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Structuring Learning in a Makerspace Using a Design Method

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As one of Quinnipiac University's Founding Faculty members, John Reap helped shape, foster and guide its undergraduate focused engineering school. Founded in 2012 with civil, industrial, mechanical and software engineering programs, the school grew from two faculty and ˜30 students to 17 faculty and over 400 students, adding computer science and cyber security programs along the way.

His scholarly activities are rooted in engineering design with an emphasis on bio-inspired environmentally benign / sustainable design and manufacturing. He also has a growing interest in engineering education, especially with regards to sustainability and entrepreneurial innovation in the curriculum.

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Introduction & Background

Structuring students' makerspace experiences within the context of Taguchi's Method, an embodiment and detail level design method meant to improve quality [1], is the great idea for teaching (GIFT) explored in this article. Engineering instructors responsible for courses ranging across all undergraduate years find educational uses for university makerspaces [2]. Makerspaces support: active learning pedagogy in introductory engineering [3], design skill development in courses between introductory cornerstone and final capstone [4], and even unite clinical and engineering students [5]. Some universities are exploring the best ways to encourage faculty to incorporate makerspaces in their curricula. This may take as simple a form as pop-up "inreach/outreach" demonstrations that expose faculty and staff to makerspace equipment [6]. For those seeking a higher intensity experience, B-Fab, a fabrication workshop organized by Bucknell University, trains faculty to use equipment often found in a makerspace while exposing them to related pedagogical theory and example makerspace STEM projects [7]. Carnasciali and coauthors surveyed faculty given three different experiences with makerspaces: 1) access to a third-party community makerspace for use on any project of interest to the individual faculty members, 2) a workshop on integrating makerspaces into curricula, and 3) training on a specific piece of makerspace equipment with accompanying pedagogical discussions [8]. Though working with a small faculty sample size and influenced by the emergence of the COVID-19 pandemic, they found that the second two experiences, the ones specifically involving pedagogy, increased the chances of incorporating makerspaces in courses [8]. This work continues the theme of supporting makerspace incorporation using pedagogy.

Objectives and Setting

The investigated makerspace-based course had three objectives. First, the course sought to integrate student learning with the experimentation and design facilitated by a makerspace. Second, it aimed to meld creative activities naturally fostered by a makerspace with the structure of an established embodiment or detail design phase method. Motivated by feedback from an industry advisory board, exposure to a practical, engineering focused application of statistics stood as the final course objective.

All classroom interactions with the three enrolled students occurred in the university's makerspace. The makerspace occupies 1,140 ft^2 in two rooms. While these rooms contain an assortment of equipment, the students used a laser engraver and cutter, a 3D printer, and a thermoformer during this course.

Student Accomplishments

The enrolled students completed two Taguchi's Method (TM) focused projects in the makerspace using Ross' text [1] as a guide to TM. First, they worked as a team to complete process improvement of laser cutting. Then, each student undertook an individual project utilizing one of the pieces of equipment.

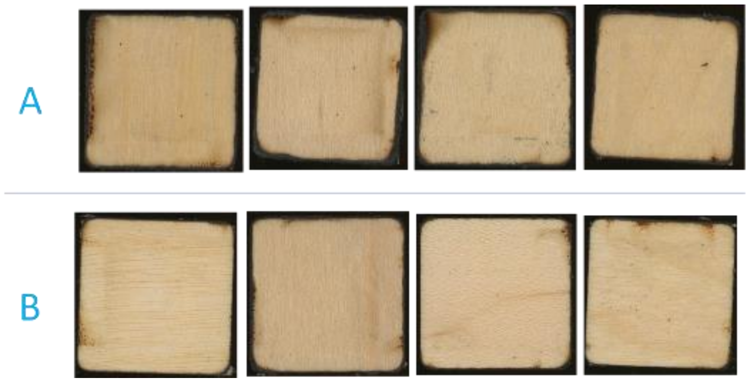

Figure 1: Most (Row A) and least (Row B) charred specimens

Using an Epilog Fusion Edge laser engraver and cutter, the student team designed, conducted, and analyzed experiments meant to reduce charring on laser cut 1 in^2 wood specimens. They selected an L9 orthogonal array [1] with four control factors (cutting speed, power, frequency [number of cycles], presence of masking tape on the surface) and two noise factors (position in the laser bed and wood thickness). They quantified charring using an automated pixel counting method adapted from work on air void detection in concrete [9]. The control factors responsible for the specimens in Figure 1's Row A exhibited the most charring and highest variation as measured by signal to noise ratio (S/N). Row B exhibited the least.

For the individual projects one student chose to investigate laser settings that minimize engraving time. Another student explored the effects on the surface quality of parts printed with the Stratasys F170. He measured differences in surface height to ±0.0005 in to quantify surface quality. This student went beyond the means and signal-to-noise (S/N) ratios required in TM data analysis, conducting a one-factor ANOVA using R-Studio software. The final student's individual project used the Formech 450 DT to investigate factors responsible for fabrication of accurate thermoformed molds.

Student Accomplishments in Light of Objectives

By holding all lessons in the makerspace and by basing student evaluation on projects completed with makerspace equipment, the course integrated the learning process with the makerspace. However, the students' embrace of experiment driven parametric optimization inherent in Taguchi's Method led them to develop only process optimization projects, limiting the expression of creativity expected as part of the second goal. Turning to the third objective, each student designed an experiment, and each analyzed the results using the basic statistical measures (mean, S/N) required by TM. One student drew upon knowledge from a prior statistics course to analyze the data generated by his individual project with a more advanced tool – Analysis of Variance (ANOVA).

Overall, these results illustrate the impact of pedagogy on incorporation of makerspaces into an engineering curriculum. Use of Taguchi's Method decisively influenced the approach taken by students when using the makerspace. They gravitated toward process improvement guided by experiment driven parametric optimization. While intended to give beneficial structure, TM unintentionally dominated student activities to the detriment of conceptual development and creative "making." Structural changes that require conceptual design or that direct students to work with products might balance the course, promoting it from an idea for teaching to a great idea for teaching.

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