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Over the last few years, virtual voice assistants have become more widespread in different fields. The purpose of this research is to develop and perform a quality-based evaluation of the model for voice assistant integration in the software engineering classroom to teach software architecture design. The model creation included identification of general software design principles, SOLID software design principles, software design strategies, and software design patterns that consider the software design process from different perspectives and different abstraction levels. As a result, software architecture is created, and the presented concepts can be considered as building blocks of software architecture design. They can be related to the software quality attributes that refer to the non-functional requirements. The design of skills and intents of a voice assistant as well as the creation of a user interaction model was considered through the Amazon Alexa platform. For this purpose, different teaching and learning resources including textbooks, videos, presentations, and source code, were used. Furthermore, in order to investigate possibilities of applying the model in the software design classroom, an experiment was conducted. The experiment included identification of software system architectures as well as their evaluation in the context of software quality metrics. Despite the experiment being limited, preliminary results indicated that the design of the model for voice assistant integration is feasible. Based on the completed evaluation, it was concluded that the implementation of the proposed software design model enables application of generic, general, and stable software solutions that consequently facilitates the maintenance and evolution of software.

Keywords: voice assistant; amazon alexa; software architecture; software design model; software quality; software metrics

The quality of teaching can be reflected in the quality of homework that students produce. However, if students copy homework, teachers will be unable to evaluate their work accurately. At present, there are no effective means to objectively verify that homework copying has occurred, or to quantify its scale. In this paper, homework copying is studied through experiments and statistical analysis. An experimental group and a control group which are consistent in all possible influencing factors are selected. A customized exercise generation system (CES) is designed and applied to prevent homework copying in the experimental group. In contrast, the control group has no restrictions on copying homework. The answer sheets handed in by the two groups are graded according to a standardized process, and the correct rate for each question of the two groups is calculated. Subsequently, we studied the relationship between "the difference of the correct rate between the two groups" and "homework copying". Results indicate that there is a significant difference in the overall mean of the correct rate between the experimental group and the control group, and the existence of homework copying is highly plausible. To quantify the homework copying scale, we propose a method to calculate the homework copying scale of each question in the experiments. Then, the factors that influence homework copying, particularly the question difficulty, are studied and a relationship between the difficulty of a question and its scale of homework copying is obtained.

Keywords: assessment; customized exercise generation system; homework copying; higher education, statistical analysis

Choosing a doctoral advisor is the most critical decision students will make in their doctoral journey. The relationship between doctoral students and their advisors can determine if students will complete the doctorate. Yet, little is known about how students experience this decision process and whether students are supported in this selection. The purpose of this study was to explore how students experience the satisfaction of their basic needs in the advisor selection process of one Chemical Engineering program. Using case study methodology, we interviewed 14 doctoral students about their experience in selecting an advisor. Self-Determination Theory guided evaluative and theoretical coding. The findings revealed that most doctoral students who participated in research experiences prior to the doctorate are more satisfied with their choice and practiced a better-informed selection. They had a clearer understanding of what they needed to look for in an advisor when compared to students who had not participated in such research experiences. This study shows that the process of finding an advisor in the Chemical Engineering Program studied may not provide sufficient competence support for students who have not participated in research, limiting their ability to make a decision when selecting an advisor.

Keywords: doctoral students; self-determination theory; advising relationship; engineering; graduate education

Although K-12 engineering outreach commonly involves college students, the young professionals who act as ambassadors for their field are less likely to be studied than the students they serve. Yet, outreach activities may offer opportunities for undergraduate students to develop aspects of their professional selves. As there is currently no comprehensive measure that allows researchers, program evaluators, and outreach advisors to examine ambassadors' professional development and growth, this study sought to develop and validate an Ambassador Questionnaire (AQ). The multi-step process included the selection and adaptation of items from extant measures of engineering students' motivation, beliefs, professional skills, and perceptions of ambassador training. After an expert panel evaluated the initial group of items, the 57-item AQ was completed by a diverse group of 350 undergraduate engineering students engaged in ambassadorship. Exploratory and confirmatory factor analyses were used to examine construct validity, and internal consistency reliability analyses followed. The findings indicated a five-factor model that accounted for 53% of the variance and demonstrated strong internal consistency reliability. Potential uses for the measure are discussed.

Keywords: K-12 STEM outreach; undergraduate students; engineering ambassadors; program evaluation; engineering identity

The concept of transformational leadership skills (TLS) has gained the attention of educators. However, it is still unclear how TLS influences students' learning outcomes, particularly as a means of performance measurement in a multidisciplinary team environment. This research improves the pedagogical designs for collaborative teamwork by the design of the framework of TLS. The primary contribution of this study is the structured assessment framework that coordinates the key mechanisms and supports instructional strategies for multidisciplinary teams. Additional outcomes also include the selection guidance of teaching contents and coordination policy for working with student teams. To verify this pedagogical design of innovative teamwork architecture for team-based learning (TBL), we collected and analyzed the performances of 307 students on 104 comprehensive course projects over five consecutive academic years of face-to-face teaching (2013–2018) using students' curricular experiences and questionnaires. This study found that a curricular emphasis on the engagement of all members in the TBL significantly contributed to their continuing professional development. Furthermore, students believed that team planning and readiness assurance were critical to teamwork. After the comparison to the data collected from a different group of engineering students using the same questionnaire, individual preparation and communication skills were proved to be significantly and positively improved by the TLS deployment. Future research should analyze the influencing factors of the students with low motivation in TBL and possible variations of TLS implementations.

Keywords: leadership; team-based learning; pedagogical design; structural equation modeling; systematic factor analysis

The current rapid technological advancements and the dynamic workplace environments call for engineering graduates to be equipped with a combination of interdisciplinary skills. Among the core skills for the engineering profession is problem-solving. Although industry professionals and academics consider problem-solving an essential attribute of engineers in industry 4.0, research shows that several engineering graduates are not adequately equipped to apply the problem-solving approach in workplace environments. During the past years, the most common approach referred to in the literature for enhancing problem-solving skills in engineering education is Problem-Based Learning (PBL). While research reported that PBL could improve students' skills in the early stage of higher education or within their degree programmes, most engineers generally accept that graduates will "really" learn how to be an engineer at the workplace. This paper reports on the methodological process of designing and developing a postgraduate vocational training programme to enhance engineering graduates' problem-solving skills through PBL. Specifically, it aims to investigate the programme's impact on engineering graduates' problem-solving skills and their perceptions about the PBL experience. A mixed-methods study was applied to answer the research questions. The Problem-Solving Inventory (PSI) was used to collect quantitative data regarding engineering graduates' problem-solving skills and semi-structured interviews were used to gather qualitative data regarding the implementation of the PBL programme. The results showed that the programme was successful in developing engineering graduates' problem-solving skills. Furthermore, engineering graduates reported several additional benefits regarding their learning experience. Examples include gaining a deeper understanding of the problem-solving process, developing professional knowledge, and enhancing employability potential. They also referred to various challenges which emerged during the programme, such as the time allocation for the assimilation of new knowledge, the application of problem-solving processes, and the communication with the technical staff in the workplace settings. We hope that this work can open a platform for discussion regarding the engineering curricula and the use of problem-oriented pedagogies toward improving employability and professional skills through industry-academia collaboration.

Keywords: problem-based learning; problem-solving; vocational training; internship; engineering education

Postdoctoral fellows report experiencing misalignment between their expectations and their experiences in postdoctoral training. Little research explores their experiences with less still attempting to identify advisors' expectations of postdoctoral fellows. This research aims to describe the knowledge, skills, and attributes (KSA) advisors/principal investigators expect when postdoctoral fellows begin and the expectations for developing postdoc KSA during the fellowship. Qualitative semi-structured interviews with postdoctoral advisors provide data about the hiring, starting, and development expectations advisors have for postdocs. Axial coding with KSA and abductive analysis identify advisors' KSA expectations. Postdoctoral advisors describe hiring requirements and development expectations that do not clearly align. This misalignment starts postdocs and advisors in a new relationship with already misaligned expectations. Clarified language in hiring requirements and development expectations can help advisors and postdocs begin the fellowship with better-aligned expectations. The research reported here provides language to advisors and postdocs to assist and guide KSA expectations.

Keywords: postdoctoral; mentorship; qualitative; KSA; professional development

With Internet of Things (IoT) becoming ubiquitous, there is an enormous need to train IoT engineers. Owing to multidisciplinary nature of IoT, it is a big challenge to expose engineering students to both theoretical knowledge and practical applications. Firstly, this paper presents an integrated IoT laboratory platform, which allows students to explore all aspects of IoT technology, such as embedded systems, 4G communication, wireless sensor networks (WSNs) and RFID. Then, by combining project-based learning (PBL) with three-phase pedagogy, a three-phase project-based learning (TPPBL) method is proposed to offer students a progressive learning path from understanding IoT knowledge through lectures, to practicing IoT knowledge through experiments, and to creating IoT knowledge based on their own ideas. Since autumn 2020, the proposed TPPBL method using the integrated platform

has been implemented at an IoT course in Central China Normal University. Evaluations of educational results for pre-test (using traditional method) and post-test (using TPPBL) show that the proposed TPPBL has significantly improved students' final grades and self-efficacy, which prepares them for becoming future IoT professionals.

Keywords: Internet of Things (IoT); three-phase pedagogy; project-based learning (PBL); laboratory platform; multidisciplinary; engineering education

Engineering graduate students may form multiple role identities through the many roles they assume in graduate school, including engineer, researcher, educator, and student. The importance of this research is to demonstrate how engineering graduate students identify with and define their multiple academic role identities in order to learn how institutions might better support engineering graduate students' academic goals. Further, examining the variety of role identities of engineering graduate students has implications for increased support for and representation of women and racially minoritized students in engineering, who may face additional barriers to identifying with engineering. An open-ended survey exploring role identities was completed by over 80 engineering graduate students at a southeastern research university. Responses were qualitatively coded and patterns among the codes were used to foreground salient themes. Students identified with the roles of engineer, researcher, and student at similar levels while they identified less with the educator role. Participants most frequently identified with these academic roles through their associated practices. The identification of these defining practices is important due to the demonstrated link between performance and identity. Results highlight that a researcher role identity and the associated practices are especially essential to perceived success in graduate school. Findings suggest that research needs to be integrated throughout an engineering graduate school experience such that engineering graduate students can engage in research from the start of their program.

Keywords: engineering identity; higher education; graduate students; teaching assistants, research assistants

This study aims to develop the talent development strategies in facing industry 4.0 trend for the technical and vocational education (TVE) system. We surveyed data from academic literature and government publication materials and adopted SWOT analysis to reveal the advantages, disadvantages, opportunities, and threats of the TVE system. Taiwan is selected as the case study. A systematic strategy formation procedure is proposed for talent cultivation in the context of Industry 4.0. Based on the TOWS analysis, short-term and long-term strategies of TVE for promoting industry 4.0 are proposed. The outcomes of the present study can be a reference for TVE institutes, industry, and government to facilitate industry 4.0 talent development.

Keywords: educational strategy development; industry 4.0; SWOT analysis; technical and vocational education

Remote Laboratories (RLs) are software and hardware tools that allow students to remotely perform real experiments by means of an online system or platform. They represent an evolution in the learning process by making the execution of real-world experiments accessible for many students at distance. Learning Analytics (LAs), by contrast, is the research area concerned with the collection, measurement, analysis and reporting of data associated with learning and its outcomes. The application of LA to RLs leads to a better understanding and planning of the main teaching and learning processes, and their outcomes. This paper aims at providing a systematic review of the application of learning analytics to remote laboratories, thus building an up-to-date body of knowledge for researchers and professionals interested in the application of digital technologies into the educational context. This research follows a procedure based on three main steps: *planning, conducting, and reporting*. We searched seven STEM (Science, Technology, Engineering and Mathematics) databases with two search queries. The retrieved documents were analyzed under the umbrella of five research questions, and a comprehensive organization and structure of the surveyed literature was proposed. The results obtained showed eight main RL platforms/systems (*NetLab, WebLab-Deusto, Go-Lab, FORGE, Lab4CE, GOLDI, and MOOLs-based*), and four categories of data to be retrieved and analyzed by LA methods. Also, we identified five types of metrics usually used to measure the outcome of the learning process, and five learning outcomes. This paper provided an up-to-date systematic review on the use of learning analytics within the remote lab context. We explored platforms, use cases, data retrieved, performance metrics, analysis methods, and learning outcomes. Among the many conclusions, it is possible to stress that the application of LA to RLs aids in the visualization of the learner's strengths and difficulties during a RL experiment, the automatic evaluation of the experiment, and efficient feedback.

Keywords: educational analytics; remote experimentation; taxonomy; STEM

This study investigates the Swedish engineering students' mathematical self-concept and how it depends on their study habits and beliefs about the nature of mathematics. Our findings show that the students' mathematical self-concept is related to their study habits, but none of the habits alone explains a major part of the variation in the domain- and course-specific self-concept variables contained in our data. Nevertheless, active reading textbooks and discussing one's own solutions to exercises with the teacher(s) of the course are clearly related to a better mathematical self-concept. Similarly, students who think that exact reasoning characterizes the nature of mathematics have a better mathematical self-concept compared to, e.g., students who consider mathematics merely as a toolbox of procedures for solving mathematical problems. In our data, male students have a little better self-concept than female students, e.g., in the domain of interpreting and manipulating mathematical expressions. This may be due to the fact that male students, on average, have a stronger formalism-related orientation to mathematics, whereas female students have stronger scheme- and process-related orientations to mathematics.

Keywords: engineering student; self-concept; study habits; view of mathematics

An advisory board, often called an Industrial Advisory Board or a Board of Advisors, is generally defined as a group of volunteer external experts that support a program's activities. Many ABET-accredited engineering programs use advisory boards to help ensure that Program Educational Objectives meet the needs of program's constituencies. The limited published research on advisory boards suggests that many boards are underutilized. Advisory boards can support programs through the following three fundamental functions: advising, mentoring, and assessing. This work shows how an advisory board can be leveraged to (1) advise by improving the curriculum and enhancing compliance with ABET criteria; (2) mentor by developing students' abilities to recognize ethical and professional responsibilities; and (3) assess by providing feedback on students' design and communication skills.

Keywords: advisory board; ABET; engineering ethics; assessment; capstone; curriculum

This paper details the case-study of incorporating project-based learning through a virtual materials characterization project. This project exposes students to characterization technology, manufacturing processes, data analysis and the application statistical tools. Moreover, by utilizing the project-based learning methodology, students develop skills in teamwork, oral and written communication, and problem solving that do not come from the back-of-the-book. In the present case study, material properties of a pair of failed multipurpose crafting shears labeled as 'stainless' are characterized. The student teams are challenged with identifying the manufacturing process that was used based on the data acquired from metal spectrometer testing, Rockwell C hardness testing, and scanning electron microscope (SEM) imaging of the failure surface of the sample. Based upon the analysis of this data, students are tasked with identifying the type of metal alloy for the crafting shears, the manufacturing process used, and possible root cause of failure. This case study provides a pedagogical framework to bridge concepts of materials science with manufacturing methodology and statistical analysis tools as well as creative thinking and problem-solving skills. By investigating and determining the root cause of failure the students have gained a better understanding of the relationship between manufacturing process, material properties, and product quality. The outcomes could be used directly in an existing course, since all the data have been provided or it could also be adapted for different contexts by replacing the existing data with a new data set.

Keywords: project-based learning; engineering education; distance learning; manufacturing process; materials science; applied statistics

A growing trend in engineering education is to infuse entrepreneurial minded learning (EML) into design-based courses across the curriculum. This educational approach supports students in developing an entrepreneurial mindset by the time they graduate and enter the workforce where such a mindset will be vital for their success. We posit that the infusion of EML in the first year of engineering education sets students on a trajectory to develop an entrepreneurial mindset by graduation, along with enhancing their motivations to succeed in the field and developing their identity as engineers. To investigate the impacts of EML, motivation, and identity, we surveyed first- and fourth-/fifth-year engineering students across five different institutions representing variation in academic setting, approach to EML, and maturity of their EML program. Through our multi-method analysis, we did not find evidence of major differences across the five institutions as we anticipated. However, we found noteworthy differences in the impact of one particular program at one site compared to the other sites, including higher average scores for all EML student outcomes at this site. We also found differences between male and female students and students in different educational years. We observed a positive relationship between EML and motivation across all sites. Based on our analysis, we believe the practice of using EML in engineering education holds promise for supporting students' success as engineers in the field. However, additional research into the nuances of EML experiences is needed to identify what makes them successful as our work did not show as many unique findings across sites as were anticipated. We attribute the lack of patterns to the variability between and within site EML implementation.

Keywords: entrepreneurial minded learning; identity; motivation; engineering

Since the formal accession to the Washington Accord, the cultivation of the ability to solve complex engineering problems has become the focus of China's undergraduate engineering education. Because complex engineering problems are innovative, it is necessary to study the effect of TRIZ teaching on the cultivation of the ability to solve complex engineering problems. However, there are few studies on the effect of TRIZ on the cultivation of ability to solve complex engineering problems. Taking China's civil engineering major as an example, based on the network questionnaire, this paper investigates the ability of 1532 junior and senior students to solve complex engineering problems at four universities. The findings were that the ability of the surveyed students to solve complex engineering problems needs to be improved, especially their ability in the areas of engineering design, problem identification and problem analysis. At present, the cultivation of systematic thinking in China's engineering education is also inadequate. Normative research, course teaching and graduation design were used to verify the effectiveness of TRIZ in training Chinese civil engineering students' ability to solve complex engineering problems. Based on the text analysis of students' course reports and graduation designs, combined with the results of students' self-assessment questionnaires and TRIZ expert interviews, the results indicate that TRIZ can effectively cultivate students' ability to solve complex engineering problems, especially problem identification, problem analysis and innovative thinking. This paper provides guidance for further exploring the cultivation of the ability to solve complex engineering problems and for the integration of innovative methods and professional education.

Keywords: engineering students; ability to solve complex engineering problems; TRIZ method; normative research; course teaching; graduation design

Project-based Learning (PBL) has been widely adopted in engineering education considering its proved usefulness for improving students' multiple skills and their academic progress. Prior research suggested that participation in PBL could benefit students' development of self-regulated learning. Nevertheless, how self-regulated learning was demonstrated and improved in PBL activities, and the relationship between students' self-regulated learning and PBL activities both remain unclear. In this research, the goal was to understand what students' lived experiences of self-regulated learning are in PBL activities. Together, a group of twenty-one engineering students were recruited for one-on-one semi-structured interviews. They were from a first-year *Introduction to Engineering* course from a leading Chinese university. The course was structured around PBL activities. The interviews and the follow-up qualitative analyses were guided by a theoretical framework of self-regulated learning that consists of three dimensions, that is, Motivation/Emotion, Learning strategies and Learning Context. The qualitative analyses suggested that students' perception of project difficulty and project values, and students' self-efficacy can go through a dynamic change in PBL activities. Also, students demonstrated a variety of self-regulated learning strategies in this process. Moreover, students' motivations/emotions, specific learning strategies and their perceptions of learning context are closely associated and could affect each other in the PBL learning activities.

Keywords: self-regulated learning; project-based learning; engineering students

This study examines the effects of using a gamification tool as a teaching strategy. Specifically, *Kahoot*! is evaluated as a tool for enhancing student learning. The activities were part of the laboratory sessions of the subject Mechanism and Machine Theory during two consecutive academic years. We analyze the effect of a gamification learning system on both, students' grades and motivation, in a course with a large number of students (n_1 = 283 students, n_2 = 306 students). The students were divided into three different groups (control group, gamification group and writing group) and their results were evaluated depending on the learning method applied during the class. In terms of gamification, this project introduces real-time feedback to stimulate the interest of students and help them use the typical tools and methodologies of game-based learning. The analysis of their performance in the laboratory exam shows significant differences between the group that used gamification and the groups that did not. The results suggest that gamification in engineering lab activities has a positive effect on students' motivation and learning outcome. The study concludes that game-based elements and competitive activities enhanced student performance.

Keywords: gamification; game-based learning; higher education; mechanical engineering

We explored whether a project-based approach and experiential-learning activity would improve learning of complex concepts related to concrete manufacturing in the workplace. We designed a group-based laboratory activity, followed by student-peer teaching and marking and a final report writing task, based on the job of a concrete technician/engineer in a concrete production plant. An action research approach was used to assess student satisfaction (N = 269), their perception of the learning experience, and the impact on their grades. There were four data sources: Observations made by lecturers and TAs, standardised student evaluations, a targeted survey, and course grades. We correlated measures of student peer-teaching with academic output.

Students were satisfied overall with the activity and their perceptions of experiential-learning were positive. The student peer-teaching activity needs improvements. Despite extra online-learning resources provided to compensate for Covid disruptions, students were more satisfied with the in-person activity than with the on-line counterpart. Our positive results suggest that student learning about concrete manufacturing improves when complex theory is integrated with practical learning activities using a project-based approach. We will further modify and integrate learning activities based on these results in our new multi-disciplinary learning spaces.

Keywords: active learning; project-based learning; problem-based learning; peer-learning; peer-teaching; experiential learning; laboratory learning; Covid disruption; concrete manufacturing; student feedback; student survey

Industry 4.0 represents the digital transformation of industrial production, characterized by intense automation and digitalization of manufacturing and management processes, bringing new technologies such as Big Data Analytics, Industrial Internet of Things, Cloud Computing, and Additive Manufacturing. This transformation changes how processes are organized, demanding a new profile of engineers. This article presents a survey with professors of undergraduate courses in Industrial Engineering about the inclusion of i4.0 technologies in these courses. The research is guided by five questions about the importance, maturity, challenges, strategies, and impacts of these technologies in Industrial Engineering courses. A total of 95 professors responded to the survey, representing 17.9% of the total number of invited professors. The results show that, although most of these technologies are considered necessary for the new profile of the industrial engineer, the degree of maturity in teaching these technologies, in most cases, is still in the early stages of adoption. In addition, challenges related to capacity, infrastructure, and resources need to be overcome for successful innovation. In this sense, some strategies were pointed out in the survey. An evident limitation of the work is that it reflects the reality of a given country, which also presents significant regional differences. An extension of the present work would be to replicate and compare the results of this survey with those of other countries at different stages of Industry 4.0.

Keywords: industry 4.0; enabling technologies; industrial engineering; engineering education