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Section I Special Issue Maker Spaces in Engineering Education

Guest Editor

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Chih-chao Chung, Cheng-Lung Tsai, Yuh-Ming Cheng and Shi-Jer Lou	1136–1150	Action Research on Integrating Maker Spirit and Maker Space for the Special Topic Courses of Engineering Students in Vocational High Schools

This study aims to integrate Maker Spirit and Maker Space to establish Maker Space courses for engineering students in higher vocational schools, and explores students' feedback and learning effects in their expression of the Maker Spirit and the utilization of Maker Space in the learning portfolio. This study adopts Action Research, and takes 43 second-year engineering students in special topic courses in higher vocation schools as the subjects. This research covers the teaching of one semester, and relevant qualitative and quantitative data are collected for statistical analysis. The research results are, as follows: (1) Maker Space courses have significant positive effects on students' expression of Maker Spirit, the utilization of Maker Space, and Learning Outcome; (2) Maker Space courses can lead students towards seven Maker education objectives; (3) the teaching model of the Maker Space courses includes seven focuses in the implementation of curriculum and seven educational objectives. Finally, this study summarizes the research results, and provides suggestions for teaching application and future studies.

Keywords: Maker Spirit; Maker Space; engineering in higher vocation education schools; special topic courses; Action Research

Dámari Melián, José Luis Saorín, Jorge de la Torre Cantero and Vicente López-Chao	1151–1160	Analysis of the Factorial Structure of Graphic Creativity of Engineering Students through Digital Manufacturing Techniques
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The development of creativity must be an axis in engineering training, and maker spaces are presented as ideal environment to achieve it. Specifically, in engineering degrees, creativity is considered among the generic competences included in the Tuning project and in the Engineering White Papers that regulate the university degrees of engineer in Spain. The measurement of creativity has been and is a focus of interest in literature, as well as to find out what factors it is divided into. Above all, graphic creativity is one of the factors of creativity, essential for engineers. The objective of this paper is to explore how digital manufacturing experiences influence the different variables of graphic creativity and to explore the factorial structure before and after them. For this, two maker workshops with different approach based on creativity theories have been carried out at the University of La Laguna during the academic year 2016/17. The sample consists of 100 engineering students from two different degrees. Wilcoxon signed-rank test, Kruskal-Wallis and exploratory factor analysis were carried out. Both maker workshops have increased graphic creativity with statistical significance in 36.96 ($p = 0.002$) and 37.68 ($p > 0.001$) points respectively, which were measured with TAEC test. Meanwhile, the creativity of students who did not attend to any workshop increased by less than two points without statistical significance ($p = 0.875$). The distribution of variables and the percentage of explanation of the tool has varied depending on the level of graphic creativity (pre-test and post-test). Moreover, relations between maker workshop design and the development of different variables of graphic creativity are discussed.

Keywords: maker space; creativity; engineering graphics

Barış Doğan, Buket Doğan, Eyup Emre Ulku, Anil Bas and Hasan Erdal	1161–1169	The Role of the Maker Movement in Engineering Education: Student Views on Key Issues of Makerspace Environment
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Makerspaces are becoming increasingly important as a new approach to enable individuals to experience new technology applications and increase creativity in universities and other educational institutions. Such learning implementations offer many advantages like learning-by-doing and applying theoretical knowledge in engineering education into practical skills in an interdisciplinary environment. Despite the advantages, makerspaces still lack integration into the curriculum of engineering schools. For a quality engineering education, establishing maker workshops where students can experiment, design and practice as well as feel encouraged to open-ended development projects are required in addition to standard theoretical and laboratory applications. In this study, we present student views on the learning opportunities, challenges and contributions of the makerspace environment. In this context, IHA Makerspace established within the Faculty of Technology, Marmara University, Turkey, aims to provide high-level engineering experience to students by designing and prototyping effectively in a multidisciplinary development environment.

Keywords: Makerspace; learning environment; engineering education; student views

Hannah D. Budinoff and Sara McMains	1170–1183	Improving Outcomes and Participation in the Prototyping Process Using Design-for-Additive-Manufacturing Training
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University makerspaces provide students with resources to build and prototype, which is helpful in engineering design projects. In fall 2018, in a sophomore-level engineering class with a semester-long design project, we introduced a design-for-additive-manufacturing training activity with several goals in mind. We hoped to familiarize students with the interplay between design and manufacturing, reduce 3D printing failures leading to inefficient prototyping, and help novices build confidence with using 3D printing in our university makerspace. By evaluating individual homework assignments as well as team design project deliverables and grades for 58 students in the class, we seek to evaluate outcomes and participation in the prototyping process. The additive manufacturing training did not significantly decrease the occurrence of common manufacturability problems during team

prototyping. However, we identified several interesting trends regarding participation. A moderate positive correlation was identified between a student's level of initial 3D printing experience relative to their team members' experience and the amount of prototyping responsibility that student undertook. Students who did not help prototype received lower peer review scores from their teammates than those who did. Although the participation was still unequal, the overall fraction of students who helped prototype in the semester with design-for-additive-manufacturing training was approximately 20% larger than the prior semester with no training, indicating that the training may be an effective way to foster more inclusivity in the prototyping process.

Keywords: university makerspaces; engineering design process; prototyping; engineering education; gender diversity; women in engineering; spatial visualization ability; design for manufacturing

Gordon D. Hoople, Joel Alejandro Mejia, 1184–1195 **Makerspaces on the Continuum: Examining Undergraduate Student Learning in Formal and Informal Settings**
Diane Hoffoss and Satyan L. Devadoss

This qualitative study focuses on sociocultural aspects of learning in makerspaces with a focus on engineering projects. The project at the center of this study, a two ton interactive metal sculpture called Unfolding Humanity, was completed simultaneously in two makerspaces: a university machine shop (embedded in a formal academic space) and a community-based arts space (an informal space). Taken together, these sites span the continuum of formal/informal learning that exists in makerspaces. Using a phenomenographic approach, we examined how students experienced these spaces and the ways in which the characteristics of both environments may complement, hinder, or support student learning. Results indicated that the presence of experienced practitioners, clear rules of engagement, and a culture fostering student creativity are key to supporting learning in makerspaces.

Keywords: engineering epistemology; STEAM; multidisciplinary design; informal learning; makerspace

Cindy Lenhart, Jana Bouwma-Gearhart, 1196–1207 **Engineering Faculty Members' Perceptions of University Makerspaces: Potential Affordances for Curriculum, Instructional Practices, and Student Learning**
Idalis Villanueva, Kate Youmans and Louis S. Nadelson

We detail an exploratory study of faculty members' perceptions of activities associated with undergraduate engineering programs in university-based makerspaces. Our study examines the affordances and constraints faculty perceive regarding teaching and learning in these spaces and, specifically, how makerspaces support engineering faculty members in accomplishing the goals and expectations they have for undergraduate students' learning and development. We found that makerspaces inspired faculty members' curricular and instructional innovations, including design of new courses and implementation of practices meant to result in more team-based and active learning. Faculty perceived student activities in makerspaces as fostering of student agency and development of engineering skills, knowledge, and affect. Faculty also identified concerns related to the teaching of engineering in these spaces, including the need to change their instructional practices to more fully engage students and to balance the sophisticated tools and resources with the rigor of completing complex engineering tasks. We use structuration theory to illuminate how faculty act, rationalize, and reflect on their teaching practices and goals in relation to structures present in university-based makerspace. Our study is intended to inform faculty and administrators working to engage students through interactions in makerspaces or similar innovations, and to consider how access to and impact of these structures support undergraduate engineering education.

Keywords: makerspaces; engineering education; undergraduate; faculty perceptions; diverse populations

Lei Jiang, Lingxia Gao, Qingchun Wang, 1208–1219 **The CDIO-based Maker Space Framework: Application with Engineering Management Students**
Yunli Gao and Feng Shi

Creating maker spaces is an effective approach to enhancing creativity. Maker spaces, commonly libraries, are often utilized within the science, math, technology, and engineering (STEM) field; their use has not been extensively researched in the context of engineering education. Conceive-Design-Implement-Operate (CDIO) is an already well-established engineering education technique. This paper establishes a Framework of Maker Spaces (FMS) based on CDIO for engineering management students composed of the Innovation Studio Project (ISP) I–IV. A total of 160 students participated in the experiment who were randomly assigned into two groups: Group A, given maker spaces with teacher guides, and Group B, who were taught by teachers in the form of traditional curricula. The results indicate that maker spaces have a positive impact on student performance, especially team innovation and individual innovation indicators. Group A students also reported higher satisfaction than Group B. This study marks the first CDIO-based maker space framework applied to the ISP I–IV for engineering management students. The results presented here may represent workable guidelines for further research on maker spaces.

Keywords: maker spaces; engineering education; CDIO; syllabus

Nikolaos Kalogeropoulos, Pierre Walker, 1220–1233 **Facilitating Independent Learning: Student Perspectives on the Value of Student-Led Maker Spaces in Engineering Education**
Colin Hale, Klaus Hellgardt, Andrew Macey, Umang V. Shah and Marsha P. Maraj

Embedding and effectively managing independent learning within engineering curricula can be somewhat challenging. This work examines the development of a student-led maker space to facilitate independent learning and explores the value that these spaces can add to engineering curricula from a student perspective. Student-led maker spaces as used here, refer to learning environments created and developed solely by students, generally outside of the university setting and with minimal faculty support, to explore concepts related to their studies. We examine the experiences of two undergraduate engineering students involved in creating a student-led maker space to develop and produce a working prototype of a 3D printed modular separation column. The results show that these spaces can provide rewarding independent learning situations that encourage entrepreneurship, promote life-long learning, build project management skills, increase self-efficacy and motivation and allow the freedom to work in accessible spaces that are not confined or controlled by the university. Effectively managing student-led maker spaces however requires both students and staff to carefully reflect on the balance between independent learning activities and other work commitments as well as the availability of departmental support in particular areas relating to the academic and technical staff access and laboratory scheduling. Managing a small number of student-led maker spaces within academic programmes is potentially easy and feasible; larger numbers however may require a careful consideration of resources which, for some departments are already constrained during their normal academic year activities.

Keywords: student-led maker spaces; independent learning; interdisciplinary collaboration

Matthew A. Wettergreen, Ann Saterbak, 1234–1251 **Makerspaces in Low-, Middle-, and High-Income Countries to Support Student Development of Engineering Design Skills**
Amy J. Kavalewitz, Alex M. Nunez-Thompson, Veronica Leautaud, Theresa Mkandawire, Matthew Petney, Carlos A. Dos Santos and Z. Maria Oden

Design spaces are important for the development of engineering design solutions in low-, middle-, and high-income countries. Only recently has literature begun to comprehensively document and compare makerspaces; however, this comparison is frequently only based on measurable properties such as size and number of machines. Instead, we argue that the defining characteristics of a makerspace are facilitation of prototyping, curricular outcomes, and management philosophy. This study compares three makerspaces in countries with different economic backgrounds: the Oshman Engineering Design Kitchen (OEDK) at Rice University in Houston, TX, USA; the Laboratório de Fabricação (LABFAB) at the Pontifical Catholic University of Rio Grande Do Sul in Porto Alegre, RS, Brazil; and the Polytechnic Design Studio (PDS) at Malawi Polytechnic in Blantyre, Malawi. We

provide insight into how these economic differences present themselves in the governance of the makerspaces including space access, partnerships, policies, procedures, and staffing models. Additionally, we highlight how economic differences impact the level and quality of prototypes achievable by students. Despite these differences, all three institutions have experienced rapid growth in the number of users, supported projects, and staff within their makerspaces. Support for this growth came from investments made into curricular resources like dedicated classes, workshops, and one-on-one mentoring. We conclude with some suggestions for future makerspace development incorporating these same principles.

Keywords: makerspace; engineering design; student development; prototyping; engineering education

Mohamed Jalal and Hanan Anis 1252–1270 The Integration of a Maker Program into Engineering Design Courses

The integration of making activities into engineering curricula has the potential to increase students' self-efficacy and allows for participation in problem-solving, design and fabrication activities. In this study, we discuss the authenticity of the learning environment of cornerstone design courses that have integrated making activities as a central theme. We conducted fourteen interviews with seven students in two different teams during their learning experience in a second-year cornerstone design course with a making curriculum. Drawing from our interviews and observations of the students, we discuss the authenticity of the learning environment and students' experiences within it. We also discuss the challenges that students go through as they are completing their projects and the implications for engineering instructors who are interested in integrating making activities into their courses. We describe how situating formal design courses in a makerspace environment offers students an authentic design experience, with opportunities to develop and practice authentic engineering skills and to solve problems that are similar to workplace problems. It also helps students increase their confidence in their design and problem-solving skills and exposes them to multiple topics and disciplines.

Keywords: authentic learning; situated learning; engineering design education

Satesh Namasivayam, Mohammad Hosseini Fouladi, Sivakumar Sivanesan and Se Yong Eh Noum 1271–1279 The Role of Makerspaces in Enhancing the Student Learning Experience

Makerspaces are areas where its participants are able to design and build products of varying complexity. Many such areas exist within institutions of learning as well as in common areas that are frequented by children and adults alike. In fact, there are those that run a business based on the frequency or popularity of operating a makerspace. One of the main reasons makerspaces are so popular is due to the nature of the space itself, where it allows a person to touch and feel their own product after designing and subsequently building it. This "hands-on" approach is highly motivating for young learners and assists in further enhancing their awareness of STEM based activities. It is hypothesized that makerspaces are able to significantly enhance the learning experience of young learners who engage in these areas. These learners are able to enhance a variety of skills while designing a tangible product within a makerspace. The present investigation aims to validate this hypothesis, focusing on the roles makerspaces play in enhancing the learning experience. Through the review and results obtained, the key attributes or roles a successful makerspace should consist of would be identified. The main objective of the study would be to identify how makerspaces enhance the student learning experience. The research methodology is that of a case study, focusing on qualitative results obtained from a questionnaire. The questionnaire was answered by students who were tasked to design and build an engineering system while (in parallel) given access to a particular makerspace (to be used in assisting them to accomplish their design and build task).

Keywords: market space; STEM; PBL

Cheng-Lung Tsai, Chih-chao Chung, Ming-Hsiu Liu and Shi-Jer Lou 1280–1294 The Effect of Positive Instruction on a Maker Project in a Vocational High School

This study aims to conduct experimental research on the impact of the application of positive instruction in the "Maker Project Practice" courses of vocational high schools on the students' learning outcome. By purposive sampling, 80 juniors taking the "Maker Project Practice" course in two classes of the Department of Automotive Technology in a vocational high school in southern Taiwan were selected as subjects. They participated in the "fuel saving Maker Project Practice" activities during the period of one academic year. Regarding activity design, positive instruction was adopted as the learning strategy, and a "Maker Project Practice" course on fuel saving was implemented with students as the subjects. The "Quasi-experimental design" was adopted, and pretest and post-test were carried out on the experimental group and the control group. In the experimental treatment, the experimental group received the intervention of positive instruction in the "Maker Project Practice" course, while the control group did not receive any experimental treatment. In addition, by reorganizing the statistical analysis of the quantitative questionnaire and qualitative triangulation result, this study determined the following learning outcome conclusions: (1) the application of positive instruction in the "Maker Project Practice" course has significantly positive influence on students' "flow experience"; (2) the application of positive instruction in the "Maker Project Practice" course has significantly positive influence on students' "auto fuel saving literacy". Thereby, this study puts forward suggestions for teaching and future related research.

Keywords: positive instruction; Maker Project Practice; learning outcome; flow experience; auto fuel saving literacy

Xaver Neumeyer and Susana C. Santos 1295–1301 Makerspaces as Learning Sites at the Intersection of Engineering and Entrepreneurship Education

Makerspaces have become an important intersection between engineering and entrepreneurship. Drawing from data on a team-based engineering entrepreneurship program that included peer-reviews and faculty/advisor assessments, we examine how prototyping in combination with team process and composition variables affect entrepreneurial performance. Using a three-step hierarchical regression model, we found that team compositional variables such as gender, entrepreneurial and prototyping experience, had a positive effect on entrepreneurial performance. We also found that team process variables such as prototyping efficacy and communication frequency were positively linked with entrepreneurial performance. We conclude our study with a discussion of the implications of our findings for engineering entrepreneurship education.

Keywords: makerspaces; entrepreneurship; gender; prototyping

Section II

Contributions in: Transport Engineering, Global Learning, Institutional Data, Transnational Education, Academic Success, PBL, Inverted Classroom, Socialization Process, Software Testing, STEAM

E. Diez-Jimenez, C. Gomez-Huelamo, M. J. Gómez-García, and I. Valiente-Blanco 1302–1311 Practical Approach for Teaching Vehicle Design to Engineering Undergraduates

We present a new practical methodology for teaching vehicle design to engineering undergraduates. Students, after receiving theoretical lessons, programmed an interactive automatic spreadsheet where inputs were the main geometric and physical

parameters of a selected vehicles and as output, the spreadsheet must deliver maximum speed, 0–100 km/h acceleration time, maximum slope, tilt and skid. More than 150 students were taught with this practical methodology, turning the theoretical topic into something really applied, close and attractive for the students. The experience assessment shows that students obtained very good grades in the topic while they were very satisfied with the methodology. They demonstrated an excellent understanding of the vehicle mechanical performance calculation process while their curiosity and interest on the topic was very high because it dealt with their preferred vehicles.

Keywords: automotive engineering education; vehicles; road vehicle design; transport engineering

Kerry L. Meyers and Mark J. McCready 1312–1320 The Benefits of Short-Term Study Abroad Programs for Engineering Students

Engineering students are among the least likely to study abroad as undergraduate students despite the increasingly global nature of related work due to: (1) the high number of credits required for graduation, (2) challenging courses that build upon each other and are sequential, (3) students not typically having foreign language skills. While many universities are focused on trying to increase study abroad access and opportunities, there are little data to assess the tangible benefits for engineering students. Approximately 200 undergraduate engineering students at a selective private institution in the Midwest were part of the current study. The students that participated in a 6-week summer study abroad program during the summer of 2019 were surveyed before and after participating in the program. The results were analyzed statistically (primarily with paired t-tests) to better understand the programmatic benefits. Students were asked to evaluate themselves on measures of cultural self-assessment, and students pre vs. post responses showed growth in every category (statistically significant at 95% confidence level or above). Students participating in a summer study abroad program were more likely to graduate with a higher number of overall credits earned and more likely to have earned an additional credential such as a minor or second major.

Keywords: engineering; global learning; study abroad; short term Study abroad

Marisa K. Orr, Matthew W. Ohland, Susan M. Lord and Richard A. Layton 1321–1332 Comparing the Multiple-Institution Database for Investigating Engineering Longitudinal Development with a National Dataset from the United States

The Multiple Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD) has been used to conduct a significant amount of research on student pathways in engineering. The representativeness of the database has generally been established on the basis of its size, its completeness, and the similarity of its partner institutions to those educating the majority of engineering graduates in the USA. In this work, a richer analysis of the extent to which MIDFIELD is nationally representative has been conducted based on data available from the American Society for Engineering Education (ASEE). The MIDFIELD and non-MIDFIELD institutions are compared based on the demographic composition with respect to race/ethnicity and sex at matriculation and graduation. The similarity of the demographic composition of the five most common engineering disciplines (Chemical, Civil, Electrical, Industrial, and Mechanical) provides evidence that the MIDFIELD institutions are largely representative of the ASEE national sample to the extent that the comparison can be conducted.

Keywords: representativeness; validation; institutional data; demographic composition; undergraduate

Rami Ghannam, Sajjad Hussain, Qammer H. Abbasi and Muhammad Ali Imran 1333–1339 Remote Supervision of Engineering Undergraduates in a Transnational Programme between Scotland and China

Due to the nature and challenges of undergraduate teaching in transnational education (TNE) programmes, there are potential drawbacks that distance supervision may create. Indeed, various telecommunications technologies can facilitate remote supervision. However, nonverbal cues are lost in telecommunications media, which means that information and guidance from supervisors can be misjudged or poorly perceived. This is particularly important in the context of joint degree programmes between a greater number of *Western* universities and their international counterparts. Among the aims of this study was to understand Chinese student preferences towards remote supervision. Statistical analysis of data collected from 70 final year electronic engineering students clearly demonstrated that 56% of undergraduates preferred a hybrid approach, which reaped the benefits of telecommunications technology with face-to-face meetings. Furthermore, 80% of students were highly satisfied with the communications effectiveness of social media tools for their supervision purposes. Consequently, we believe that these findings can be used as a pilot model for remotely supervising engineering students in TNE programmes. Therefore, our intention is to share best practices and recommendations that have made a positive impact on undergraduate transnational learners.

Keywords: electronic engineering education; remote supervision; transnational education

Kyle M. Whitcomb, Z. Yasemin Kalender, Timothy J. Nokes-Malach, Christian D. Schunn and Chandralekha Singh 1340–1355 Engineering Students' Performance in Foundational Courses as a Predictor of Future Academic Success

Math and science courses (physics, chemistry and mathematics) are considered foundational in engineering curricula and all engineering undergraduates must successfully complete courses in these subjects. However, relatively little is known about the predictive relationships between foundational math/science/engineering coursework and later engineering courses. This study uses large-scale institutional data to investigate the relationships between grades earned in foundational courses and early engineering courses in two large majors in order to gain insight into which foundational courses are most predictive of later performance and whether the relationship follows a linear or threshold function. Multiple regression analyses were performed on course grades using 10 years of data on 5,348 engineering students to construct a predictive model. We find that the predictive relationship between early and later performance is generally linear rather than threshold and that the strongest predictors are advanced mathematics courses along with cumulative STEM GPA, which is in turn strongly predicted by high school GPA and entry test scores. Physics and introductory engineering programming and modeling courses from the first year also predict performance in later courses. Advanced mathematics courses are critical to the long-term success of engineering students in these two common majors and students should be encouraged to aim for high rather than minimally passing grades.

Keywords: engineering curriculum; academic advising; equity; mathematics; predictive model

Xiangyun Du, Claus M. Spliid, Anette Kolmos, Niels E. R. Lyngdorf and Youjin Ruan 1356–1371 Development of Critical Reflection for Transformative Learning of Engineering Educators in a PBL-Based Professional Learning Program

This study investigated how 35 Chinese university instructors developed and engaged in critical reflections in a six-month Problem-Based Learning (PBL) professional learning program in Denmark. Data sources included individual progressive portfolios, team-project reports, and focus group interview. Quantitative analysis indicated that participants developed significantly in content, process, and premise reflection in the domains of instructional knowledge and pedagogical knowledge. This result provides evidence for the effectiveness of using a PBL methodology to organize professional learning activities aiming for the development of critical reflection for transformative learning. Nevertheless, participants demonstrated little premise reflection regarding curricular knowledge, an area that demands more time and more systemic support. Qualitative analysis identified systemic, individual, and cultural factors constraining engineering teachers from critical reflection. The study also suggests that to facilitate premise reflection it takes longer than six months and demands more systemic support.

Keywords: critical reflection; university instructors; PBL-based professional learning; transformative learning; China and Denmark

Blerta Prevalla Etemi and Huseyin Uzunboylu 1372–1382 The Effects of Flipped Learning Method on Students' Perception and Learning of Java Programming

The aim of this study is to evaluate the effects of flipped learning method on students' perception and learning of Java programming where the content of the course is delivered in two ways with two groups of students, one experimental group and one control group. The experimental group was taught with flipped learning method where all materials were developed by the researcher in a form of pre-recorded video lectures delivered to the students and in-class group activities supervised by the instructor. The control group had traditional weekly lectures and exercises at home. This study was conducted for 10 weeks with 174 students in total and employed an explanatory mixed method research design with qualitative and quantitative approaches. The data collected through the achievement test, Course Evaluation (CEQ), and Students' Perceptions/Opinions of Flipped Learning in Engineering Education Questionnaire (SOFLEEQ) were analyzed by using descriptive and inferential statistical analysis techniques. For data analysis, SPSS 24.0 was used and alpha level was determined as .05. Significant differences were found between the experimental and control group in terms of students' achievements and positive reactions towards flipped learning methodology. In the experimental group, students' learning attitudes, motivation and self-evaluation were enhanced. The findings show that flipped classroom outperforms traditional classroom and students' perception toward flipped learning became more positive.

Keywords: engineering education; flipped classroom; flipped learning; inverted classroom; students' perception

Emma Brennan-Wydra, Joanna M. Millunchick, Trevion S. Henderson, Aaron W. Johnson and Cynthia Finelli 1383–1395 Investigating the Adaptation of Socialization Processes Scales in Engineering Education Context

Socialization is an important concept for understanding how students gain the knowledge and skills necessary to become effective in the college community. In this paper, we adapted two scales taken from the organizational behavioral literature for the engineering college context. We used structural equation modeling to validate an instrument measuring socialization processes using survey data collected from 934 engineering students at a large, public, Midwestern university. We find that for institutional tactics, which is a socialization process having to do with how the institution itself socializes newcomers, our data did not match the originally proposed factor structure. On the other hand, our data was consistent with the model for proactive behaviors, which describes how individuals learn about their new environment, suggesting that the adapted proactive behaviors scale may become a useful indicator for detecting students who do not acquire important socialization processes during the college transition.

Keywords: confirmatory factor analysis; socialization processes; institutional tactics; proactive behavior

Tonći Dadić, Vlado Glavinić and Marko Rosić 1396–1410 Automated Software Testing Based on Semantic Distance

Automatic student program assessment is found in both grading and tutoring systems; its purpose is to verify correctness in addition to programming bug localization and fixing. Respective assessment tools should therefore deal with logical programming errors in a way that is comparable to the functionality of modern compilers, which localize syntax errors by highlighting erroneous code in addition to delivering messages that help programmers understand and correct possible syntax errors. Because the number of possible program implementation variants, which are the correct solutions for a given problem, can be quite large, issues can arise when comprehensive assessments are performed. This prompts a novel approach to student program assessment. In this paper, we analyze approaches to student program assessment according to reliability of verification, bug localization and fixing as well as freedom of design. A novel method, described in this paper, localizes bugs precisely and provides minimal corrections, which are made according to students' intentions. The experimental evaluation of the method shows that it is reliable with respect to both false and missing alarms and that it also efficiently localizes and corrects programming bugs.

Keywords: computer program assessment tools; program verification; program recognition; semantic distance of programs

Swapnil Sinha, Kelsey Rieger, Aaron D. Knochel and Nicholas A. Meisel 1411–1427 The Impact of a Mobile 3D Printing and Making Platform on Student Awareness and Engagement

3D printing technology has played an integral part in the growth of makerspaces, showing potential in enabling the integration of art (A) with science, technology, engineering, and math (STEM) disciplines, giving new possibilities to STEAM implementation. This paper presents the effectiveness of a deployable mobile making platform and its curriculum, focused on 3D printing education. This setup, which draws inspiration from modern makerspaces, was deployed for 227 undergraduate students in Art and Engineering majors at multiple campuses of a large northeastern university and used in either a pre-arranged hour-long session or voluntary walk-in session. Self-reported surveys were created to measure participants' pre- and post-exposure awareness of 3D printing, design, and STEAM quantified through their (1) familiarity, (2) attitude, (3) interest, and (4) self-efficacy. Additionally, observations on participant engagement and use of the space were made. Statistically significant increases in awareness of 3D printing technology were observed in the participants from both Art and Engineering majors, as well as at different campus locations, irrespective of their initial differences. Observations also show a difference in engagement between prearranged sessions and walk-in sessions, which indicates that different session formats may promote specific engagement with different participant types. Ultimately, this research demonstrates two key findings: (1) though they may gravitate to different elements of 3D printing and design, a single makerspace can be used to engage both Art and Engineering students and (2) by introducing mobility to the traditional idea of a makerspace, participants with different initial levels of AM awareness can be brought to similar final awareness. This second finding is especially essential given the disparities in modern student access to 3D printing technology.

Keywords: makerspaces; informal learning; 3D printing outreach; STEAM