	560	500	NO	NO
MENTEE 3	25	26	37	540	610	500	540	NO	NO
MENTEE 4	25	35	40	680	680	500	660	NO	YES
MENTEE 5	27	26	36	540	620	610	600	NO	NO
MENTEE 6	27	40	45	680	850	700	700	YES	YES

On average, mentees spent 6.73 hrs/wk (33.65 hours over five weeks) using ALEKS in self-paced practicing of mathematics. They learned, on average, 3.54 items per hour. Almost all students experienced an increase in mathematics aptitude and advanced one to two classes in most cases. Comparisons between pre- and post-program test scores showed significant aptitude improvement. Still, to clarify uncertainties some data suggested, Mentees that post-tested out of either Alg or Trig without mastery of the other subject post-tested a second time. Overall, seven ECSE III students attained Calc-readiness, and scholarship worthiness, by program end. However, one student did not receive a scholarship offer despite the achievement.

In addition, conclusions based on self-report survey responses indicated that connecting ECSE III new incoming minority freshmen with needful education in supportive environments

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[c] MILE = Milestone
[d] PLACE = Placement

mattered. To illustrate, all of them found college research and technical writing exciting and challenging, but very helpful. To them, completing five projects and actually "doing" E/CS increased their proficiency. For example, the winning entry in the ECSE III Structural Engineering Bridge Competition displaced a load of 87 lbs, which far surpassed the existing CEAS record. The team with the research project judged the best explored nanotechnology.

Moreover, survey results also showed that co-curricular activities strengthened participants resolve to pursue their intended E/CS degrees. Networking with professionals in the field helped ECSE III students better understand the critical need for minorities in engineering and computing, globally, as well. Additionally, residing in the LLC better prepared them for campus life, the academic system, and increased their confidence in leadership, business, and social skills. eLife class helped ECSE III students consider scientists' lifestyle, career development issues, and hone creative as well as critical thinking skills.

Data analyses following the fall 2008 semester showed that 100% of ECSE III participants matriculated into UWM, which helped increase the 2008 CEAS student population by 12% over 2007. Though all ECSE III students completed their fall college semester, three of them received standard academic holds. To explain, one Mentee passed Trig but failed Alg. One scholarship recipient failed Calc though four recipients retained their funding. One Mentor missed the sustained GPA requirement by .03, which resulted in scholarship probation the spring semester. Still, as in Figure 2, 90% of students remained in CEAS while 10% transferred to the College of Letters & Sciences in spring 2009. Even so, UWM retained 100% of ECSE III students.

Figure 2. Percentage of ECSE III Students Retained after Fall 2008 Semester.
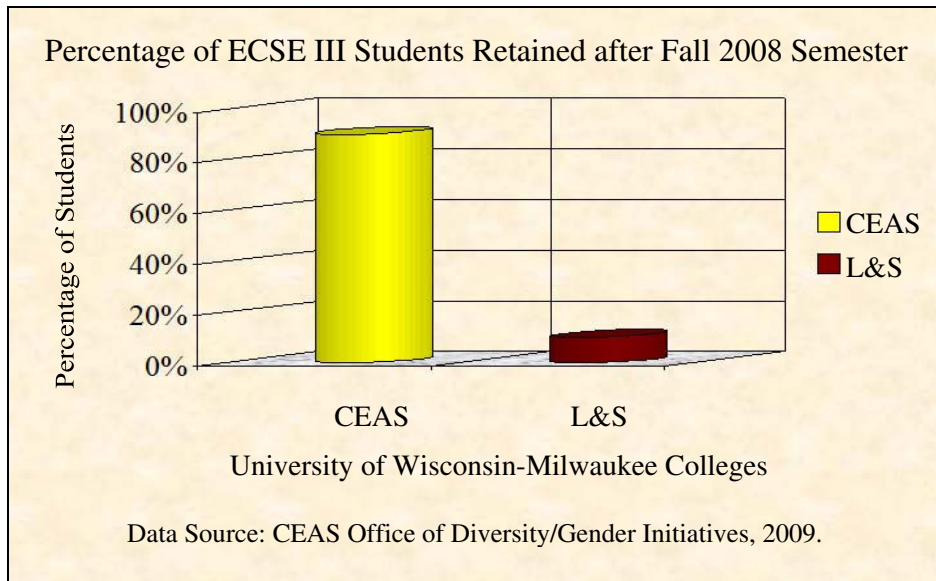
In contrast to ECSE III, the conventional four-week CEAS Summer Bridge Program enrolled 35 incoming freshmen (five onsite and 30 online independent study students), none of them traditional underrepresented minorities. However, one female participated in that program. Though 18 students advanced, only three of the 35 placed into Calc 1. The CEAS Summer

Bridge Program involved only mathematics instruction and review. One instructor taught the onsite course while another oversaw independent study students.

Of the 35, mathematics placement post-test scores remained unchanged from pre-test scores for 12 students. As well, post-test scores for four CEAS Summer Bridge Program students decreased from their pre-tests. One onsite and five independent study students advanced to Alg but not Trig. Two independent study students advanced to Trig but not Alg. Four independent study students advanced to both Alg and Trig. Overall, 51% of the CEAS Summer Bridge Program students tested higher.

Recommendation

A focus group session with ECSE III completers should occur to determine what contributed to performance during the fall and spring semesters after program completion. The goal is to discover whether performance and/or resource gaps exist and develop strategies accordingly.

Acknowledgements

Appreciation extends to ECSE III instructors (Craig Ashley, Ulices Sepúlveda), dedicated volunteers (Harold E. Reyna, JoAnn Crump), industry representatives, and others who devoted a significant amount of time to ensuring an enriching summer experience for these minority incoming freshmen.

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