The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #44223

Board 229: Computational Thinking in the Formation of Engineers: Year 4

Dr. Noemi V Mendoza Diaz, Texas A&M University

Dr. Mendoza is a faculty member of Technology Management in the College of Education-Engineering at Texas A&M University. She has worked as electrical engineering professor in Mexico. She recently obtained funds from NSF to investigate enculturation to engineering and computational thinking in engineering students. She is the co-advisor of the Society for Hispanic Professional Engineers at TAMU and is interested in computing engineering education and Latinx engineering entrepreneurship.

Dr. Deborah Anne Trytten, University of Oklahoma

Dr. Deborah A. Trytten is a Professor of Computer Science and Womens' and Gender Studies at the University of Oklahoma. Her main research focus is diversity in engineering education and introductory software engineering education.

Dr. Russell D. Meier, Milwaukee School of Engineering

Dr. Russ Meier teaches computer architecture at Milwaukee School of Engineering. His funded research explores how first year students develop computational thinking. He received the Iowa State University Teaching Excellence Award, the Iowa State University Warren B. Boast Award for Undergraduate Teaching Excellence, and the MSOE Oscar Werwath Distinguished Teacher Award.

He belongs to IEEE and its HKN, Computer and Education Societies, as well as the American Society for Engineering Education and its Electrical and Computer Engineering, Educational Research and Methods, and First Year Programs divisions. In these groups, he helps deliver engineering education conferences, webinars, and certificate programs. He leads teams accrediting engineering degrees as an Engineering Area Commissioner in ABET.

IEEE elevated him to Fellow for contributions to global online engineering education. And, the International Society for Engineering Education bestowed International Engineering Educator Honoris Causa for outstanding contributions in engineering education.

Dr. Harry A. Hogan, Texas A&M University

to be updated soon

Dr. So Yoon Yoon, University of Cincinnati

Dr. So Yoon Yoon is an assistant professor in the Department of Engineering and Computing Education in the College of Engineering and Applied Science at the University of Cincinnati, OH, USA. Dr. Yoon received her Ph.D. in Gifted Education, and an M.S.Ed. in Research Methods and Measurement with a specialization in Educational Psychology, both from Purdue University, IN, USA. She also holds an M.S. in Astronomy and Astrophysics and a B.S. in Astronomy and Meteorology from Kyungpook National University, South Korea. Her work centers on elementary, secondary, and postsecondary engineering education research as a psychometrician, data analyst, and program evaluator with research interests in spatial ability, STEAM education, workplace climate, and research synthesis with a particular focus on meta-analysis. She has developed, validated, revised, and copyrighted several instruments beneficial for STEM education research and practice. Dr. Yoon has authored more than 80 peer-reviewed journal articles and conference proceedings and served as a journal reviewer in engineering education, STEM education, and educational psychology. She has also served as a PI, co-PI, advisory board member, or external evaluator on several NSF-funded projects.

Computational Thinking in the Formation of Engineers: Year 4

Abstract

Computational thinking has evolved to a subject of great interest in all areas of education. The last three years have witnessed an explosive growth of initiatives, studies and even literature reviews. Yet, computational thinking research is still focused on pre-college levels and few studies have investigated it within engineering education at the college level. In this context, our work spearheads the effort to understand computational thinking in the engineering context and advances the current state of knowledge.

During the fourth year of this project, the major results have been in dissemination. The validation of our diagnostic has been published in a peer-reviewed journal, the technology transfer offices in the multi-institutional project agreed on intellectual property rights, and a project website was launched to help interested institutions access the diagnostic. The public availability of our validated diagnostic opens an opportunity to engage in another validation cycle with a more diverse pool of participants helping our instrument become better calibrated for extended audiences. In addition, the prior work on engineering enculturation that led to this project was also published in a peer-reviewed journal. An instrument on enculturation that considers computational thinking as one of its constructs is getting validated.

Our current focus as we enter the final months of our project is semi-structured interviews with students that struggled (with a grade of D), failed (grade of F), or withdrew (either with a grade of Q for students remaining at the institution, or W for students leaving the institution) in an effort to understand how their performance in computational thinking affected their career trajectories. In addition, we are also completing the longitudinal study of computational thinking development in our student cohorts.

Introduction

During the last period, the major achievements of this project were the validation of the Engineering Computational Thinking Diagnostic (ECTD) and its dissemination. The validation of the instrument afforded the opportunity to identify its predictive characteristics, strengthening our rationale that this diagnostic can be a powerful tool in assessing entry-level skills and guiding informed decisions in terms of student support. Validation of this instrument provides a supporting diagnostic that can be used by engineering programs to identify at-risk students with which to apply interventions; broadening and increasing participation of underrepresented groups in engineering. The diagnostic can also be used in a pre-post manner to help achieve proper assessment of effective teaching [1, 2].

Moreover, the precursor study on enculturation in engineering, from which this computational thinking project emerged, gained new momentum, and instrument validation for enculturation is underway. In this enculturation to engineering model, interestingly enough, computational thinking was one of the constructs that challenged the understanding of enculturation the most (along with ethics). Further analyses and follow-up studies are being designed to investigate this result [3, 4].

In terms of the dissemination efforts taking place, the official website for this project was launched (https://ectd.engr.tamu.edu/), and the Office of Technology Transfer has approved dissemination to other institutions with the proper intellectual property acknowledgments. Additionally, a proposal for a workshop devoted to increasing researcher's knowledge of the ECTD was approved for the ASEE 2024 conference. This workshop affords the opportunity to run another cycle of validation for this instrument that will ensure its relevance and applicability to even wider audiences.

We are also at a point where we can attempt an answer to the last research question of our project which is a question measuring the long-term impacts of computational thinking skill development. Such a question requires a longitudinal approach that our IRB offices have approved.

Finally, during our project, we came to the realization that our recruiting mechanism – self-selection – limited our participants by demographic categories, and thus our results seemed incomplete. We have initiated steps towards expanding our research to the DFW audience. While we seek IRB approval to include this audience in this final stage of the project, we have analyzed the cohort from which we did gain access to their grades (n=296). We plan to interview individuals who have struggled with computational thinking as well as those who transferred or withdrew from engineering altogether. The following charts provide a preliminary analysis of this cohort and constitute an entry point for the planned semi-structured interviews. All charts are based on percentages according to the final counts per category.

The research questions guiding our study are:

1. How are participants' grades in computational thinking courses related to student performance in AP computer science and AP math courses?
2. How do participants' grades in computational thinking courses relate to their First-Gen, Race/Ethnicity, Gifted Status Identities?
3. How are participants' grades compared to non-participants' grades?
4. How are perceived difficulty and confidence, as related to the diagnostic, related?

Methodology

To answer research questions 1-4, demographic and grade data from a single institution for the Fall 2021 semester were analyzed. There were 296 students in the dataset who had consented to participate in the research and provided us with demographic data, data about student background and experiences prior to college, data about confidence and perceived difficulty, as well as ECTD results. Both pre and post results were available for some students, but only pre-test results were used in this analysis because the number of students who took the pre-test was larger. Using Excel, we created charts to examine subordinate questions related to the overarching research questions above about how relevant data fields related to each other. Histograms showing the percentage of students who fell into intersecting categories were graphed, often using percentages.

Results and Discussions

Figure 1 shows the distribution of final grades in the college introductory programming course in relation to the type of advanced placement (AP) computer science courses taken prior to college. It can be noticed that students with the most pre-college computing courses obtain better grades in the introductory course. The y-axis represents the percentage of students receiving a given grade, based on CS background. For example, almost eighty percent of students with an AP background of Computer Science A received an A.

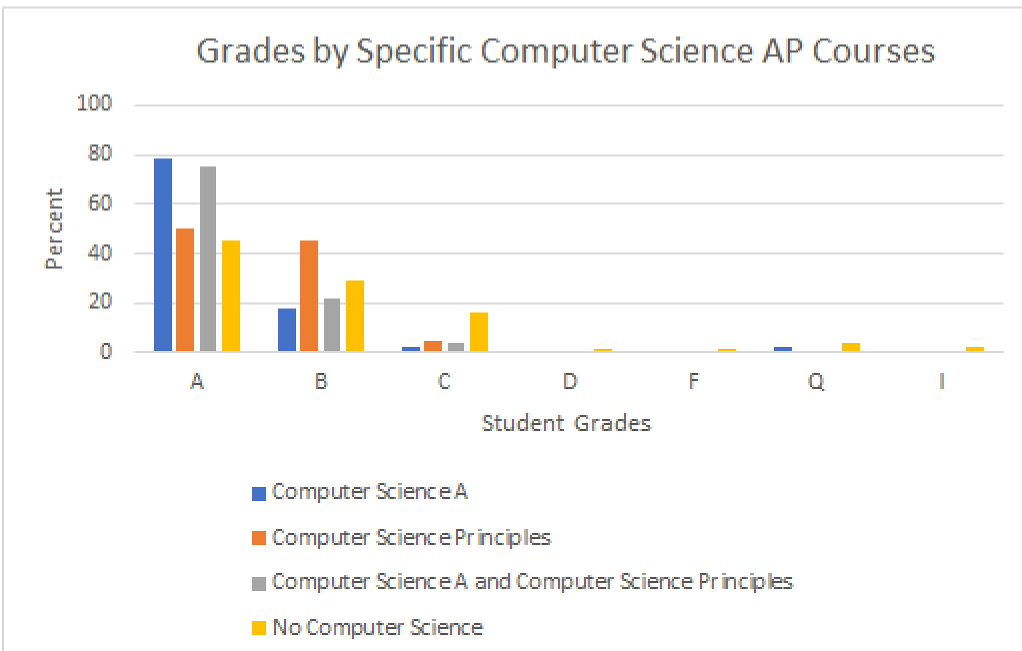

Figure 1. Grades by Specific Computer Science AP Courses

Figure 2 shows the final grades in relation to the number of prior AP math courses taken. It can be noticed that math is also a strong predictor of computing performance but not as strong as the computer science courses.

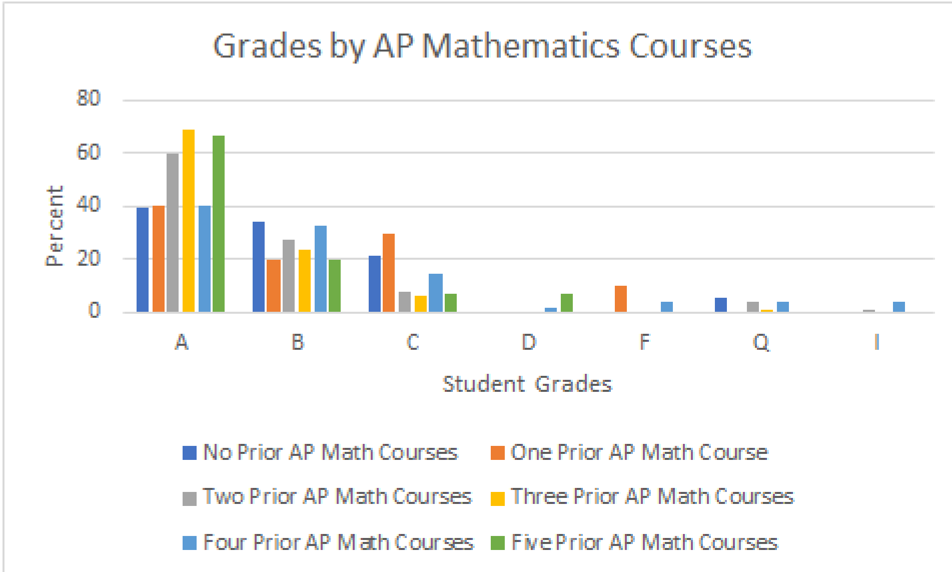

Figure 2. Grades by AP Mathematics Courses

For specific social identities, Figure 3 shows the difference between grades obtained by students with parents with college experience and those without it. It is clear that students whose parents are familiar with the college experience have a greater likelihood of obtaining a passing grade.

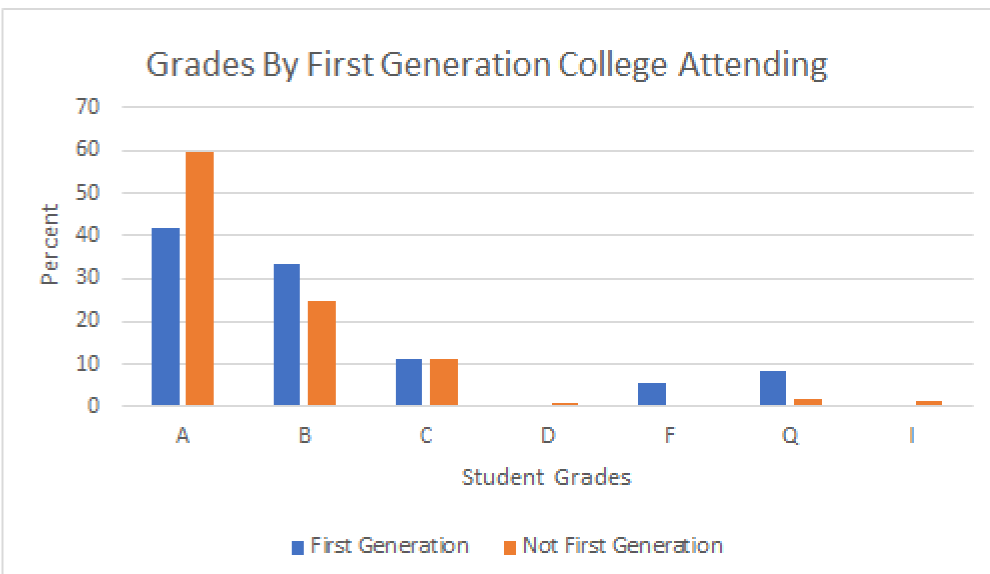

Figure 3. Grades by students acknowledging First Generation identity

Grades by gender, Figure 4, show that females are more prone to obtain a failing grade and not an A at the end of the course. It is important to note that only two participants did not fall into the binary category, and both obtained a C.

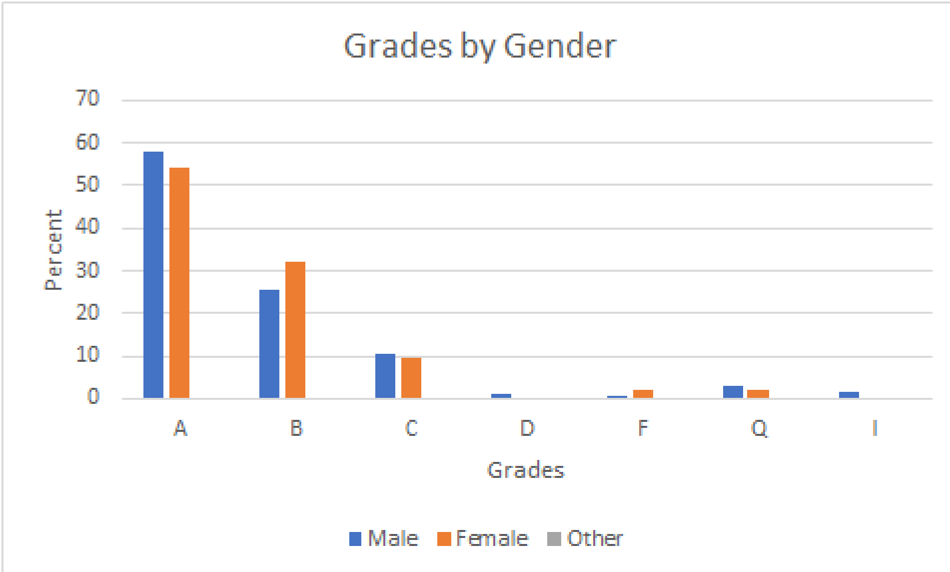

Figure 4. Grades by Gender

The comparison by ethnicity showed that minorities had a higher presence in the failing grades. It is important to note that only one American Indian student was part of the pool; therefore, their representation was 100% in the failing side of the chart (obtaining an F).

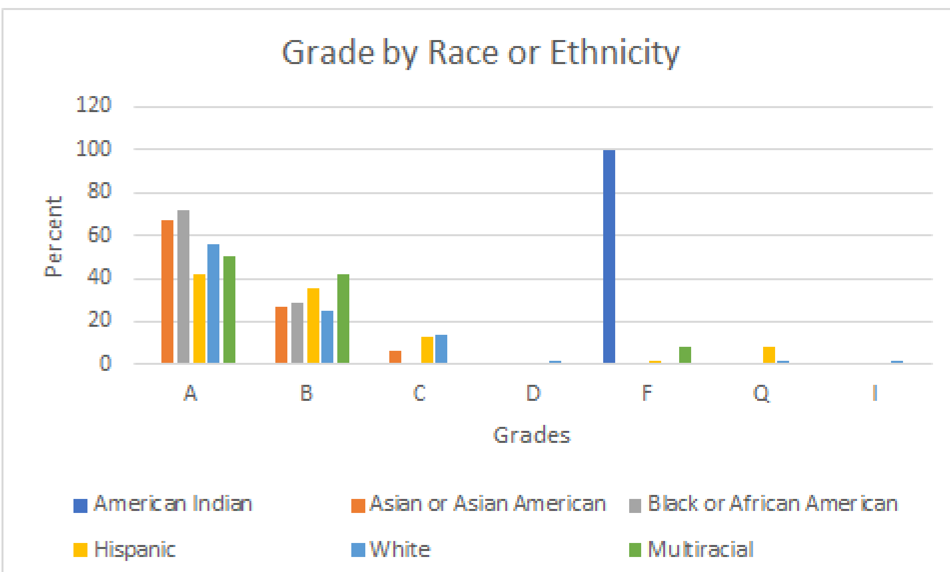

Figure 5. Grades by Race or Ethnicity

Figure 6 shows the distribution of grades based on gifted status and does not portray any notable difference according to this classification. If gifted status were meaningful, it would be expected that students who were identified as gifted would perform better than those who were not.

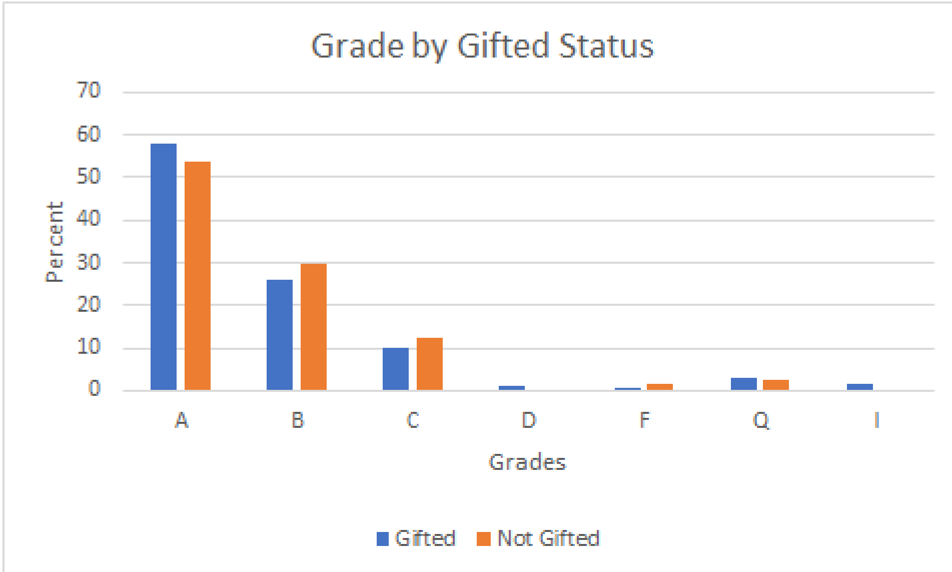

Figure 6. Grades by Gifted Status

It was important for the research team to corroborate that the self-selection process did impact the data collected. Figure 7 confirms that students who participated and took the ECTD diagnostic outperformed those who did not participate, except for the incomplete grade.

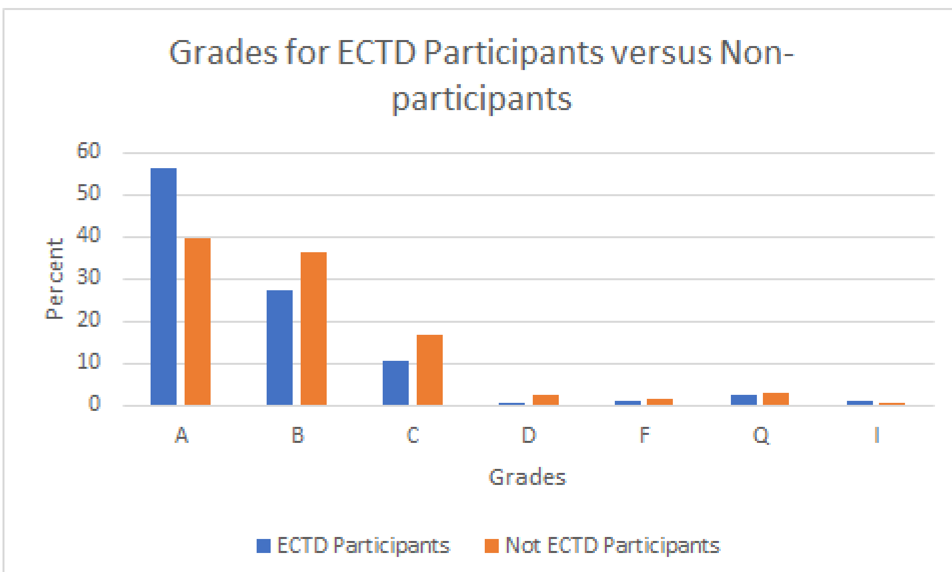

Figure 7. Grades for ETCD participants vs. non-participants

The final analysis was conducted on those who expressed difficulty with the ECTD after taking the diagnostic and their confidence in the class. As expected, those with less confidence and who perceived the most difficulty with the ECTD obtained the lowest grades (Figure 8).

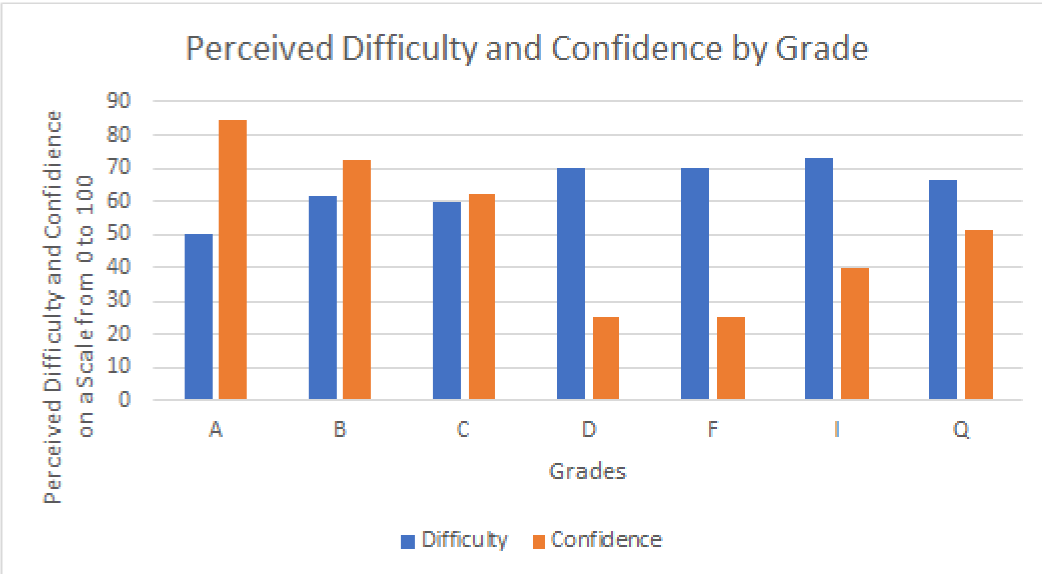

Figure 8. Average perceived difficulty and confidence in the introductory engineering course distributed by grades obtained at the end of the course.

This preliminary analysis constitutes the basis for the interviews with DFW students and students who participated early in their engineering programs and have progressed near their completion. The research team expects to unveil characteristics in the development of computational thinking skills that constitute long-term impacts and that could be hidden from the majority of successful cases reported in the literature.

Conclusion

We did not find strikingly different patterns by race/ethnicity and gender. We found that categorization as gifted did not appear to have any effect. However, the results of this analysis show that students who have had advantages like AP computer science classes, multiple AP mathematics classes in high school, or not being a first generation college attending student typically obtain better grades in the introductory engineering course.

While these patterns may seem to be modest, they are significant in the context of this institution. At this institution, students matriculate into a general engineering major and only after a year are given permission to pursue specific engineering majors. Students who have a GPA above 3.75 are permitted to select their major of choice, while those with lower GPAs have to give a prioritized list of majors and have their major selected by the institution. Hence these small advantages are accumulating to something that is really important: their choice of major and their eventual career path.

Bibliography

1. N. V. Mendoza Diaz, S. Y. Yoon, D. A. Trytten and R. Meier, "Development and Validation of the Engineering Computational Thinking Diagnostic for Undergraduate Students," in IEEE Access, vol. 11, pp. 133099-133114, 2023, doi: 10.1109/ACCESS.2023.3335931.
2. Noemi V. Mendoza Diaz, Trinidad Sotomayor, Effective teaching in computational thinking: A bias-free alternative to the exclusive use of students' evaluations of teaching (SETs), Heliyon. Volume 9, Issue 8, 2023, e18997, ISSN 2405-8440, doi.org/10.1016/j.heliyon.2023.e18997.
3. N. V. Mendoza Diaz, A. M. Esparza, K. E. Rambo-Hernandez and B. Nepal, "Enculturation of Students to Engineering and COVID's Impact Associated," *2023 IEEE Frontiers in Education Conference (FIE)*, College Station, TX, USA, 2023, pp. 1-5, doi: 10.1109/FIE58773.2023.10343256.
4. Mendoza Diaz, N. V (2023). Enculturating first-year engineering students: A theoretical framework. *International Journal of Engineering Education, 39(5)*, 1102-1117.