WIP: Impact of an Authentic Introductory Computer Programming Course on New BAE Undergraduate Students' Learning Motivation and Interest in the Discipline

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Introduction

From automating tasks to analyzing large amounts of data, or solving complex mathematical problems, computer programming is a fundamental skill for engineering students and professionals [1], [2], [3]. Learning to program is difficult, and undergraduate engineering students are required to learn it regardless of their initial interest and motivation for it. They traditionally take their programming course in the computer science department, a course that generally delivers to a mixed audience of multiple majors and relies on generic problems for the application of coding skills.

Research suggests that motivation plays a key role in student success in programming courses [4], [5]. Interest in the content and activities, and relevance or usefulness, i.e. the content is useful for students' short or long term goals, are among the factors that contribute to academic motivation [6], [7]. Students perform better in environments where they feel a solid connection to their field [8]. One way to foster students' motivation in the programming classroom is to deliver tailored courses that engage students in activities relevant to their own disciplines and favor authentic tasks [9]. Forte and Guzdial [10] reported that engineering students enrolled in an introductory programming course with programming language and skills tailored to engineering needs had lower D -grade, withdrawal and failure rates compared to those enrolled in a traditional course. The students who took the tailored course also commented that they learned useful content. Pullu and Gomleksiz [11] investigated the impact of authentic task-oriented applications on undergraduate students' attitudes and success in a 2nd year programming course. The students enrolled in the course featuring authentic tasks performed significantly better on a posttest than students enrolled in the traditional course and exhibited more positive attitudes towards programming. Individual engineering departments have also designed their own computer programming courses, allowing discipline specific instruction and example applications. At Michigan State University, a computer programming course was integrated with the introduction to mechanical engineering course, and uses assignments dealing with the disciplines of mechanical engineering [12]. On the post-course survey, a majority of students reported they could use MATLAB and Excel to perform engineering calculations and solve engineering problems. At Milwaukee School of Engineering, a programming course was designed for mechanical engineers, using example applications in mechatronics [13]. On the course evaluations, students reported that they were inspired to put more effort into making sure their codes were working in order to see their mechatronic systems function. At Hong Kong University of Science and Technology, an Excel VBA course for chemical engineering students that focused on problems like solving ordinary differential equations, fluid flow in pipes and batch reactor modeling was designed [14]. In the end of course survey, students reported that VBA programming was useful to solve Chemical Engineering problems, and that the programming also enhanced their understanding of the subject. They also found that the course had a broad application to their remaining core courses in chemical engineering.

In addition to being more relevant to students' goals and interests, tailored courses offered by the home department provide opportunities for students to develop connections with peers and professors in their major and to create a sense of belonging to the program [15].

In the biological engineering program at North Carolina State University, BAE 200 – Computer Methods in Biological Engineering is a 2-credit hour course taken by 2nd year undergraduate students in the Biological Engineering Program. The course was created to replace the introductory computer programming course that students used to take in the computer science department. It focuses on teaching computer-based problem-solving using Excel and R and contextualizes instruction with real-world BAE problems. This is the first BAE course that Biological Engineering students typically take, and it serves as a pre-requisite for multiple courses. The goals of this authentic course are twofold. The first is to increase students' motivation towards learning programming by focusing on applications in their chosen discipline. The second is to introduce students new to BAE to the different concentration areas in the degree program (agricultural, environmental, ecological, bioprocess engineering) to help them choose a degree concentration and elective courses. As part of the course, a meet-and-greet event between BAE 200 students and faculty members is organized in the first month of the semester. Each faculty member introduces their area of expertise to the group and then students are split into three groups representing the different concentrations: Agricultural Engineering, Bioprocess Engineering, and Ecological and Environmental Engineering together. Students learn more specific information about the concentrations, including the future courses they will take and career opportunities, and can ask questions to faculty working in that concentration area. Until 2022, there was no linkage between the problems used as programming assignments and the degree concentrations they represented. We hypothesized that structured course assignments that specifically highlight concentrations would increase students' motivation for learning programming and help them make a more informed choice of concentration for the remainder of their studies.

In 2023, assignments were developed or updated and labelled with colored icons picturing the concentration they represented: 9 in Environmental Engineering, 7 in Ecological Engineering, 16 in Agricultural Engineering, 12 in Bioprocess Engineering) (Fig. 1). The assignments were also worded specifically to provide background knowledge and context about the problem and to project students as engineering professionals solving the problem (Fig 2).

Figure 1. Icons depicting the degree concentrations designed for the course

Ureolysis Kinetics

Bioprocess Engineering

Background Knowledge

Ureolysis is the degradation process of urea into ammonium and carbonate. This reaction is catalyzed by the urease enzyme, which is produced by bacteria. Carbonate compounds obtained by ureolysis can be utilized in a diverse array of applications, including hydraulic fracturing, enhanced oil recovery, soil stabilization, dust suppression, pond/reservoir sealing, subsurface barriers, CO_2 sequestration, immobilization of radioactive chemicals in contaminated soils, and remediation of groundwater..

The rate at which ureolysis occurs depends on the concentration of urea. It can be described by the Michaelis-Menten kinetic equation:

$$V = \frac{V_{max}[S]}{k_m + [S]}$$ (Eq. 1)

Figure 2. Example of assignment presenting background knowledge and labelled with the representative concentration

To test our hypothesis and evaluate the impact of labelled and structured assignments highlighting specific concentrations, students were surveyed in Fall 2022 (pre-labelling) and Fall 2023 (post-labelling).

The objectives of this study are to: (i) assess the effectiveness of a tailored programming course with authentic assignments on students' interests, motivation, and sense of belonging in the programming course, (ii) identify course strategies that help students make an informed choice of degree concentration.

Methods

Mixed methods data collection

To answer the objectives, BAE 200 cohorts were surveyed at the end of the course in Fall 2022, and at the beginning and the end of the course in Fall 2023. In addition to the survey questions, students were invited to answer open-ended questions about the positive aspects of the course and to write a reflection after the meet and greet event. The survey questions are presented in Table 1. The sense of belonging questions were adapted from the Sense of Belonging to Math Scale by Good et al. [16], and the motivation question was taken from the MUSIC model by Jones [6].

Table 1. Survey items related to students' interests, motivation and sense of belonging

Measurement	Survey Questions	Answers	Time of Collection
Interests	How much are you currently interested in concentrating on each BAE discipline for your degree? • Bioprocess Engineering • Agricultural Engineering • Ecological Engineering • Environmental Engineering	Likert scale 1. Not interested 2. Barely interested 3. Somewhat interested 4. Interested 5. Very interested	• FALL 22 END • FALL 23 BEG • FALL 23 END
Perceived Learning Outcome	Now that you have nearly completed this course, please rate your current knowledge or skill levels related to this course learning objective: CLO 3: Distinguish the focus areas in BAE disciplines to plan for degree concentration.	Likert scale 1. Novice - Just starting out 2. Beginning - Getting by 3. Intermediate - Generally good at 4. Competent - Very good at 5. Master - Extremely good at	• FALL 22 END • FALL 23 END
Sense of Belonging 1	In the BAE 200 class… • I feel that I belong to the biological and agricultural engineering community.	Likert scale: 1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree	• FALL 22 END • FALL 23 END
Sense of Belonging 2	• I consider myself a member of the biological and agricultural engineering world.	Likert scale: 1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree	• FALL 22 END • FALL 23 END
Sense of Belonging 3	• I feel like I am part of the biological and agricultural engineering community.	Likert scale: 1. Strongly disagree 2. Disagree 3. Neutral 4. Agree	• FALL 22 END • FALL 23 END

		5. Strongly agree	
Sense of Belonging 4	• I feel a connection with the biological and agricultural engineering community.	Likert scale: 1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree	• FALL 22 END • FALL 23 END
Motivation from materials	I was intrigued by the learning materials and activities in this course.	Likert scale: 1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree	• FALL 22 END • FALL 23 END
Information in course materials	How much information did the problems used in this course give you about each BAE discipline? • Bioprocess Engineering • Agricultural Engineering • Ecological Engineering • Environmental Engineering	1. None at all 2. A little 3. Some 4. A good amount 5. Abundant	• FALL 22 END • FALL 23 END
Beneficial aspects	Which aspects of this course were beneficial for your learning	Open ended	• FALL 22 END • FALL 23 END
Reflection	• What made you interested in your selected discipline? • What new insights did you get from interacting with the discipline's faculty? • What are your next steps to move forward in this discipline?	Open ended	FALL 23 after meet and greet event

Data analysis

For each survey question, the distribution of responses and mean scores were calculated for the 2022 and 2023 class cohorts. Statistical analyses were also performed to determine whether significant differences were observed between the two cohorts, which could be attributed to course changes adopted to emphasize the different degree concentrations. According to a Shapiro test, the data did not follow a normal distribution, so a Mann-Whitney U Test was used to determine if the differences between the two means were significant at a 0.05 significance level. Students' comments and reflections were analyzed using a thematic analysis.

Results

Students' interests, motivation and sense of belonging in 2022 and 2023

The levels of interest in each concentration were surveyed among BAE200 at the end of Fall 2022, and at the beginning and end of Fall 2023. The Mann Whitney U test revealed no statistically significant difference in preference levels for a given concentration between the three surveys. Environmental Engineering is the concentration that is the highest rated in terms of interest by students in both 2022 (average of 3.45/5 with 51.2 % of students interested or very interested) and 2023 (average of 3.74 /5 or 61.8% students interested or very interested at the start of the semester, and average of 3.65 or 64.7 % of students interested or very interested at the end of the semester) (Table 2). After completion of the course in 2023, the level of interest in Ecological engineering slightly increased, whereas the level of interest in Agricultural and Bioprocess Engineering slightly decreased.

Table 2. Students' interest levels in the degree concentrations in Fall 22 END and Fall 23 BEG and END

	Average (on a scale of 5)			Percentage of ratings ≥ 4		
	Fall 2022 END	Fall 2023 BEG	Fall 2023 END	Fall 2022 END	Fall 2023 BEG	Fall 2023 END
Interest Bioprocess	3.02	3.35	3.06	44.2	47.1	38.2
Interest Agricultural	2.98	3.15	2.94	44.2	41.2	32.4
Interest Ecological	3.21	3.47	3.59	41.9	50	52.9
Interest Environmental	3.45	3.74	3.65	51.2	61.8	64.7
no statistically significant difference between semesters for a given concentration						

Students' sense of belonging to the BAE discipline in the BAE 200 class was quite high for both cohorts as exhibited by average belonging ratings of 4.22/5 in 2022 and 4.32/5 in 2023. The increase observed between 2022 and 2023 was not statistically significant (Table 3).

The degree of motivation that the course materials brought to students significantly increased from 2022 to 2023. In 2023, 100% of students "Agreed" or "Strongly Agreed" that they were intrigued by the course materials and activities compared to 72 % in 2022. This suggests that emphasizing the connections between assignments and the discipline had a positive impact on students. This result is further supported by students' comments related to the aspects of the course that they found beneficial to their learning. They reported that the use of authentic problems made the course more interesting and meaningful as they could see how their programming skills will help them in other courses and jobs. Example quotes include:

- *The real-world examples and not just numbers to use.*
- *The problem statements in the problems seemed to have connections or reflected my learning from other course in engineering.*
- *The assignments were relevant to that of our major making them easier to complete when we can see that we are doing work that will be beneficial in the future*
- *The instructor also effectively connects the lessons to real application in our discipline which makes it practical and meaningful to learn.*
- *I really liked this course. I felt like it reaffirmed my decision to join this major.*

Table 3. Survey Results in Fall 22 and Fall 23 END for motivation from course materials and sense of belonging (p-values in Bold highlight significantly different results)

	Average 2022	Average 2023	Percentage of ratings ≥ 4 in 2022	Percentage of ratings ≥ 4 in 2023	P value
Sense of Belonging 1	4.35	4.47	86.0	100.0	0.643
Sense of Belonging 2	4.09	4.32	74.4	91.2	0.429
Sense of Belonging 3	4.14	4.21	74.4	85.3	0.908
Sense of Belonging 4	4.28	4.26	79.1	85.3	0.718
Motivation	3.95	4.50	72.1	100.0	**0.018**

Impact of course materials and activities on students' ability to choose a concentration

In 2022, 76.7 % of students considered themselves "Very good at" or "Extremely good at" distinguishing the BAE concentrations, a percentage that increased to 85.3% in 2023, although the increase was not statistically significant. (Table 4.)
In both cohorts, approximately 60% of students considered that the amount of information given by the problems on the degree concentrations was "a good amount" or "abundant". There was also no statistically significant difference in students' perceptions of the amount of information provided by the course problems on each concentration, despite the efforts put in designing and labelling new assignments representative of the different concentrations for the 2023 cohort. One student commented that "*I've realized the broadness of BAE and have become interested in looking at the other concentrations as well*".

Table 4. Survey Results in Fall 22 and Fall 23 END for students' knowledge of concentrations and amount of information provided in the course

	Average 2022	Average 2023	Percentage of ratings ≥ 4 in 2022	Percentage of ratings ≥ 4 in 2023	P value
Perceived Learning outcome	4.09	4.12	76.7	85.3	0.943
Info Bioprocess	3.53	3.50	62.8	58.8	0.893
Info Agricultural	3.44	3.59	58.1	64.7	0.511
Info Ecological	3.53	3.53	62.8	58.8	0.825
Info Environmental	3.63	3.59	67.4	61.8	0.638

The ratings for the amount of information provided by the course problems are lower than student's perceived abilities to distinguish between concentrations, which suggest that other factors impacted this learning outcome. Students' reflections emphasize the role that the meet and greet event had played in their ability to distinguish between the different concentrations and choose one. Example quotes include:

- *I was able to put a stamp on which concentration I wanted to focus on.*
- *After talking to a few other staff, I realized that precision agriculture may be the best suited discipline for my interests.*
- *Interacting with faculty also made me more sure of what I'm studying and why I chose this major.*
- *I eventually decided on bioprocessing leading to where I ended up at the faculty meet and greet.*
- *I learned the difference between the ecological concentration and environmental concentration.*
- *I didn't previously know that this is what Ecological Engineers do so I was really excited to learn more about the discipline!*

Discussion

Students in BAE 200 exhibited a strong sense of belonging to the BAE community, with scores of 4.22/5 in 2022 and 4.32/5 in 2023, compared to findings from other studies. For example, Benson et al. [17] reported that sophomores enrolled in Civil Engineering and surveyed in a Civil Engineering courses exhibited belonging scores to engineering of 3.56/5 and 3.31/5. Smith et al. [18] reported that sophomore engineering students enrolled at a large research university showed belonging scores to engineering of 3.57/5.

O'Hara et al [19] and Schar et al. [20] have shown that there is a strong positive correlation between students' sense of belonging in an engineering course and their sense of belonging in the discipline.

In the BAE 200 course, students with similar academic backgrounds, goals and interests learn content that is tailored to their discipline from an instructor in their discipline. These strategies contribute to the development of classroom and discipline belonging.

In addition, the interactions with members of the BAE community, namely faculty members, during the meet and greet event contributed to strengthening students' sense of belonging to the discipline.

Conclusions

Going one step further than computer programming courses tailored to engineers, the BAE 200 introductory programming course is offered only to BAE students by a BAE instructor and tailored to the discipline in terms of programming contents and applications. As a result, BAE 200 students exhibited a strong sense of belonging to the BAE discipline and community.
The authentic materials developed in the course seem to be a motivational factor for students to learn about programming and understand its applications to the discipline. Redesigning course assignments with background information and labelling the concentrations had a positive impact on students' academic motivation.
The course materials and activities did not impact students' levels of interests in one or several degree concentrations. However, they equipped them with a broader and deeper knowledge of the discipline that helped reinforce their choices of concentration. The meet-and-greet event between students and BAE200 faculty member was a key activity that contributed to helping students select a degree concentration and think about career opportunities.

References

[1] A. Baker *et al.*, "Preparing the Acquisition Workforce: A Digital Engineering Competency Framework," in *2020 IEEE International Systems Conference (SysCon)*, Montreal, QC, Canada: IEEE, Aug. 2020, pp. 1–6. doi: 10.1109/SysCon47679.2020.9275661.

[2] R. Mansbach *et al.*, "Reforming an undergraduate materials science curriculum with computational modules," *Journal of Materials Education*, vol. 38, no. 3–4, pp. 161–174, 2016.

[3] D. Ahmed, M. Nayeemuddin, T. Ayadat, and A. Asiz, "Computing Competency for Civil Engineering Graduates: Recent Updates and Developments in Saudi Arabia and the US," *IJHE*, vol. 10, no. 6, p. 57, Jun. 2021, doi: 10.5430/ijhe.v10n6p57.

[4] A. Robins, J. Rountree, and N. Rountree, "Learning and teaching programming: A review and discussion," *Computer science education*, vol. 13, no. 2, pp. 137–172, 2003.

[5] J. Figueiredo and F. J. García-Peñalvo, "Increasing student motivation in computer programming with gamification," in *2020 IEEE Global Engineering Education Conference (EDUCON)*, IEEE, 2020, pp. 997–1000.

[6] B. D. Jones, "Motivating students to engage in learning: the MUSIC model of academic motivation.," *International Journal of Teaching and Learning in Higher Education*, vol. 21, no. 2, pp. 272–285, 2009.

[7]   J. M. Keller, "Development and use of the ARCS model of instructional design," *Journal of instructional development*, vol. 10, no. 3, pp. 2–10, 1987.

[8]   S. Al-Qudah, J. Davishahl, E. Davishahl, and M. A. Greiner, "Investigation of sense of belonging to engineering in undergraduate introductory classes," in *2018 ASEE Annual Conference & Exposition*, 2018.

[9]   E. Vanhala and J. Kasurinen, "Goals and Principles for the Redesign of a Programming Course," in *Workshop on PhD Software Engineering Education*, CEUR-WS, 2018.

[10]   A. Forte and M. Guzdial, "Motivation and nonmajors in computer science: identifying discrete audiences for introductory courses," *IEEE Transactions on Education*, vol. 48, no. 2, pp. 248–253, 2005.

[11]   E. K. Pullu and M. N. Gömleksiz, "Authentic teaching tasks for academic success, attitude, problem solving, and creative thinking skills," *Discourse and Communication for Sustainable Education*, vol. 12, no. 2, pp. 108–123, 2021.

[12]   T. Hinds and C. Somerton, "Integrating the teaching of computer skills with an introduction to mechanical engineering course," in *2007 ASEE Annual Conference & Exposition*, 2007, pp. 12–931.

[13]   J. Musto, J. Lumkes, and W. Carnell, "A Freshman Programming Course For Mechanical Engineers Using Mechatronics Applications," in *2004 ASEE Annual Conference*, 2004, pp. 9–41.

[14]   K. W. Wong and J. P. Barford, "Teaching Excel VBA as a problem solving tool for chemical engineering core courses," *Education for Chemical Engineers*, vol. 5, no. 4, pp. e72–e77, 2010.

[15]   J. A. Crowe, "Creating a Departmental Climate that Increases a Student's Sense of Belonging, Perceived Faculty Support, and Satisfaction with the Major," *Innov High Educ*, vol. 46, no. 1, pp. 95–109, Feb. 2021, doi: 10.1007/s10755-020-09530-w.

[16]   C. Good, A. Rattan, and C. S. Dweck, "Why do women opt out? Sense of belonging and women's representation in mathematics.," *Journal of personality and social psychology*, vol. 102, no. 4, p. 700, 2012.

[17]   L. Benson, C. Bolding, J. Harper Ogle, C. M. Spence, J. Murphy, and R. Lanning, "Engineering students' perceptions of belongingness in civil engineering," 2019.

[18]   T. F. Smith, D. Wilson, D. C. Jones, M. Plett, R. A. Bates, and N. M. Veilleux, "Investigation of belonging for engineering and science undergraduates by year in school," in *2012 ASEE annual conference & exposition*, 2012, pp. 25–858.

[19]   R. M. O'Hara, C. W. Bolding, J. H. Ogle, L. Benson, and R. Lanning, "Belonging in Engineering," in *2020 ASEE Annual Conference & Exposition*, 2020.

[20]   M. Schar *et al.*, "Classroom belonging and student performance in the introductory engineering classroom," in *2017 ASEE Annual Conference & Exposition*, 2017.