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WIP: Effects of Arduino Microcontroller on First-Year Engineering Students

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Aamir received his master's degree in Mathematics Education from University of Texas at Dallas and is currently a Ph.D. candidate at Texas A&M university. Aamir served as a mathematics teacher and varsity tennis coach in Dallas ISD for 10 years. During his tenure at Pinkston high school in West Dallas, he became an advocate for the cause of access and inclusion in STEM education for all students. He founded the first STEM club in Dallas ISD and encouraged his students who were mostly from underprivileged families to aim for college education and careers in STEM fields.

Aamir's research interests include equity in STEM education and infusion of open source hardware and software in STEM classrooms through Internet of Things (IoT) Technology. Aamir is also interested in expanding the academic research opportunity to undergraduate students in in-service teachers in K-12. Aamir is an Aggie Research Leader and is active in mentoring undergraduate research scholars. Aamir has presented his research both at regional (SERA, TAMU LAUNCH) and at international (FIE, AERA) educational research conferences. Aamir has published his research in a high impact peer reviewed journal, conference proceedings and is currently working on several research projects dealing with technology and equity in STEM classrooms.

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Asma Maredia is currently a senior at A&M Consolidated High School in College Station, Texas. She obtained her high school diploma in May 2021 and will be attending the University of Texas at Austin as an Honors Human Development and Family Science Major. This is her first time partaking in engineering-related research and she has thoroughly enjoyed the experience and ability to learn new material with Professor Fidai and her fellow co-authors.

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Insha Umatiya is a graduate from A&M Consolidated High School in College Station, Texas. She plans on majoring in Biology at the University of Texas at Austin. This is her first experience in research related to engineering and enjoys learning new information. She anticipates to continue major-related research in her college career.

WIP: First Year Engineering Experiences With Arduino Microcontroller

Introduction and Background

In this WIP research study, we present the preliminary findings from the meta-analysis of quantitative research on the effects of Arduino-enabled activities on first-year engineering students. First-year engineering courses serve as an introduction for students to the concepts, ethics, and the eco-system of the field of engineering. These courses also help budding engineers solidify their engineering identities. Recent years have seen a greater call for developing engineers who are able to diverse and ambiguous real-world problems [1]. This call for reform comes from the industry as well as the call from the Accreditation Board for engineering and Technology (ABET) [2]. Engineering students often go on to becoming committed professionals but also leaders in their communities. Therefore, it is extremely important to develop student engineers who are able to work collaboratively in interdisciplinary teams [3]; take on short- and long-term projects [4]; are motivated to solve real-world problems [5]; and are able to develop new and affordable tools using open source technology [6]. The engineering schools are also under pressure for designing first-year engineering courses that support innovative approaches that engage students in problem solving using open source and inexpensive control system development (Borgstorm et al., 2012; Start et al., 2013). The reform efforts in first-year engineering education revolve around engaging students in hands-on problem solving and tool development activities.

Students' engagement in hands-on engineering design activities hold great promise. Both in developing student engineers into insightful professionals and innovative problem-solver. However, these activities require access to equipment, peripherals, and sensors. Traditional the high cost of these laboratory equipment have made their use restrictive [7] [8]. In recent years, open source hardware and software has helped to reduce the cost of laboratory equipment and make hands-on engineering education accessible to more students [9] [10]. Open source Arduino microcontroller has become the go to tool for researchers, academics, and DIY enthusiasts for prototyping control systems [11]. Arduino is a simple and easy to use device that has helped to democratize prototyping and making for all [12]. Open source Arduino microcontroller has helped to make scientific experimentation affordable and created more opportunities for first-year engineering students to engage in hands-on problem solving.

Open source Arduino has shown great promise in improving first-year engineering students' academic achievement as well as their attitudes and perceptions towards engineering design process. Arduino-enable interventions in first-year engineering courses have helped students improve their physical computing skills [13]; knowledge of embedded systems [14]; gain exposure to control systems [15]; learn the fundamentals of scientific modeling [14] and many other aspects of engineering education. The positive effects of Arduino-enabled interventions on students in first-year engineering education should encourage greater integration of Arduino-enabled teaching and learning practices at all grade levels.

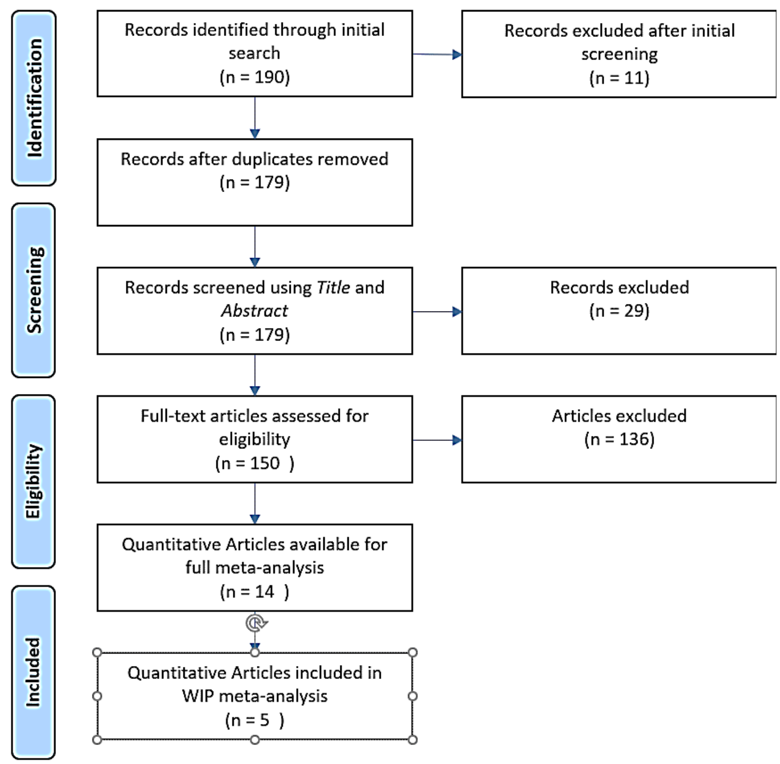

Figure 1. PRISMA flow diagram of study selection for the meta-analysis

Statement of Problem

There is growing research both qualitative and quantitative on the effects of Arduino enabled interventions at solving the problems of first-year engineering education and the findings are promising. But, to date, there has not been an effort at determining an overall effects of those interventions. To address this gap in research, we began work on a meta-analysis of the effects of Arduino based intervention in first-year engineering courses. In this work-in-progress research paper, we present the preliminary findings of our meta-analysis.

Methodology

In this research study we wanted to calculate an overall effect of Arduino-enabled interventions on students' academic achievement in first-year engineering courses. To achieve this goal we conducted a meta-analysis [16] [17] of quantitative studies that were published between 2000 and 2020. In this work-in-progress meta-analysis we present the preliminary finding from the analysis of the studies that were published between 2017 and 2020.

Research Question

This work-in-progress meta-analysis was guided by the following research question: *Do Arduino-enabled interventions improve student's academic achievement in first-year engineering courses?*

Inclusion Criteria

We only included those studies in this meta-analysis that a) were published between 2000 and 2020; b) were in English language; c) were set in first-year engineering coursework; d) focused on the use of Arduino as an intervention to improve students' academic achievement, their affect towards engineering, or their attitudes towards engineering; and e) provide quantitative information such as mean, standard deviations, *t*-test results, *F*-values and/or odds-ratio to enable the calculation of Cohen's *d* effect size.

Literature Search

Our search of relevant literature was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) [18] guidelines. We present the PRISMA search process in Figure 1.

Coding Procedure

We coded the studies using an excel worksheet. We noted the following major characteristics of each study: author, year, publication type, majority gender, duration in weeks, type of microcontroller, subject area, control sample, control mean, control standard deviation, experiment sample, experiment mean, experiment standard deviation, total sample, Cohen's d, and confidence intervals.

Statistical Analysis

We first calculated Cohen's *d* effects sizes from provided statistics. Then we used STATA 16 statistical software to conduct a meta-analysis of those effects. The meta-analysis was conducted using the META package and *meta esize* commands.

Findings

In this meta-analysis we aggregated the effects of Arduino-enabled interventions on first-year engineering students. We obtained 16 effect sizes from four studies. A forest plot of the effects is shown in Figure 2. The findings indicate that Arduino-enabled interventions had a large positive effect on students' academic achievement. The overall effect was $d = 0.35$ ($CI = [0.02, 0.68]$). This effect is statistically significant since the 95% confidence interval of the overall effect does not contain a zero, also known as a zero effect. The statistically significant Q value of 63.69 ($df = 15, p < .001$) indicated that the effects were not homogenous and were grouped according to some moderating variable. We grouped the studies by the engineering dimensions: design, project development, and control training. Two studies [4] [18] provided ten effects on design aspect of first-year engineering education. The effect on design was $d = 0.53$ ($CI = [0.30, 0.76]$). This effect was statistically significant. One study [20] provided five effects for control dimension of first-year engineering education. The effect on control was $d = 0.57$ ($CI = [-0.45, 1.59]$). This effect was positive however, it was statistically non-significant. One study (Haughery et al., 2017) provided one statistically significant negative effect for project management and this effect was $d = -0.5$ ($CI = [-0.73, -0.41]$).

Conclusion and Suggestions for Future Research

In this WIP paper we presented the preliminary findings from a meta-analysis of Arduino-enabled interventions in first-year engineering courses. The preliminary findings suggest that the use of Arduino has the potential to make hands-on engineering education affordable and accessible to all students regardless of their geographic location and level of financial resources. The use of Arduino-enabled intervention was useful in introducing students to the fundamentals of control system and physical computing. We intend to continue working on this meta-analysis and hope to present our full findings in near future. We also believe that the positive effects of Arduino-enabled interventions should encourage the use of open source hardware and software in all grade levels, specially in K-12 grade to provide students with early exposure to physical computing and control system as well as fundamentals of engineering design process.

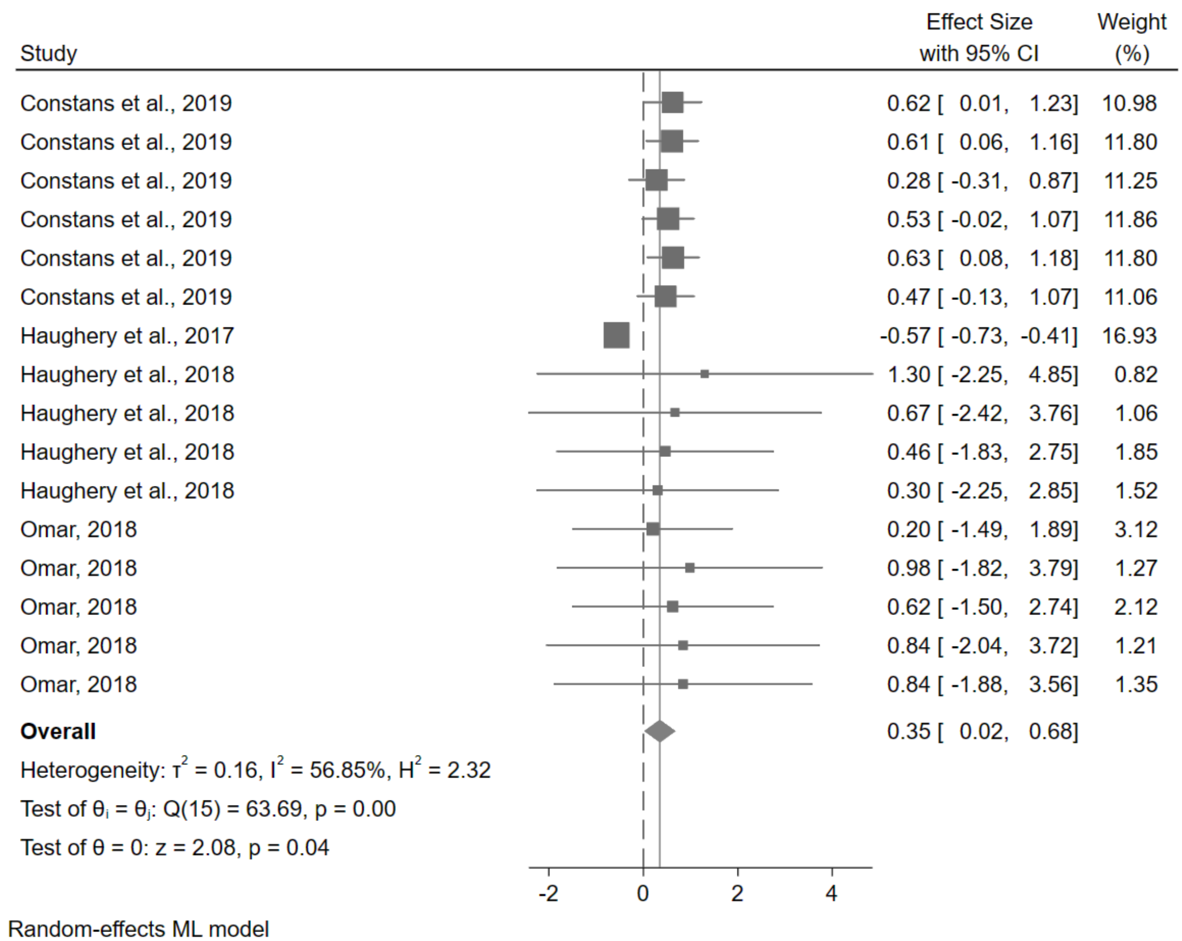

Figure 2. Forest plot of effect sizes

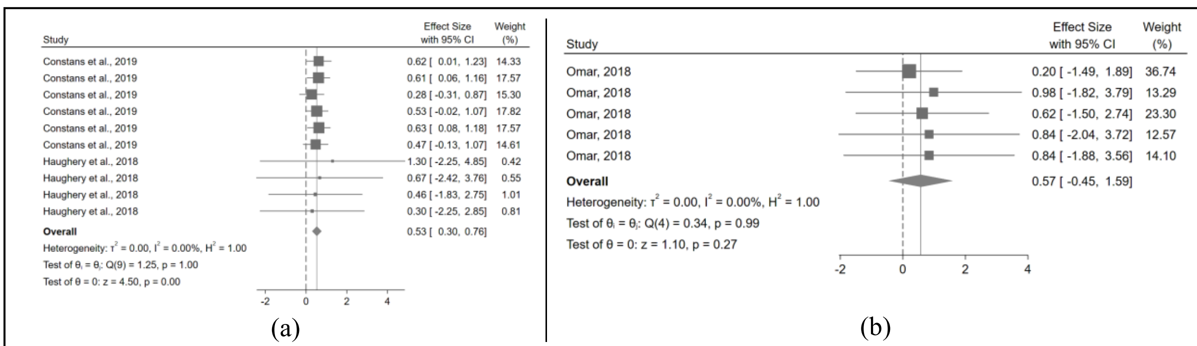

Figure 3. Forest plot of effect sizes on a) design and b) control dimensions of first-year engineering education

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