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Contents

Contributions in: Conceptual Understanding, Engineering Design, Emotions, Student Perception, Student Veteran, Educational Technology, Capstone Design, Personality Traits, Aquaponics, Persistence, Classroom Engagement, Emotional Intelligence, Female Students, Building Information Modelling, Enrollment Patterns, Retention, Motivation, Engineer Identity, Gender Differences, Quality Function, Capstone Courses, Team Estimation Game, Cost Analysis, Verbal Feedback, Gateway Courses, Tutoring Systems, Teaching Quality, Collaborative Projects, Self-Study Platforms

Circuit concepts are abstract in nature and have been proven to be difficult for students to understand. Instructors often rely on the use of analogies and metaphors to help students associate what is being taught with their prior knowledge or experiences. This study was guided by the following research questions: (1) What types of analogies and metaphors do students use to explain basic circuit concepts? and (2) What characteristics of *constructive analogies* are most common in electrical engineering students' discussion of circuit concepts? A think aloud protocol consisting of conceptual questions about circuits was used to interview nine participants who were juniors or seniors majoring in electrical engineering at a selective public university in the Western United States. The protocol was initially developed to assess students' misconceptions about introductory circuit concepts. However, a second round of analysis indicated students spontaneously used analogies and metaphors in their discussion of these concepts. The students' use of analogies and metaphors also highlighted lingering common misconceptions about the nature of current and the faulty interchangeability of voltage and current. Additionally, the most common characteristic of analogies used by the students was the basic surface comparison of features between the base and target concept. These findings support the use of the teaching with analogies (TWA) model and can inform instructional strategies used in circuit courses where students are exposed to the concept for the first time. This work also highlights implications for current and future instructors of introductory circuit concepts.

Keywords: analogies and metaphors in instruction; conceptual understanding; circuits; scientific models

Little is known about the impact self-efficacy and topic emotions have on novice engineering students when first exposed to an engineering design course. Freshman students may have difficulties regulating their emotions when exposed to new or complex topics such as engineering design. Consequently, they may become frustrated or discouraged as the semester progresses that can lead to feelings of hopelessness and anxiety. In contrast, novice students may experience feelings of hope and interest that may foster positive learning outcomes in engineering design. The authors explored freshmen engineering students' (n = 58) levels of self-efficacy and topic emotions while participating on a freshmen-level engineering and graphics design course. Our findings suggests that while positive and negative topic emotions are inversely related, both seem to be associated with self-efficacy. Further, topic emotions appear to mediate self-efficacy as topic emotions such as curiosity, happiness, and interest were reported by engineering students during engineering design activities. Self-efficacy increased over the course of the semester for these freshman engineering design students.

Keywords: engineering design; self-efficacy; topic emotions

Research on the implementation of case studies in engineering has suggested that students find that cases allow them to see the relevance of engineering concepts to real world issues. Research has also found that students do not perceive cases to be beneficial to their learning while actual learning outcomes suggest otherwise. The goal of this study was to examine the relationship between students' perceptions of their learning confidence and engagement with their actual learning performance for case-based instruction and traditional lecture-based approaches. Thirty-five students enrolled in an undergraduate engineering course participated in the study. The study utilized a within subjects A-B-A-B experimental design with traditional lecture as the baseline condition and case-based instruction as the experimental condition. Participants completed a quiz to assess their learning and a survey to measure their perceptions of learning and engagement. Results suggested that students' perceptions about their own learning did not predict their actual learning outcomes while their perceptions of engagement predicted their conceptual understanding. We also found that cases can lead to significantly greater conceptual learning gains as compared to traditional lecture approach; however, case-based instruction does not influence measures of rote learning. Given that prior research on case studies in engineering has primarily focused on using student perceptions as proxies for actual learning outcomes, these results suggest that engineering educators need to be cautious when interpreting student outcomes based on their perceptions. Our results suggest that engineering education researchers should be careful when using student perceptions to assess the impact of curricular innovations.

Keywords: case-based instruction; student learning; student perceptions

Our multi-method qualitative study examined how educational experiences of first-generation student veterans in engineering (FGSVE) in the United States are shaped by their first-generation, engineering, and military identities. Our study explores the extent to which FGSVEs' first-generation identities are central to the FGSVEs, as compared to their military and engineering identities. We also investigate how these identities are related to one another and whether they influence the FGSVEs' engineering education experiences. Our qualitative data were derived from 15 in-depth interviews of FGSVEs conducted at four institutions in Fall 2016 and Spring 2017. Our case studies of four of these FGSVEs reflect several themes pertaining to identity salience, including: "The military was a bridge beyond first-generation status and into engineering;" "The military provided access to higher education and an engineering career will provide financial security;" "There is a dissonance between my first-generation, engineering, and military identities;" and "The military was both a detour and a necessary pathway into engineering education." The results reveal that the FGSVEs' engineering and military identities were more central to their current experiences in engineering education than their first-generation status. All of these identities, however, were a source of pride in that the FGSVEs felt a sense of accomplishment for serving in the military, pursuing a college degree, and succeeding in a challenging major like engineering. For these students, their military service and engineering pursuits both offered promise for upward mobility. The results have implications for the design and implementation of programs for first-generation students in engineering and for student veterans in general.

Keywords: engineering education; first-generation student; identity; student veteran

Project Oriented Learning in Mechatronics courses curricula is a key aspect in the teaching-learning process. In addition, graduated engineers with competences in design and implementation of renewable energy systems are in strong demand by today's society. This paper presents a solar tracking system test-bench used to track the path of the sun and to redirect the solar beams to a specific point. The system is composed by an electromechanical plant and a control system implemented in National Instruments LabVIEW IDE. Such system is proposed to carry out a project in mechatronics engineering curricula for introducing undergraduate engineering students to mechatronics design and prototype implementation in the context of actual renewable energies. This proposal aims to develop students' competencies oriented to the design, implementation and validation of mechatronic systems. The experimental platform would allow the teacher to complement theoretical aspects, whereas students would learn in a challenging environment where they would generate a complex prototype focused to solve a current world problem.

Keywords: educational technology; mechatronics; motion control; solar energy

Effective frameworks for the assessment of student outcomes are vital to the success of a technical higher-education program. While ensuring the accuracy of the student outcomes assessment usually translates to employing complicated setups, thoughtful abstraction can lead to the desired reliability of assessment with great simplicity. In this paper, a minimalistic framework for the assessment of student outcomes is proposed. The proposed framework is based on senior design experiences of undergraduate computer engineering students. Senior design experiences provide unique opportunities for students to demonstrate their abilities, skills, and experiences that are attained throughout a Bachelor of Engineering program. The proposed framework is based on capstone design projects and a selection of senior design courses of complementary nature. The learning outcomes of the proposed selection of courses are carefully designed to map to all student outcomes. The proposed minimalistic assessment framework leads to results that are only marginally different from those based on a large bouquet of courses ranging from sophomore to senior years of study and thus demonstrates its reliability. The effectiveness of the proposed framework is supported by evaluative and comparative statistical analysis of student outcomes assessments within a multi-year case-study.

Keywords: capstone design projects; senior courses; embedded system design; signal processing; assessment; programmatic accreditation

The purpose of this study was to explore whether and to what extent general personality traits based on the Big Five model correlate with and explain unique variance of academic success among undergraduate civil engineering students. In total, 151 college civil and environmental engineering students completed the 240-item NEO Personality Inventory-3 (NEO-PI-3) and released their GPA and SAT scores. We conducted analyses of descriptive statistics, correlation, and hierarchical regression using the IBM statistics software SPSS Version 21. Neuroticism (positively), Extraversion (negatively), and Agreeableness (negatively) were significantly correlated with current term GPA. Neuroticism (positively) and Agreeableness (negatively) were significantly correlated with cumulative GPA. Conscientiousness explained unique variance in the cumulative GPA. The findings from this research indicate that the Big Five personality traits are a significant predictor of academic achievement of engineering students. The results highlight the importance of examining non-academic factors in explaining variance in academic achievement of engineering students.

Keywords: general personality traits; big five model; college engineering students; academic achievement

Practical work is an important part of the educational process. In this paper the requirements, hardware and software architecture development and the implementation of an aquaponics embedded device (laboratory model SmartVegeTech) are presented. This system has the possibilities of remote control, rich user interface and other features. The SmartVegeTech system could be used in education in different engineering fields such as control engineering, process engineering, software engineering, as well as agricultural engineering. The educational tasks in control engineering as well as initial feed back from students will be presented.

Keywords: aquaponics; remote control; control engineering; process engineering; software engineering; agricultural engineering; education

Matthew Meyer and **Ning Fang**   99–108   A Qualitative Case Study of Persistence of Engineering Undergraduates

Recent years have seen a surging need for engineering undergraduates, as many countries have looked to such a group to spur economic growth and compete internationally. However, the retention rate of engineering undergraduates has been a long-standing issue in the United States. Most often, literature provides aggregate results about student retention, but does not describe in sufficient detail how individual students make their decisions to leave or stay in engineering. This paper contains a qualitative case study of persistence of engineering undergraduates by describing the detailed narratives of five study participants who recently dropped out of engineering programs at a large, public research university in the Mountain West region of the USA. Each participant had different family backgrounds and varying experiences within engineering and education. Common themes expressed among the five participants included: a loss of connection and interest in engineering, and experiencing barrier courses that challenged them academically. Participants urged future engineering students to understand the high level of commitment necessary to make it through the academically rigorous undergraduate engineering program before starting.
Keywords: persistence; engineering undergraduates; qualitative case study

Ryan Falkenstein-Smith, Jeongmin Ahn   109–118   Reinvigorating Classroom Engagement and Performance in an Advanced
and **Ryan J. Milcarek**   Energy Systems Course

Today, the technology landscape is at a highly competitive playing field forcing companies to seek engineers who can provide the upper hand over others through innovative thinking. This study presents a Fuel Cell Science and Technology course focused on encouraging innovative thinking by adopting a T-shaped philosophy through the principles of incorporating greater perspectives, active learning environments, and practical lectures into the classroom. The course was offered for two years in which 67 undergraduate and graduate students were enrolled. During that time, student performance and engagement was monitored using standard course evaluations, anonymous surveys, and classroom observations. Course evaluations and survey results found that all participating students were able to demonstrate a deep understanding of the course content. A discrepancy between undergraduate and graduate students' survey responses were also observed, possibly suggesting a difference in student engagement based on student background.
Keywords: T-shape philosophy; innovative course curriculum; advanced energy course

Ali Rizwan, Hemaid Alsulami, Nabilah   119–125   Impact of Emotional Intelligence on the Academic Performance and
Elnahas, Maha Bashir, Fatema Bawareth,   Employability of Female Engineering Students in Saudi Arabia
Rawan Kamrani and **Razan Noorelahi**

Present study aims to investigate the impact of emotional intelligence (EI) on academic performance and employability of female engineering students in Saudi Arabia. Data were collected from 50 industrial employers and 300 female students of varied engineering disciplines. Academic performance was assessed using cumulative grade point average of the students, while EI was assessed with the help of a structured questionnaire comprising 24 questions divided into four categories. Findings of the study revealed a strong relationship between EI and the academic performance of students with less variation between fresh and senior students. However, significant variation in EI was observed among students of different engineering disciplines. In addition, the employability chances of female engineering students were found to be around 60% based on an analytical equation, which was derived with the help of inputs from industrial employers. Findings clearly indicate a strong impact of EI on the academic performance as well as future employability of these students.
Keywords: emotional intelligence; academic performance; employability; female engineering students; Saudi Arabia

Joosung Lee, Byeol Kim and **Yonghan Ahn**   126–141   Building Information Modeling (BIM) Technology Education for the
                                                                Needs of Industry in Developing Countries

Building Information Modeling (BIM) technology is now globally accepted as a means of creating a knowledge-based construction industry that uses 3D (or more) visualization and simulation techniques to improve business efficiency. However, developing South Asian countries such as Vietnam, Malaysia, and the Philippines have yet to introduce BIM technology, largely due to a lack of appropriately trained professionals. Many countries need to develop the necessary environment and curriculum to teach BIM-related knowledge and skills and thus produce skilled construction professionals capable of implementing this technology. Using a systematic course approach, we developed a BIM course that was specifically designed to address the needs of both those entering the profession and construction companies in developing countries. In addition to understanding the applicability of BIM for construction projects, newly qualified professionals will appreciate the advantages and prospects of Integrated Project Delivery (IPD) systems and BIM technology, as well as the importance of cooperation. The new course will support the development of accomplished professionals with the BIM skills needed by construction companies in today's competitive market.
Keywords: building information modeling; BIM training; systematic course development approach; South Korea

David Reeping, David B. Knight, Jacob R.   142–155   Visualization and Analysis of Student Enrollment Patterns in Foundational
Grohs and **Scott W. Case**   Engineering Courses

The literature in engineering education and higher education has examined the implications of course-taking patterns on student development and success. However, little work has analyzed the trajectories of students who need to retake courses in the curriculum, especially those deemed to be fundamental to a student's program of study, or sequences of courses. Sequence analysis in R was used to leverage historical transcript data from institutional research at a large, public, Land-Grant university to visualize student trajectories within individual courses—with attention to those who re-enrolled in courses—and the pathways students took through a sequence of courses. This investigation considered students enrolled in introductory mechanics courses that are foundational for several engineering majors: Statics, Dynamics, and Strength of Materials (also called Mechanics of Deformable Bodies). This paper presents alluvial diagrams of the course-taking sequences and transition matrices for the different possible grades received upon subsequent attempts for the Mechanics core courses to demonstrate how visualizing students' paths through sequences of classes by leveraging institutional data can identify patterns that might warrant programs to reconsider their curricular policies.
Keywords: archival data; course-taking patterns; gatekeeper courses

Lorenzo Salas-Morera, M.ª Antonia Cejas-   156–167   Factors Affecting Engineering Students Dropout: A Case Study
Molina, José L. Olivares-Olmedilla, Laura
García-Hernández and **Juan M. Palomo-**
Romero

Engineering professions have a high demand in the global labor market but, in spite of this, there are high dropout rates and low graduation rates specially in engineering and STEM in general all over the world. A research has been conducted in the Polytechnic School of Córdoba University (Spain) to determinate the reasons for engineering degree dropouts using data from a quantitative and qualitative survey (n = 315) and analyzing the behavior of students during a period of one year. A set of causes of dropout and attrition has been identified, including students' lack of motivation, bad planning of the course by the students, high level of the course's starting point, syllabus too long, too many targeted activities, exams too difficult, inadequate class timetables, and inadequate examinations calendars, as a consequence a set of measures to improve the situation has been proposed.
Keywords: engineering dropout; students retention; students motivation; outreach; tutoring

Researchers theorize that commitment to a college major is supported when there is alignment between career values and perceptions of a career field's value affordances. Research shows substantial gender differences in occupational values and interests, where women are more likely to prefer communal occupations, which may cause misalignment when engineering is seen as only affording the pursuit of status values. The goal of this study was to explore the relationship between first-year engineering students' career values, their perceptions of engineering as a career field that meets different career values, and how this relationship affects major commitment. Using a pre/post-survey design, we explored whether engineering students (N = 996) varied in their perception of engineering as a communal vs. status profession, comparing male/female and underrepresented/other racial groups. We also explored how perceptions and career values predicted commitment to their engineering major. We found variability in perceptions of the affordances of engineering but no group differences, which suggests this is an individual difference that may influence perceptions of career fit. Predictions of major commitment revealed complex relationships between affordance beliefs, career values, and commitment to staying in an engineering major.

Keywords: engineer identity; occupational value; perceptions of engineering; gender differences; underrepresented minorities

This paper considers ways to increase service quality levels at engineering programs and actions to be taken for accomplishing this. The aim of this paper is to develop and implement a Quality Function Deployment (QFD) model for engineering programs in Turkey. The research determines the most important technical requirements based on considering Voice of the Student (VOS), which is measured with a Service Quality (SERVQUAL) application-based measurement model. The students' responses to SERVQUAL survey are considered by a group decision-making approach. Group decision-making approach is used to attach importance to the ideas of students. The Choquet integral as an aggregation operator is used firstly for aggregating the weights of each response in order to determine the weight of each dimension of SERVQUAL application and secondly for aggregating the SERVQUAL weights and relationship matrix. Finally key factors for increasing qualified and sustainable education are proposed.

Keywords: fuzzy quality function deployment; choquet integral; large column large row (LCLR); voice of student (VOS); SERVQUAL

Effort estimation is a crucial part of software development projects. Despite the availability of several assessment techniques, accurate assessment still remains an extremely difficult task. Team Estimation Game is a relatively new estimation technique for agile software development methods that has not received significant attention from the scientific community despite its growing popularity between practitioners. In this paper, we attempt to bridge this gap by presenting the results of an empirical study with undergraduate students in which we compare Team Estimation Game with the more established Planning Poker technique. We mainly focus our analysis of the two techniques on the time needed for user story estimation and estimation accuracy. The results of the empirical study reveal that Team Estimation Game produces more accurate story estimates than Planning Poker. Additionally, we found that for the Team Estimation Game, estimation and planning skills of the development teams improve from Sprint to Sprint. Team Estimation Game proved to be a useful estimation method for agile projects within the capstone course. Furthermore, we have shown that the study can be successfully incorporated into a software engineering capstone course without hindering the teaching goals while retaining the validity of research goals.

Keywords: empirical study; capstone course; agile software development; scrum; planning poker; team estimation game

Many experiences in engineering education boast positive gains to students' learning and achievement. However, current literature is less clear on the economic costs associated with these efforts, or methods for performing said analyses. To address this gap, we proposed a structured approach to analyzing the incremental costs associated with an experience in engineering education. This method was modeled after those found in medicine and early childhood education. We illustrated our methodology using marginal (above baseline) time and cost ingredients that were collected during the *development*, *pilot*, and *steady-state* phases of a mechatronic experience in a first-year undergraduate engineering technology course. Specifically, our method included descriptive analysis, Pareto analysis, and cost per capacity estimate analysis, the latter of which has received limited discussion in current cost analysis literature. The purpose of our illustrated explanation was to provide a clear method for incremental cost analyses of experiences in engineering education. We found that the *development*, *pilot*, and *steady-state* phases cost just over \$17.1k (∼\$12.4k for personnel and ∼\$4.7k for equipment), based on 2015 US\$ and an enrollment capacity of 121 students. Cost vs. capacity scaled at a factor of –0.64 ($y = 3,121x^{-0.64}$, $R^2 = 0.99$), which was within the 95% interval for personnel and capital commonly observed in the chemical processing industry. Based on a four-year operational life and a range of 20–400 students per year, we estimated per seat total costs to range from roughly \$70–\$470, with our mechatronic experience averaging just under \$150 per seat. Notably, the *development* phase cost, as well as the robot chassis and microcontroller capital cost were the primary cost terms of this intervention.

Keywords: incremental cost analysis; cost-effectiveness analysis; cost ingredients

Recent implementations of design review meetings in engineering design courses encourage student peers to provide feedback, in addition to the course instructor and industry client. The purpose of this investigation was to compare feedback provided by students and course instructors and to determine how student peers' feedback related to their own performance in the design course. We collected verbal feedback comments provided by the instructor and student peers in twelve design review meetings of a management engineering capstone design course. A total of 553 comments were coded along two dimensions: topic (design, project management, or communication) and function (comprehension, evaluation, or recommendation). Comments falling in the comprehension function were also further coded using an existing question-type typology. A comparison of instructor and student feedback revealed that the instructor provided not only more feedback than individual students, but also distributed it better across the different topics and functions. Specifically, the instructor provides more feedback in the topics of design, communication and project management and is more likely to provide direct assessments and recommendations to student teams. Stronger student teams (i.e., those with better design outcomes) generally provide more feedback to their peers. Findings can help instructors promote better feedback-giving for themselves and students alike.

Keywords: instructor feedback; peer feedback; engineering design; capstone projects

So Yoon Yoon, P. K. Imbrie, Teri Reed and **Kristi J. Shryock** Identification of the Engineering Gateway Subjects in the Second-Year Engineering Common Curriculum

With increased improvements in retention after the first-year engineering (FYE) experience, the next largest hurdle is the second year, also known as sophomore slump, where there can be even larger losses than in the first-year. Considering attrition when students have an unsatisfactory grade in an engineering gateway course, poor performance in the gateway subjects may cause slump of the sophomores, resulting in many leaving engineering. This study attempted to identify engineering gateway courses as part of the seven second-year engineering (SYE) common subjects (i.e., Multivariate Calculus, Differential Equations, Statics/Dynamics, Materials, Solid Mechanics, Thermodynamics, and Electric Circuits), while providing a holistic view of engineering student performance in the SYE common subjects. At a southwest public university, course performance and graduation status of 1,581 engineering students who were admitted in 2006 and attempted to take at least one course of the seven SYE common subjects were tracked for 8.5 years. Descriptive statistics were applied to identify trends in students' performance in the common subjects and individual courses, followed by subgroup analyses using inferential statistics. Among the seven subjects, Multivariate Calculus was the engineering gateway subject with the highest failure rate, followed by Differential Equations and Statics/Dynamics. Materials had the lowest failure rate. Student performance varied by gender, race/ethnicity, residence, and admission type. As an exploratory study, the findings of this study will enable engineering faculty to consider ways to improve student performance in the SYE gateway subjects, which will hopefully ease sophomore slump and facilitate junior jump.

Keywords: sophomore engineering students; sophomore common subjects; engineering gateway courses

Qinbo Li and **Sheng-Jen Hsieh**   An Intelligent Tutoring System for Computer Numerical Control Programming

G-code is the language used to control computer numerical control (CNC) machines. Although most CAD/CAM software can generate G-code based on a design and machine tools needed, the ability to understand G-code is valuable, especially when a machining job does not run smoothly. Intelligent tutoring systems (ITS) have been shown to be successful in helping students to learn programming. However, G-code is different from general purpose computer programming languages. CNC programming also requires that students master many hardware-related facts and concepts, such as cutting speed and feed rate, and tools for several types of drilling. We built a web-based ITS for CNC programming called CNC-Tutor, and proposed a data-driven approach to generate proper hints and feedback during students' problem-solving process. The approach is based on finding past submissions that are most similar to a student's solution. The similarity is measured using a "behavior & machine state distance" metric. The system was evaluated by 93 undergraduate students. Results suggest that the design is instructionally effective, and that students' subjective impressions of the system were positive. It also appears that CNC Tutor's explanations and feedback are a good fit for active, visual learners.

Keywords: intelligent tutoring system; computer integrated manufacturing; mechanical engineering

Abdelhakim Abdelhadi and **Mohammad Nurunnabi**   Engineering Student Evaluation of Teaching Quality in Saudi Arabia

Prior research suggests that student evaluation systems are a valuable aid to effective teaching quality. Research on student evaluations of teaching (SET) in engineering programme is somewhat lacking in the Middle East, particularly in Saudi Arabia. This study therefore focuses on the factors that influence engineering students' evaluations of teaching. A survey of 63 students from an engineering programme was carried out. Multivariate statistical analysis was used to group students into clusters based on the closeness of their decisions in rating instructors according to selected factors. Using Vroom's model of "expectancy theory" to investigate students' decision-making processes with regard to "improving teaching" or "improving the course format", the study reveals that meeting students' needs in the classroom appears to be an important factor when evaluating instructors at the end of the semester. In addition, the study suggests that instructors should not average or compare the average of student scores when considering the results of SET surveys. The findings also suggest that instructors should use a balanced approach in the classroom, paying attention to a range of factors in order to improve their overall teaching performance. In an attempt to raise awareness of SET, several implications are drawn out, and some directions for future research are suggested.

Keywords: student evaluations of teaching (SET); expectancy theory; multivariate statistical analysis; Saudi Arabia

José Miguel Blanco, César Domínguez, Ana Sánchez, Arturo Jaime and **Jónathan Heras**   Managing Telecollaboration among Engineering Students and Faculty: A Case Study from Two Spanish Universities

In today's globalized world, it seems important that students can telecollaborate in a team by making effective use of information and communication technologies. This collaboration format can positively influence their academic performance, enhance engineering student interest in the subject, and improve skills such as communication and teamwork. In this work a collaboration model between engineering students, and also between instructors, from two distant traditional universities is presented and analyzed. Potentialities, challenges and key elements for a viable experience are identified, that would be capable of achieving the proposed objectives, and sustainable over time. Considering these activities as projects, instructors are actively involved in the initiation, planning, monitoring and controlling, and closing of these activities. On the other hand, students are those who must perform scheduled tasks. This article identifies the difficulties and potentials for each of these roles.

Keywords: cooperative/collaborative projects; traditional universities; information and communications technology tools; telecollaboration, engineering education

David Baneres and **Robert Clarisó**   Evaluation of a New Self-Study Platform for Introductory Digital Systems

Most Bachelor programs in Computer and Electrical Engineering include an introductory course on the foundations of digital system design, e.g., combinational and sequential circuits. In this course, students have many difficulties understanding core concepts such as Boolean function minimization or circuit analysis. A potential remedy to these difficulties is self-assessment with automatic feedback, which can facilitate the acquisition of digital system design competences by allowing students to experiment with a large collection of exercises and quickly realize their mistakes. This paper aims to evaluate how an educational software tool with self-assessment features capable of providing feedback with different levels of granularity can help students acquire these core concepts. To this end, a tutoring tool to promote the acquisition of Boolean function minimization and circuit analysis skills has been implemented. Next, a quantitative and qualitative analysis on its use has been performed. Evidence shows that the self-assessment tutor has a positive impact on academic performance during the semesters under analysis. Additionally, survey responses show a high degree of acceptance and satisfaction with the tutoring tool.

Keywords: digital circuits; electrical engineering education; educational technology; automatic assessment