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Self-Efficacy as a Long-Term Outcome of a General Education Course on Digital Technologies

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***Abstract*— This study investigates the long-term outcomes of a general education course on digital technologies. Through cross-sectional and longitudinal interviews with students, the authors find that self-efficacy is a long-term student outcome. The primary sources of self-efficacy in the course for students were verbal persuasion and mastery experience. Faculty and teaching assistants were key sources for verbal persuasion. Some students experienced a success paradox: they felt successful in the course even though they failed to meet all of their initial expectations. This study can guide faculty in designing a course to promote student self-efficacy.**

***Index Terms*—general education engineering courses, student outcomes, self-efficacy, digital information technology**

I. Introduction

Literacy in science and technology is an important, national need [1]. In some colleges and universities, this need has been addressed through the creation of engineering courses for non-engineering majors [2], which usually satisfy a general education requirement. So far, however, little is known about the long-term student outcomes of these courses. Without knowledge about student outcomes, faculty would be unable to gauge the effectiveness of these courses. Thus this study seeks to understand the potential long-term student outcomes of a general education engineering course.

Typical general education courses focus on the acquisition of intellectual skills. Laird, Niskodé-Dossett, and Kuh [3] studied the contributions of general education to student learning through the use of the Faculty Survey of Student Engagement (FSSE). The survey was administered to faculty and instructors in 109 colleges and universities. Laird et al. found that faculty who teach general education courses focus more on developing intellectual skills, such as critical thinking, than do faculty who teach courses for their own majors.

Although general education courses emphasize cognitive skills, in studies of general education engineering courses, researchers also have found positive non-cognitive student outcomes. Kuc [4] found that students felt empowered by having learned the content of a digital technologies course. In other studies of outcomes of engineering courses for non-majors [5], [6], researchers found that students became more confident in their abilities to perform basic engineering tasks, and improved their understanding of engineering in the real world [4], [6].

Non-cognitive student outcomes were also found in computer science courses for non-majors. Wiedenbeck [7] studied the factors that affected how well students learned to program in an introductory computer science course. Wiedenbeck found substantial increases in students' perceived self-efficacy during the semester. Guzdial [8] found that after completing a media computation course for non-majors, students understood how computer science could be applied. Forte and Guzdial [9] found that non- computer science students were more likely to complete and pass a computer science course when the course was tailored to the students' discipline.

This study makes three contributions to engineering education. First, the authors identify the potential long-term outcomes of general education engineering courses. Second, the authors investigate student outcomes through the interviews, which have been minimally used especially in the study of self-efficacy in engineering courses. Third, as the primary result of this study, the authors describe the mechanisms that promote student self-efficacy in a course on digital technologies for non-engineering majors.

II. Context

ECE 101 is an elective course offered by the electrical and computer engineering department at a large public research university. This course introduces students outside the engineering college to the design and development of digital technologies. Most students in the college of engineering take higher-level circuits courses. In the past, a very small number

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of students who completed ECE 101 transferred to the college of engineering in a later semester.

The overarching learning outcomes for ECE 101 include learning about the mathematical and scientific principles that underlie information technologies, the engineering processes in design and development, and the tradeoffs that engineers make during the design process. The learning outcomes are not explicitly related to self-efficacy or repairing devices.

ECE 101 meets the university's general education requirements in quantitative reasoning and in physical sciences. In each week of the semester, ECE 101 students attend two 50-minute lectures taught by a lead instructor and one two-hour laboratory session taught by a graduate teaching assistant (TA). The TAs are graduate students in the ECE department and are chosen by the department. In each semester, the course enrolls an average of nearly thirty students; most are first year and second year students. Instruction in engineering processes and tradeoffs is supported in the laboratory, where students find multiple engineering solutions to the assigned problems. Some of the topics addressed in laboratory are HTML and JavaScript, digital filters to process music and images, and digital logic circuits.

ECE 101 students are responsible for one final project during the semester. The students work either in a group or alone on this project. Throughout the project, the instructor and TAs provide feedback to help students scale up or down their project. The students have the freedom to address the feedback or change the project in its entirety. At the end of the semester, the students demonstrate their projects in front of their classmates, the instructor, and the TAs. To assess the demonstration and final project, the instructor and TAs use a rubric with five criteria: time/effort, creativity, application of ECE 101 topics, value of the design, and technical description of the design. On the rubric, the instructor and TAs provide comments and to rate the project based on a grading rubric.

As an example of a final project, a student proposed to work on a music synthesizer. In the feedback to the student, the instructor recommended that the student either use waveform synthesis or construct hardware based on a finite-state machine, as learned in ECE 101. As a result, the student constructed a circuit-based keyboard synthesizer. The student did not design the synthesizer; instead, the student followed instructions from an example project documented on the Internet. The demonstration at the end of the semester was excellent and subsequently the student earned a strong grade for the final project with higher marks on time, effort, application of ECE 101 topics and technical discussion, despite somewhat lower marks on creativity. The student demonstrated comprehension of oscillator concepts and formulae that had been covered in the course.

In order to improve student engagement in ECE 101, the instructor introduced content personalization into the teaching of the course [10]. Content personalization aims to improve student engagement and students' confidence in applying new skills to their lives and careers. Students contribute to the class by sharing applications of the topics covered. The students' ideas are then integrated into the lectures, homework exercises, and examination problems. In this way, the content is adapted throughout the semester to incorporate the students' connections of digital information to their academic, personal, or professional interests. Content personalization is an individual version of course tailoring [9].

The instructor did not have any formal training on self-efficacy. The TAs were instructed on assessment of final projects. They were encouraged to work closely with students, taking a hands-on approach.

III. Theoretical Framework

This study was guided by Bandura's self-efficacy theory [11]. Self-efficacy refers to "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" [12, pp. 3]. According to Bandura [11], [12], there are four sources of self-efficacy: mastery experience, vicarious experience, verbal persuasion, and physiological and affective states. In this study, self-efficacy theory was used to guide the development of the interview protocol for the follow-up longitudinal interviews as well as the data analysis. The four sources of self-efficacy were interpreted as follows: "mastery experience" to encompass experiences in which students achieved their learning objectives; "vicarious experience" to be the perspective the students gained on their own ability or skill based on what they saw from their peers, teaching assistants, and instructor; "verbal persuasion" to be the verbal feedback that students received from their peers, teaching assistants, and instructor; and "physiological state" to be the emotions that the students felt in association with an activity related to the course.

IV. Research Questions and Methods

The first research question addressed was, "What are the potential long-term impacts of a digital technologies course for non-engineers?" In a report of the preliminary results to the first research question [13], the authors found that self-efficacy was one of the long-term student outcomes. Other long-term outcomes included retention of particular technical skills (e.g. HTML, JavaScript) and perseverance through challenges (e.g., final projects). As a result of finding self-efficacy as a long-term student outcome, a follow up interview was designed to further investigate the sources of self-efficacy in the course. Subsequently, qualitative methods were employed to address a second research question: "Which sources of self-efficacy influenced students' experiences in the digital technologies course?"

A. Data Collection

To develop a qualitative understanding of student outcomes from the student's perspective, data were collected through interviews with students. Interviews were also chosen to provide rich understanding of how students use knowledge gained in general education engineering courses. Following Institutional Review Board approval, an e-mail message was sent to invite all 188 students who had completed ECE 101 from the fall of 2007 through the fall of 2010 to participate in individual interviews. Twenty students responded to the message, and all 20 were interviewed. These students included nine women and eleven men. At the time of the interview, six were first-year students, three sophomores, nine juniors, and two seniors. At the time of the interview, one student was majoring in computer engineering, and two students expressed interest in switching majors to electrical or computer engineering. The remainder of the interviewed students were in majors outside of engineering, including accounting, physiology, psychology, and journalism. Each interview lasted 25 to 45 minutes. The interviews were audio recorded and later transcribed verbatim. Each interviewed student received $10 as compensation for their time.

Through the use of cross-sectional and longitudinal interviews, long-term outcomes were assessed one to six semesters after the students took the course. Cross-sectional interviews were conducted the spring of 2011 with 12 students. The interviewed students were asked to recall the most important ideas and significant experiences in ECE 101 and in one other general education course. Some of the memorable courses that students chose were in animal sciences, Latin American studies, and psychology.

Longitudinal interviews consisted of an initial interview and a follow up interview. The follow up interview was conducted one semester after the initial interview. As shown in Table I longitudinal interviews began in the spring of 2012. Four initial interviews were conducted spring of 2012. Two of those interviewees were available for a follow up interview in the fall of 2012. Four more initial interviews were conducted in the fall of 2012. Two of those interviewees were available for a follow up interview in the spring of 2013. In total, only four of the eight interviewees were available for a follow up longitudinal interview.

The same interview protocol was used for the cross-sectional interviews and the initial longitudinal interview. After the findings from the first interview were analyzed, a second protocol was created to further investigate self-efficacy as a long-term student outcome. Using the second protocol, in the follow up longitudinal interviews, students were asked questions about sources of self-efficacy. There were four parts to the interview; in each part, questions were directed towards one of the four sources of self-efficacy according to Bandura's self-efficacy theory [11]: mastery experience, vicarious experience, verbal persuasion, and physiological and affective states.

B. Data Analysis

In the spring of 2012, two of the authors analyzed the first set of cross-sectional interviews using inductive data analysis. After analyzing the interview transcripts individually, the authors met to negotiate on codes and arrive at a final code list. The final code list was used to analyze all interviews and develop a final set of categories and themes. As part of the member check, a draft report was sent to the twelve participants, to which three responded positively and with no changes.

In the spring of 2014, two of the authors analyzed the follow up longitudinal interviews. The data analysis was primarily guided by [11] with some emergent coding. The two authors analyzed the interviews individually and met to discuss and negotiate on codes. The final list of codes included codes that indicated sources of self-efficacy (e.g., mastery experience).

C. Limitations

One of the limitations of this study is that the students were self-selected. More students who may have had very positive or very negative experiences may have volunteered to participate in an interview. Self-selection bias may have been mitigated by the $10 compensation because students who did not have extreme experiences may have participated in the study because of the compensation. A second limitation is that only students who completed the course were interviewed. The experiences of the students who did not complete the course were not captured in these interviews. A third limitation is that the students may have experienced the course differently depending on the semester they took the course. However, the same instructor taught the course from 2007 through 2011, and the core content remained constant.

TABLE I
SUMMARY OF INTERVIEWS

Student	Interview Type	Spring 2011	Spring 2012	Fall 2012	Spring 2013
1	CS	X			
2	CS	X			
3	CS	X			
4	CS	X			
5	CS	X			
6	CS	X			
7	CS	X			
8	CS	X			
9	CS	X			
10	CS	X			
11	CS	X			
12	CS	X			
13	LG		X		
14	LG		X	X	
15	LG		X	X	
16	LG		X		
17	LG			X	X
18	LG			X	
19	LG			X	
20	LG			X	X

CS stands for cross-sectional interview
LG stands for longitudinal interview
Note: There was no overlap between CS and LG students

V. RESULTS

The following set of results reflects the findings from the cross-sectional and longitudinal interviews with a focus on self-efficacy and sources of self-efficacy. In the quotations below, all names are pseudonyms.

A. Self-efficacy as a long-term outcome

Reflecting on what they had learned in the ECE 101 course, students recounted experiences that improved their confidence in their ability to perform tasks related to the course. Danielle described an example where, after the fan in her laptop computer stopped working, she asked her brother if he could fix it, but she reassessed the situation after her brother took too long to work on it. She recalled,

> I am going to try fixing it myself all on my own, forget asking him, I am going to do this and I did fix it. … If I haven't taken that class I wouldn't have taken that step ... I wouldn't have taken that final step of just being like "I am going to fix this on my own or this is just going to stay broke." [sic] (Danielle)

Other students, like Felix, said that after completing the course, they were able to do something that would otherwise have felt "scary" or something that they were unable to do.

> As much as I disliked this class and it was a struggle for me, I did well when all was said and done, and I realized that even though I … don't see myself as someone who is good at these things, I can do them when push comes to shove and math and science aren't these scary things I can't do. (Felix) (from [13])

Some students recalled feeling self-efficacious about certain course activities six semesters after they had taken the course.

Students' self-efficacy was improved primarily by verbal persuasion and mastery experience. Students also reported vicarious experience and physiological state as sources of self-efficacy, but verbal persuasion and mastery experience were consistently influential and more prominent for all students.

B. *Verbal Persuasion*

Through their interactions with the teaching assistants (TAs) and the instructor, students were persuaded into believing that they could persist in the course. All of the students gave examples of verbal persuasion in their interviews. In particular, students said they would not have been able to persist in the course without the assistance and encouragement from the TAs. The representative quotation from Lana below highlights the critical role that TAs played in providing encouragement, as a form of verbal persuasion. Lana further recognized that the encouragement was "as important" as the technical assistance provided by the TAs. With the encouragement from the TA, students felt more capable of completing tasks and more willing to explore unfamiliar topics.

> They're [TAs] so much help and at students' disposal, really makes it instrumental [sic] for a person like myself with a non-engineering background that has a marginal interest in the content to be able to derive more value out of it [the course content]. I honestly don't know how much value I would have been able to derive out of it had I not had the assistance that I had and the encouragement. The encouragement is as important as the help - just having that positive reinforcement every week was pretty crucial. (Lana)

Peers also served as agents of verbal persuasion. For example, students who developed games for their final projects had a chance to be recognized by their peers for creating the best game in the class. Peers in the class provided evaluations from which the winners were selected. Andrea reported that her final project, which was a game she developed with her partner, won recognition as the best game in the class. This recognition served as positive feedback and verbal persuasion from her peers.

> My partner and I made a game that basically chose random weapons and you fought zombie giraffes, so it was pretty fun. It won for the best game in the class, so my partner and I were very proud of it. (Andrea)

While providing verbal persuasion was critical, as posited by [11], verbal persuasion needs to be substantiated by experiential performance. In this case, aside from being persuaded that they could accomplish the tasks required in the course, the verbal persuasion agents (TAs and instructor) also needed to ensure that the students had experience with attainable tasks. As an example, in the quotation below, the instructor encourages Edward, who was worried about lacking the ability to perform to his own standards in the final project, to work on a project that would be attainable. The instructor was confident that Edward had gained knowledge in the different topics taught, and Edward's comment indicates the positive effect of the instructor's statement. As a result, Edward felt comfortable changing to an attainable final project.

> I told the instructor that I didn't think I was going to get a good grade or something and he said just do something else – you learned a lot. Turn the project in some other direction. He was helpful with that too and supportive of that. (Edward)

C. *Mastery Experience*

All of the interviewed students applied their new knowledge of digital technologies in their final project. For the students, the final project was a salient experience through which they demonstrated mastery in the material. The students also stated how their mastery experience in the final project influenced their decision to undertake similar projects after the semester had ended. For example, Brian discussed soldering a battery after he had practiced soldering in ECE 101.

> I had a Game Boy game, Pokemon Silver. I love it. And the battery ran out on the game which doesn't allow you to save any more. And I was very unhappy about this.... So I Googled up why this was happening, what was going on, and it said there was an internal battery inside this game pack that's dying. So what I did was unscrewed this back piece, found a solder, went out and bought a battery, and soldered that battery, the new battery, into the back of the game, and it works perfectly now. That was pretty cool. I learned all that from ECE 101. I had no idea how to solder before that or anything. (Brian) (from [13])

Successes can raise mastery expectations and failures can lower them [11]. Although the students expressed feelings of accomplishment in their final project, a pattern was observed in which many students said they were both "successful and unsuccessful" in their final projects. They talked about having failed technically, because the projects did not meet all of their requirements. Yet paradoxically they felt they did not actually fail because they still learned something and took something away from the experience. The authors call this phenomenon the *success paradox*.

> Trying to do things that were slightly more complex than what we were doing in class - I enjoyed it. It was frustrating, of course, but it was also rewarding to get it to work … It is a rewarding feeling to learn why something isn't working. I remember feeling challenged but also enjoying myself and learning, especially [because] in a lot of the general education courses I don't really feel that too much. So it was real nice to feel challenged and actually enjoy getting into a flow of what I was doing. (Edward)

> Personally I think of it [the final project] more as a failure because I didn't get what I wanted to done. But I would say it was pretty successful in the time I had. I did manage to combine them and they were able to produce different sounds at least which was part of my goal - it was kinda slightly there but not completely. [sic] (Andrea)

Students also gained mastery experience through conversations with friends outside of the course. Some students mentioned a new ability to talk to their friends about topics in ECE 101 that they would not have been able to understand before taking the course. Andrea mentioned that she was able to follow a conversation among her friends about topics in electrical and computer engineering:

> So I actually understand what they're talking about instead, even though I'm not an engineer, because engineering is very involved, and they learn so much that an outsider would probably know nothing about. But I can actually relate some, which is great for conversation because I can follow them mentally. (Andrea)

Similarly, Cody described an interaction with a friend who was an electrical and computer engineering major regarding the circuit he built for his ECE 101 project.

> I said [the final project] won't probably be that hard, but I'll have more of a grasp on what we're supposed to do. ... I guess you could see it [the project] made me feel good - like I know what I was doing… we were able to talk about something that has to do with class. (Cody)

VI. Discussion

The results from this study confirm findings in the literature about improved self-efficacy in a programming course for non-engineering students [14]. Specifically, non-engineering students in a digital technologies course demonstrated an improved self-efficacy for tasks related to knowledge gained through the course. Some of the students provided examples of improved self-efficacy four semesters later. Also consistent with literature on self-efficacy [15], this study found that a student's self-efficacy in a digital technologies course was amplified by a mastery experience.

By developing a course structure that aims to improve student engagement in the course, the instructor's expectations of students become closely related to verbal persuasion. While research on the *Pygmalion effect* [16] has concluded in mixed findings, research generally supports the view that an instructor's expectations can affect students' academic performance [17]-[19]. If the instructor has high expectations for the students and shows confidence that the students will meet those expectations, then according to the Pygmalion effect, students' performance will generally improve. With affirmative feedback that they are doing well in achieving learning objectives, students may gain confidence in their ability to complete tasks or to perform a certain skill. In short, when the instructor has high expectations, the student works hard in order to meet those expectations and performs well. When the student performs well, she has a mastery experience and gains confidence in her ability [20].

Many students felt simultaneously successful and unsuccessful in their final project. Although the students reported feeling that they were "successful" in the final project, they also reported feeling "unsuccessful" because they did not meet all of the requirements or specifications of their initial proposal for the final project. However, instead of declaring the final project a failure, they felt that it was a success. This success paradox may have been mediated by the course structure and the support provided by the instructor and the TAs. The instructor asked the students to complete an initial proposal for their final project that was not limited by their skills or content knowledge. In other words, if students could build anything, within the scope of the course, what would they build? After the initial proposal, the instructor and the TAs provided individual feedback to help the students define and scale the project as needed while maintaining the core of the initial proposal intact. To redefine the project, the instructor and the TAs discussed with the student the realistic constraints of time, cost, resource availability, and technical skill. After three to four weeks, the students had completed final projects, though in some cases the completed deliverables may have fallen short of the initial proposal. After the final projects were completed, the vast majority of students met all of the course requirements.

The mixture of emotions (failure and success) flows naturally from the process of learning about realistic constraints of a real project. The final project is the first time many students have attempted an open-ended design. At first, students do not have a clear conception of what is possible. Generally, the students do not connect the tasks they complete in homework or in the lab with the broader tasks of the final project. When they are asked to aim high with the project, they avoid getting bogged down with self-assessment, "What am I capable of doing?" Instead, in the spirit of content personalization, students ask themselves, "What do I want to do?" At that point, the instructor and the TAs can help assess both the constraints and the students' skills to help them define feasible projects. While students still dream of solving a larger problem, they become satisfied by their accomplishments under the realistic constraints. The students gain self-efficacy from tackling a project with the confidence that their skill set might enable them to succeed.

Finally, an important source of self-efficacy, especially in connection with mastery experience, was verbal persuasion by the TAs and the instructor. In the research literature, however, verbal persuasion appears much less frequently than other sources of self-efficacy [15]. Because the majority of the students in ECE 101 do not pursue an engineering major, verbal persuasion may be essential for promoting persistence and continued interest in the course. For example, many of the interviewed students did not consider themselves "math or science" persons, and as a result, they considered dropping the course in the first week of the semester. Because the TAs and the instructor acted as agents of persuasion, they decided to stay in the course, persisted, and completed the course.

VII. Conclusions & Implications

This study found that non-majors who took a general education engineering course had notable non-cognitive, long-term outcomes. This study also found that self-efficacy was a significant long-term student outcome. Verbal persuasion and mastery experiences were two prominent sources of student self-efficacy. Verbal persuasion included purposeful encouragement from TAs, the instructor, and peers. Mastery experiences included performance tasks that students completed. When verbal persuasion and mastery experiences reinforced each other, students felt successful in the course despite perceived barriers.

This work can inform faculty who develop engineering courses for non-engineering students. Faculty can develop or redesign courses to improve self-efficacy by purposefully incorporating verbal persuasion and mastery experiences. In the ECE 101 digital technologies course, the paradoxically successful final project, encouragement and support from TAs and the instructor, and recognition from peers served as sources of self-efficacy. When the course structure supports self-efficacy, students will focus on getting the most out of the course instead of on merely earning a passing grade to complete a general education requirement.

As an implication for practice, the authors recommend three mechanisms that can be used to the design general education engineering courses that promote self-efficacy. First, instructors can incorporate purposeful encouragement (verbal persuasion) from TAs, instructors, and peers into the course structure. For TAs and instructors, purposeful encouragement can be provided to students via office hours and project consultations. For peers, instructors can set up activities that will enable students to give support and feedback to one another. Aside from providing a supportive course structure, the TAs and instructors are essential in creating a learning environment that is aligned with improved self-efficacy. Students rely heavily on the perceived encouragement and support they receive from the instructors. Specifically, instructors can incorporate ways to provide forms of verbal persuasion to the students. For example, instructors should take time during key events, such as the final project, to discuss accomplishments and opportunities with the students.

Second, instructors can incorporate performance tasks (mastery experiences) that are personalized or tailored to the students' interests. Performance tasks are often part of the curriculum (e.g., final projects), but they can also be viewed as opportunities to promote self-efficacy by reframing these experiences to engage students' interests. As an example in ECE 101, students were encouraged to work on a project that was aligned with their career or college major related interests (cf. [9]).

Finally, performance tasks and purposeful encouragement can be combined to enhance self-efficacy. When pairing these two sources of self-efficacy, instructors should ensure that the purposeful encouragement to take on a performance task is complemented with support to complete the task. Consistent with the success paradox, the students may feel that they did not accomplish the full expectations in the course, yet when mediated by verbal persuasion, a mastery experience can still feel successful. In an engineering course for non-engineers, verbal persuasion and mastery experiences should be combined in order to enhance students' self-efficacy.

Future work may entail investigating the connection between research and practice with regards to sources of self-efficacy in engineering general education courses. While this paper provided an understanding of the key sources of self-efficacy in a digital technology course for non-majors, future work can investigate the training of instructors to provide self-efficacy support to students.

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References

[1] National Science Foundation. (2012, April). Empowering the Nation Through Discovery and Innovation - NSF Strategic Plan for Fiscal Years (FY) 2011-2016. National Science Foundation, VA. [Online]. http://www.nsf.gov/news/strategicplan/nsfstrategicplan_2011_2016.pdf

[2] National Science Foundation. (1995, August). Restructuring Engineering Education: A Focus Change. National Science Foundation, VA. [Online]. http://www.nsf.gov/pubs/stis1995/nsf9565/nsf9565.txt

[3] T. F. N., Laird, A. S., Niskodé-Dossett, and G. D. Kuh. "What general education courses contribute to essential learning outcomes." *Journal of General Education*, vol. 58, no.2, pp. 65-84, Jul., 2009.

[4] R. Kuc. "Teaching the nonscience major: EE101—The Digital Information Age." *IEEE Trans. on Education*, vol. 44, no. 2, pp.158-164, May, 2001.

[5] J. J. Krupczak, S. VanderStoep, L. Wessman, N. Makowski, C. A. Otto, and K. Van Dyk, "Work in progress - Case study of a technological literacy and non-majors engineering course," in *Thirty-Fifth Frontiers in Education Conf.*, Indianapolis, IN, 2005, pp. S1-36 to S1-37.

[6] S. A. Sorby, D. E. Oppliger, and N. Boersma. "Design and assessment of an "engineering" course for non-majors," *Journal of STEM Education*, vol. 7, no. 1/2, pp. 5-14. Jan., 2006.

[7] S. Wiedenbeck, "Factors affecting the success of non-majors in learning to program," in *International Computing Education Research Workshop*, Seattle, WA, 2005, pp. 13-24.

[8] M. Guzdial, "A media computation course for non-majors," in *Annual Conference on Innovation and Technology in Computer Science Education*, Thessaloniki, Greece, 2003, pp. 104-108.

[9] A. Forte and M. Guzdial, "Motivation and nonmajors in computer science: Identifying discrete audiences for introductory courses," *IEEE Trans. on Education*, vol. 48, no. 2, pp. 248-253, May, 2005.

[10] C. D. Schmitz, R. A. Revelo Alonso, and M. C. Loui, "Diversity harnessing in a general education course on digital information technology," in the *Forty-First ASEE/IEEE Frontiers in Education Conference*, Rapid City, S.D., 2011, pp. F3D-1-F3D-2.

[11] A. Bandura, "Self-efficacy: toward a unifying theory of behavioral change," *Psychological Review*, vol. 84, no. 2, pp. 191-215, Mar.1977.

[12] A. Bandura. *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs: Prentice-Hall, Inc, 1986.

[13] R. A. Revelo Alonso, and M. C. Loui, "The long-term outcomes of an engineering course for students outside engineering," in *ASEE Annual Conference and Exposition*, San Antonio, TX, 2012.

[14] V. Ramalingam, D. LaBelle, and S. Wiedenbeck, "Self-efficacy and mental medals in learning to program," in *9th Annual SIGCSE Conference on Innovation and Technology in Computer Science Education*, Leeds, UK, 2004, pp. 171-175.

[15] E. L. Usher and F. Pajares, "Sources of self-efficacy in school: Critical review of the literature and future directions," *Review of Educational Research*, vol. 78, no. 4, pp. 751-796, Dec. 2008.

[16] S. M. Glynn, L. Price Aultman, and A. M. Owens, "Motivation to learn in general education programs," *Journal of General Education*, vol. 54, no. 2, pp. 150-170, 2005.

[17] E. T. Pascarella, "Student-faculty informal contact and college outcomes," *Rev. Educ. Res.*, vol. 50, no. 4, pp. 545–595, 1980.

[18] E. T. Pascarella, P. T. Terenzini, and J. Hibel, "Student-faculty interactional settings and their relationship to predicted academic performance," *J. High. Educ.*, pp. 450–463, 1978.

[19] P. D. Umbach and M. R. Wawrzynski, "Faculty do matter: The role of college faculty in student learning and engagement," *Res. High. Educ.*, vol. 46, no. 2, pp. 153–184, 2005.

[20] C. Tomlinson, *The Differentiated Classroom: Responding to the Needs of All Learners*, Alexadria, VA: ASCD, 1999.

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