

# The International Journal of Engineering Education

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Previous research has shown that teamwork between students underpins the communication interactions among team members, and these interactions are underscored in the work environment, job quality, work outcome and, of course, grades. Analysing the interactions among the members of a team using a learning analytics system allows for a formative evaluation that indicates the progress of each team member and taking remedial actions if appropriate progress has not been made. This paper uses a learning analytics system to study interactions between students and detect the values and attitudes demanded of a leader by society. The results of this analysis are keys for avoiding corruption and wrong practices and can even provide a solution to global intercultural troubles. In this study, a validated questionnaire of authentic leadership was given to 78 team members in a university context; the influence of some values and attitudes on leadership is proved with grades; and a learning analytics system was used to analyse information that could predict a leader's behaviour during the development of teamwork.

**Keywords:** authentic leadership; teamwork; learning analytics; flip teaching

<b>Iria Estévez-Ayres, Jesús Arias Fisteus, Lucía Uguina-Gadella, Carlos Alario-Hoyos and Carlos Delgado-Kloos</b>	865–878	Uncovering Flipped-Classroom Problems at an Engineering Course on Systems Architecture Through Data-Driven Learning Design
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Flipped classroom is a student-centered methodology that can help engineering students to acquire the cross-curricular skills demanded by society. However, its effectiveness relies on the commitment of both instructors and students. In particular, this strategy requires students to work on a number of proposed activities before face-to-face classes. Then, in order to follow the most appropriate path in those classes, instructors need a reliable way to know at which degree their students worked on those proposed activities, what issues they encountered while doing them and which concepts need to be reinforced in class. This paper presents a case study of a flipped-classroom undergraduate engineering course. By using data-driven learning design and learning analytics techniques we show that: (1) by delaying their work on the course activities our students actually drove the course towards the traditional approach; (2) despite directly asking students at the beginning of a face-to-face class might seem to be an appropriate way of getting reliable information about their previous work, it may lead instructors to erroneous conclusions; (3) our students were strongly mark- and deadline-oriented, but even a small grade encouraged them to work on the assignments; (4) the gathering and checking of students' learning data before the class can help instructors to tailor the lesson design; and (5) if students did not work on pre-class activities, dedicating a small amount of time of the in-class lesson to explain the most difficult concepts can help students to be more efficient with their work, at the cost of losing some of the spirit of the flipped classroom.

**Keywords:** flipped learning; engineering education; learning analytics; learning design; challenges

<b>Carmen Lacave and Ana I. Molina</b>	879–894	Using Bayesian Networks for Learning Analytics in Engineering Education: A Case Study on Computer Science Dropout at UCLM
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Student dropout in Engineering Education is an important problem which has been studied from different perspectives and using different techniques. This manuscript describes the methodology used to address this question in the context of *learning analytics*, using Bayesian networks because they provide adequate methods for the representation, interpretation and contextualization of data. The proposed approach is illustrated through the case study of the abandonment of Computer Science (CS) studies at the University of Castilla-La Mancha, which is close to 40%. To that end, several Bayesian networks were obtained from a database containing 363 records representing both academic and social data of the students enrolled in the CS degree during four courses. Then, these probabilistic models were interpreted and evaluated. The results obtained revealed that the great heterogeneity of the data studied did not allow to adjust the model accurately. However, the methodology described here can be taken as a reference for other works where a less heterogeneous database could be obtained, aimed at analysing student characteristics from a database.

**Keywords:** Learning analytics; Bayesian networks; Engineering dropout

**Esteban Jove, José Antonio López-Vázquez, María Isabel Fernández-Ibáñez, José-Luis Casteleiro-Roca and José Luis Calvo-Rolle** 895-904 Hybrid Intelligent System to Predict the Individual Academic Performance of Engineering Students

The present research deals with the problem of the low academic performance in engineering degrees. It has been done by analyzing the academic results of students that have attended to the bachelor's degree in industrial engineering. The dataset used was the official registered grades of their academic records in the University of A Coruña. In this work, several advanced regression techniques have been applied to create models of the academic itinerary during each student career. The created models can predict the number of attempts in every subject that the students would take in the first academic year. The attempts of the subjects from the rest of the years can be predicted by incorporating to the model the results of the already passed subjects. The developed model allows to achieve the proposed goal of predicting the academic performance of each student.

**Keywords:** academic performance; SVM; MLP

**Satesh Narayana Namasivayam and Mohammad Hosseini Fouladi** 905-914 Utilisation of Learning Outcome Attainment Data to Drive Continual Quality Improvement of an Engineering Programme: A Case Study of Taylor's University

The current educational model adopted by all accredited engineering Schools (or faculties) in Malaysia follows an Outcome-Based Education (OBE) approach. To support this model, Schools adopt a variety of pedagogical techniques, ranging from traditional lecture-based learning to project-based learning. Learning outcome attainment data are essential in order to understand the impact of Outcome-Based Education and the associated pedagogies on the overall student learning experience. Using these data, a School may decide on how to improve its engineering programmes, as well as how to ensure that the programmes evolve in parallel to the developments within the industry and, more importantly, with the needs of the learners. This study discusses how the utilization of learning outcome attainment data and the tools used to mine them has affected the programme and the overall student learning experience. The study also details out how specific Continual Quality Improvement (CQI) action plans have affected learning outcome attainment, and their impact on pass, retention and graduation rates.

**Keywords:** outcome based education; learning outcomes; continual quality improvement

**Hakan Turan** 915-923 Assessment Factors Affecting E-Learning Using Fuzzy Analytic Hierarchy Process and SWARA

The importance of distance education has increased due to its many advantages. At the same time, apart from university education, distance education also allows oneself to develop in different subjects. This work examines a distance education study conducted at a university in Turkey. The Department of Industrial Engineering was selected for this study. E-learning applications for industrial engineering education are seen to be extremely efficient, especially since they do not require laboratory applications. The Faculty of Engineering, which aims to obtain a higher quality education of students who receive industrial engineering training through e-learning, has evaluated related software companies in this regard. The infrastructure of the program has been determined as online and recorded broadcasting. Web-based training has been carried out by creating wide communication networks. This study explores in detail the necessary requirements for the successful execution of distance education in industrial engineering. In addition, it has benefited from the work undertaken in the past in order to determine the assessment factors. These assessment factors consist of five main factors and twenty-four sub-factors. These assessment factors have been established in line with the opinions of the people who constitute the infrastructure of this study. These past evaluations were usually made subjectively. Subjective evaluations often cause misinterpretation of results. This study applies both analytic hierarchy process (AHP) and step-wise weight assessment ratio analysis (SWARA) methods, both of which are multiple criteria decision-making methods. Consistency ratios are calculated to determine whether comparisons are consistent for the AHP method. In addition, the AHP method is discussed together with fuzzy logic to make the study more realistic. Due to the ease of application and common use, triangular fuzzy numbers are preferred as a fuzzy method. The results are validated by the SWARA method, which is used to weight the criteria. The purpose of this study is to weight the assessment factors affecting e-learning technology by using fuzzy AHP and SWARA methods. Thus, the study illustrates that multi-criteria decision-making methods can be used in e-learning applications to evaluate many factors.

**Keywords:** assessment factors; consistency ratio; e-learning; fuzzy analytical hierarchy process; SWARA

**Enric Peña, David Fonseca, Nuria Martí and José Ferrándiz** 924-939 Relationship between Specific Professional Competences and Learning Activities of the Building and Construction Engineering Degree Final Project

This paper presents a study in the framework of Building and Construction Engineering Degree. The aim of our proposal is to discuss if the academic activities comprising the Final Degree Project (FDP) are corrected, balanced and adapted in order to maximize the acquisition of the competences identified by the professional sector through two rounds of quantitative surveys (data also presented in this paper). Due to the economic and construction crises and the decreasing number of students in this sector, it is essential to ensure that future professionals are trained in a specific way to meet the current needs of the sector. Based on our assumption, the data obtained in the surveys, and the analytic approach of the main academic indicators, we propose new relations and FDP evaluation methods that would align the student's curriculum with the current professional needs. The obtained results reveal the need of changes in the current FDP structure in order to give more importance to certain learning activities identified as essential at the professional level. With our proposal, we will improve the FDP evaluation, and the student competences acquisition, in order to adapt them to the professional needs.

**Keywords:** building engineering studies; academic and professional competences; learning indicators; educational assessment; academic analytics

**Sheila Lucero Sánchez López, Rebeca P. Díaz Redondo and Ana Fernández Vilas** 940-952 Predicting Students' Grade Based on Social and Content Interactions

Predicting students' grades is an interesting task that may be tackled using different information, like the students' learning background or their previous and current performance. However, and with the widely use of the e-learning platforms, the interaction of the students with the platforms constitutes a dynamic, huge, objective and reliable data source. Assuming these interactions reflect the interest, feeling and way of study of each student, our proposal uses this information for the early prediction of their performance (grades). Contrarily to other approaches, we do not use the same data analysis model for all the students, neither their census or learning background data. We previously define a classification scheme of five different profiles, which represent five different ways of learning and face the course. After that, a specifically created data analysis model is defined for each kind of student. The proposal is validated with undergraduate students of a blended-course for 3 consecutive academic years.

**Keywords:** educational data mining; learning analytics; e-learning; engineering education; multiple linear regression

The development of skills in the engineering education is one of the issues that generate greater interest at present. Thanks to Learning Analytics, we found an excellent opportunity to offer a quality competence assessment of our engineering students. Research in Learning Analytics currently focuses on applying these techniques to find out how the student learns and to improve teaching/learning processes. A key aspect in improving these processes is the assessment of general competences, which constitutes key learning in engineering students and has thus been identified as a need that can be met by Learning Analytics. This article presents two related studies conducted at the University of Deusto. The first study wants to show that it is possible to carry out an assessment of the project management competence through the analysis of the data that is obtained when the students interact with certain tools for the management of projects. In this sense, in the first study conducted with 93 students in the academic year 2014–2015, it compares the automatic assessment performed with Learning Analytics and the manual assessment carried out by the teacher. Another objective of this first study is to compare the validity at the time to assess the project management competence of the three technological tools used in the study. In the second study conducted with 227 students in the academic year 2015–2016, an assessment model is designed based on analytical data that is extracted from even more complex technological tools. In this second study the objective is to demonstrate that the use of Learning Analytics assessment to carry out continuous monitoring and provide feedback to the students, directly influences their capacity to manage a project and therefore, leads to an improvement in their results. The model designed in both studies for analysis is described in this paper, in addition to the methodology and research carried out.

**Keywords:** learning analytics; project management; formative assessment; competence assessment; engineering education; self-regulated learning

Peer assessment is a widespread way of evaluating and rating the quality of a work in the field of education. Although it results to be a very effective learning instrument, it is subjected to possible problems of reliability, validity and some potential biases. Most works that study and try to solve these problems are focused on specific cases and the statistics for measuring reliability, validity or bias are global, that is, they give a measure of these values for the whole process, but they do not allow an individual study. In this work the approach is different. It proposes some metrics for reliability and validity of each reviewer, as well as an approximation to the possible biases that may appear in the assessment process, so that the review process can be itself assessed. An analogy between the work of a reviewer in a process of peer assessment and the operation of an automatic classifier is proposed. This has allowed us to leverage the usual measures in evaluating the quality of automatic classifiers to establish the quality of peer assessment. The reviewers are characterized by obtaining their confusion matrices and six new indicators: success rate (which estimates the validity); agreement degree (as a measure of reliability); assessment median and its interquartile range (for the estimation of central tendency and restriction of range biases); and average distance to diagonal and its standard deviation (to determine possible leniency and harshness biases). This method provides indicators of the reviewer's task and the detection of different profiles, so that the teacher can assess the work of the students as reviewers and introduce some correction mechanisms in the final assessment of the works. A practical example of application to an engineering degree is provided to illustrate the potential of the method.

**Keywords:** peer assessment; success rate; agreement degree; reliability; validity; bias; confusion matrix; automatic classification

This paper presents a method to evaluate the learning-teaching process using machine learning techniques and the conclusions drawn in an experience on eight courses of very diverse fields. The method is based on data visualization supported by multidimensional scaling. Students' learning behavior can be visually interpreted from the graphical results obtained with this methodology. This proposal allows to identify learning patterns that might either confirm previous assumptions or expose unknown and unexpected knowledge. Instructors who aim at identifying those factors with larger impact on the learning-teaching impact might be potential users of this approach. The results obtained on 426 students prove the usefulness of these techniques as appealing feedback in order to re-adjust the learning-teaching process in consonance with the actual performance of the students. Specifically, a case study about changing the teaching methodology to Blend-Learning by using a content management system through Moodle is presented.

**Keywords:** machine learning; classification; constructivism; Moodle

In recent years, virtual learning environments, laptops, tablets and mobile devices have been introduced in the classroom. These technologies start a snowball effect: the old tools teachers used to fathom the students' learning progress, since so much happens online, are not enough. Thus, the need for new tools to analyse the students' activity on the online learning environments arises. The field of learning analytics can provide some of these tools. In this paper, we introduce the Student's Progress Snapshot (SPS), a Learning Analytics Dashboard that allows teachers to analyse the activity of their students on Moodle courses. The SPS running as software as a service, includes both charts and automatically generated explanatory texts of these charts. During the academic course 2015–2016 a pilot was conducted to validate the SPS.

**Keywords:** learning analytics; learning management systems; virtual learning environments; moodle; student interactions

The implementation of the Bologna Process has introduced continuous assessment processes, primarily formative assessment, in many Spanish universities. In such kind of scenarios, rubrics provide many benefits that can remarkably be improved using Visual Learning Analytics techniques. This paper presents EvalVis, a system that enhances feedback based on rubric assessment and visual learning analytics. EvalVis provides different visualizations for students and teachers. The visualizations included in EvalVis have been designed upon identification of visualization needs of students and teachers. The system provides students with information about their individual learning process and performance, including the capability to contextualize their information into the group. EvalVis also allows the teaching staff to monitor different groups of students and compare their evolution and performance. The enriched feedback provided by rubrics and visualizations will help users to better understand and improve the learning and assessment processes in order to improve them. EvalVis has been evaluated to check whether it covers the identified needs obtaining very good results.

**Keywords:** formative-assessment; visual learning analytics; rubrics; open learner models

## Section II

# Contributions in: Motivation, Conceptual Knowledge, Project-Based Learning, Innovation, Entrepreneurship, Academic Performance, Design Courses, STEM, Computer Architecture

**Aharon Gero and Gershon Abraham**      1013–1024      Students' Motivation and Academic Achievement: The Case of an Engineering Preparatory Program

Engineering preparatory programs offer applicants who have not attained adequate achievements in their high school studies an opportunity to improve their chances to be accepted to undergraduate engineering programs. This study, which made use of quantitative and qualitative instruments, characterized the motivation for higher education in science and engineering in students attending an engineering preparatory program, and examined the relation between such motivation and the students' academic achievement. The study shows that at the end of the program, the degree of perceived control (coercion) in students who completed the program was significantly lower than that found in all the students at the beginning of the program. This difference was accompanied by a decline in the number of students attending the program. The gap could possibly be accounted for by the explanation that students with a relatively high initial degree of perceived control apparently withdrew from the program, whereas students characterized by a relatively low initial degree of perceived control and who completed the program probably experienced an increase in their degree of relative autonomy. The study shows that the degree of relative autonomy in students completing the program was significantly lower than that measured in outstanding 12th grade students majoring in science and engineering. The study indicates the importance of autonomous motivation in engineering preparatory programs by showing positive correlation between the Relative Autonomy Index and the students' academic achievement.

**Keywords:** engineering preparatory programs; motivation; academic achievement

**Mary Katherine Watson, Elise Barrella and Joshua Pelkey**      1025–1037      Assessment of Conceptual Knowledge using a Component-Based Concept Map Scoring Program

Conceptual understanding is an important prerequisite for engineering competence. Concept maps, which capture the content and structure of knowledge, can be used to assess conceptual knowledge, although cumbersome scoring methods limit their use. A literature review was conducted to summarize concept map scoring methods and automated scoring programs. While quantitative, component-based methods prevailed in the literature, no program was available to automate this method. Thus, the goal of this project was to present and evaluate a component-based computer program for scoring concept maps. The program automates application of the traditional scoring method in which number of concepts, highest hierarchy, and number of cross-links are counted as indicators of knowledge breadth, depth, and connectedness, respectively. A sample of concept maps ( $n = 78$ ) was scored by two judges and the computer program. High agreement (Krippendorff's  $\alpha > 0.80$ ) between manual and automated scores was observed for number of concepts and number of cross-links. Although less than acceptable agreement between manual and automated scores was observed for highest hierarchy, the two measures of knowledge depth were highly correlated (Spearman's  $\rho > 0.5$ ). Ultimately, the computer program's measure of knowledge depth was termed longest path, while judges' measure of knowledge depth was termed longest hierarchy. Overall, the computer program can be used to rapidly, precisely, and reliably score concept maps to aid in assessment of conceptual knowledge.

**Keywords:** assessment; concept maps; conceptual knowledge; educational technology

**J. Estévez, A. P. García-Marín and J. L. Ayuso-Muñoz**      1038–1048      Self-Perceived Benefits of Cooperative and Project-Based Learning Strategies in the Acquisition of Project Management Skills

This paper summarizes the results of applying cooperative and project-based learning strategies in two different engineering courses in order to explore their benefits in the students' self-perceptions of project management skills. Nine technical skills and four behavioural ones were evaluated during the academic years 2012–13 and 2013–14 in Civil Engineering, and 2014–15 and 2015–16 in Forest Engineering courses (117 students). The first strategy consisted of the preparation of a project plan to solve a customer's request and the second one was the drafting of a Facebook page to promote one specific commercial project. Results from this study show the strong improvement observed in all the skills studied, these self-rating increases were statistically significant in most of them by the end of the courses. Different tests were applied in order to appropriately assess statistical significance depending on self-rating data distribution. This work confirms the benefit of the application of cooperative and project-based learning strategies on self-perceived improvement in the students' project management skills in engineering courses. These findings are of considerable interest to engineering institutions that want to advance in favour of the students' perceptions of competence and they serve to deepen the combined effects of cooperative and project-based learning in higher education.

**Keywords:** cooperative-based learning; project-based learning; skills; project management

**Stanislav Avsec and Magdalena Jagiello-Kowalczyk**      1049–1059      Pre-Service Teachers' Attitudes Towards Technology, Engagement in Active Learning, and Creativity as Predictors of Ability to Innovate

Teacher's subject matter knowledge, pedagogical content knowledge, skills, attitudes and self-efficacy guide teacher's behaviour in the classroom. Little is understood how pre-service teachers' beliefs, affective and conative abilities along with creative potential support their technological and engineering behaviour necessary for inventiveness. The purpose of this study was to examine relationships among pre-service teachers' attitudes towards technology, perceptions and experiences with their own engagement in technology and engineering activities, and their creative potential that have been shown to support their innovative behaviour. A total of 124 pre-service teachers participated in this study. The Twenty-five-Item Technology and Me survey, the Test of Creative Thinking-Divergent Production, and the Twenty-three-Item Action and Me survey were used to measure the teachers' attitudes towards technology, creative potential, and their situational interest, perceived course learning value, satisfaction, and technological and engineering behaviour. A conceptual model was hypothesized, tested, and supported by the results using confirmatory factor analysis with structural equation modelling. Findings indicate that pre-service teachers who had higher scores on interest for technology had higher situational interest, higher creative performance, and higher ability to innovate. Students who had higher scores on perceived consequences of technology had less creative performance while students who had higher scores on perceived technology difficulty had lower scores on perceived learning value of the course and lower scores on course design quality. Pre-service teachers own creativity, perceived course design, situational interest, and perceived learning value mediate the relationship between attitudes towards technology and perceived ability to innovate. Our results offer important implications about how to prepare pre-service technology and engineering teachers for innovative performance towards enhancing technological knowledge and skills.

**Keywords:** technology and engineering education; pre-service teachers; attitudes towards technology; creative potential; ability to innovate

The rapid growth of entrepreneurship training in higher education warrants increased research on the impacts of entrepreneurship program participation. The purpose of this study is to develop a conceptual model of student participation in entrepreneurship education programs based on previously established models of student participation in learning activities and entrepreneurship education assessment theories. We systematically reviewed the literature using salsa methodology (search, appraisal, synthesis and analysis) to identify commonly used theories and variables in entrepreneurial assessment literature. Salsa method allows identification, evaluation, synthesis and analysis of most significant work in the field with respect to the area of interest. We found that these dominant theories only focused on individual factors and rarely highlighted external influences and barriers. This review led to development of an entrepreneurship-specific participation model. By merging multiple theories into one overarching model, we provide a foundational framework for systematic research examining student participation in undergraduate entrepreneurship programs. This overarching model identifies six variables that are especially important for entrepreneurship education program participation: entrepreneurial self-efficacy; desirability; entrepreneurial intent; life transitions; information and resources; and opportunities and barriers

**Keywords:** entrepreneurship education; theoretical frameworks; student participation; critical review; program development

There is worldwide concern about the presence of factors that affect the performance of students in the computer science/engineering (CS) education process. Gender, socioeconomic and institutional factors may create gaps that affect not only the quality of education but also the entire society. This paper examines the influence of these factors on the performance of two tests used in Colombia for assessing the quality of education: The SABER-11, applied to senior high-school students, and SABER-PRO, applied to senior CS students (N = 2,964). We used effect size to compare mean difference by gender, and correlation and multiple regression analysis to examine the influence of socioeconomic and institutional factors, and the results of the SABER-11 on SABER-PRO. The results suggest the existence of moderate gender differences, favouring men, at the high-school level; however, when compared to the undergraduate level, we found evidence of significant gaps in all evaluated topics and of men performing better than women do. Results also suggest the existence of gaps associated with income, parental education, and the nature and quality of the university and the academic program where the student studies.

**Keywords:** gender gap; computer science/engineering; outcomes-based assessment, socioeconomic factors

Design has been called one of the defining characteristics of engineering, and it has been long-argued that design is equally social and technical in practice. The field of Science and Technology Studies (STS) has a research tradition of exploring the interwoven social aspects of technical fields like engineering design. We borrow a concept from STS—the notion of *intermediary objects*—to better understand first-year engineering design teams and explain how prototypes mediate technical skill development and social relationships. An intermediary object is both a conceptual framework and an analytic tool that enables researchers and educators to identify critical aspects of design coordination. In this paper, we compare two differently organized sections of a first-year engineering design course as a way to highlight the importance of prototypes in mediating these technical and social relations. It is not until these two courses are compared side-by-side that we uncover the critical importance of prototypes as intermediary objects. Based on this comparative case analysis, we argue that prototypes are pivotal intermediary objects that aid in students' development of their engineering skills and pathways toward becoming an engineer. This paper contributes to the field of engineering education by connecting traditions from STS and exploring how the creation of prototypes impacts design education. In doing so, we provide some immediate recommendations for organizing engineering design courses, and we indicate future research on understanding the role of prototypes in design education and practice.

**Keywords:** first-year design; project-based learning; intermediary objects; prototypes; comparative case study

The impact of federally supported STEM education research is difficult to document, because knowledge resulting from research is deeply embedded in complex networks of social interactions, structures and artifacts. DIA2 is a web-based search and visualization tool designed to make knowledge associated with NSF-funded projects more accessible to the STEM education scholarly community. No studies have communicated its value to the community it was designed to serve. This study investigates users' perceptions of DIA2's usefulness for carrying out teaching, research, and administrative duties. Using a qualitative interpretivist approach, researchers conducted semi-structured interviews with 89 principal investigators on NSF-funded grants. We used thematic analysis, and interpreted the results using the Distributed Cognition and the Affordances of Information and Communications Technology frameworks. Results indicated ten ways DIA2 is valuable for carrying out a spectrum of routine scholarly activities, including initiating research collaborations, preparing promotion and tenure documents, and informing strategic decisions. With increased accessibility to the knowledge DIA2 provides, we are better equipped to characterize the impact of federally supported STEM education R&D.

**Keywords:** data knowledge and visualization; knowledge sharing; learning via discovery; value of information

Impact is a topic of interest among a wide range of stakeholders interested in engineering workforce development but is one in which there is a dearth of scholarship. While existing literature includes two dimensions of research impact (scientific, and societal), this qualitative study proposes and focuses on the third dimension—contextual impact. Using Toulmin's Model and the *Common Guidelines for Education Research and Development*, this study uses content analysis to explore how researchers on National Science Foundation-funded STEM education R&D projects talk about the impact of their work in abstracts ( $n = 155$ ) with an explicit impact section; special attention is given to engineering education research. Findings reveal eight claims that are commonly discussed when Principal Investigators articulate research impact; two themes relate to how their claims are supported. The findings also indicate that the discipline associated with the study and the project focus has more to do with the types of impact PIs claim than the amount of funding awarded to the project. The proposed *SCS Impact Framework* resulted from identifying the points of alignment between PIs' perspectives on impact and existing literature. This conceptual lens describing impact in this context is useful for researchers, practitioners, and policymakers around the world interested in the scientific, contextual, and societal dimensions of engineering education R&D.

**Keywords:** impact; engineering education research; STEM education; National Science Foundation

Computer architecture is one of the basic courses in computer engineering departments. In this course both training systems and simulators are widely used for practice. The objective of this study is to compare a commercially available microprocessor training system (Lab-Volt) and a more affordable simulator (Visual 6502 Microprocessor Simulator). The comparison was based on 93 students enrolled in a computer architecture course. They were divided into two groups: one used the commercially available trainer and the other used the simulator. The assessment data were based on the results from a questionnaire completed by students and on their academic performance in the course. The results revealed that both tools support learning computer architecture and do not have significant differences in terms of learning outcomes. However, the simulator offers visual advantages compared to the training system.

**Keywords:** computer architecture; training system; Lab-Volt; simulator