Understanding the Potential of a Holistic Engineering Project Experience in the Advancement of the Professional Formation of Engineers

Dr. Kakan C Dey P.E., West Virginia University

Dr. Kakan Dey is an Assistant Professor at the Wadsworth Department of Civil and Environmental Engineering, West Virginia University, WV, USA. He completed his Ph.D. in Civil Engineering from Clemson University in 2014 and M.Sc. in Civil Engineering from Wayne State University in 2010. Dr. Dey was the recipient of the Clemson University 2016 Distinguished Postdoctoral Award. His primary research area includes intelligent transportation systems, and traffic safety and operations. He has been very active in engineering education research as well.

Mr. Md Tawhidur Rahman, West Virginia University

Md Tawhidur Rahman is pursuing PhD in Civil Engineering at West Virginia University. He has completed his Masters in Civil Engineering from the same university in 2018. Mr. Rahman has been awarded CEE PhD fellowship cap for the academic year of 2019-2020 for his research contribution in the field of transportation engineering. Research interest of Mr. Rahman include winter roadway maintenance, shared-use mobility, social-media data analysis, traffic operation at intersection, and connected and autonomous vehicle.

Dr. V. Dimitra Pyrialakou, West Virginia University

Dr. Pyrialakou is an Assistant Professor at the Wadsworth Department of Civil and Environmental Engineering at West Virginia University. She received her Diploma in Civil Engineering from the National Technical University of Athens, Greece, in 2011 and in 2016 she earned a Ph.D. in Civil Engineering from Purdue University. Dr. Pyrialakou's expertise and interests involve the use of statistical, econometric, spatial, and economic analysis tools in the broader research area of transportation planning and evaluation of transportation systems. She started working in the area of engineering education at Purdue University when she taught Introduction to Transportation Engineering in spring 2016. She currently explores topics related to undergraduate STEM education improvement, including holistic engineering; connecting teaching, research, and practice; student retention in engineering; and recruitment and retention of underrepresented students in engineering. Dr. Pyrialakou also teaches courses on transportation engineering, transportation/urban planning, and civil engineering/transportation data analysis.

Dr. David Martinelli, West Virginia University

Professor of Civil Engineering at West Virginia University.

Dr. Julia Daisy Fraustino, West Virginia University

Dr. Fraustino is an assistant professor of strategic communication and director of the Public Interest Communication Research Laboratory in the Media Innovation Center of the Reed College of Media at West Virginia University. She specializes in public interest communication, particularly crisis, emergency, and risk communication science. In those realms, she has worked on grants and contracts through CDC, DARPA, DHS, NIH, and NSF. Dr. Fraustino's work has been recognized with top research paper awards at national/international conferences yearly from 2013-present. Additionally, she was named a national 2017-2018 AEJMC Emerging Scholar, earned the 2018 Doug Newsom Award for Research in Global Ethics and Diversity from the AEJMC PR Division, was the 2017 Reed College of Media Faculty Research Award recipient, was a 2016 national Frank Public Interest Communications Research Prize award winner, received a 2015 Most Promising Professor Award from the AEJMC Mass Communication and Society Division, and was selected as a 2014-2015 START/DHS Terrorism Research Award Fellow for her dissertation research. She earned a Ph.D. from the University of Maryland, where she was graduate fellow and the 2015 Department of Communication's Most Outstanding Doctoral Student.

John Deskins

John Deskins serves as Assistant Dean for Outreach and Engagement, Director of the Bureau of Business & Economic Research, and as Associate Professor of Economics in the College of Business & Economics at West Virginia University. He leads the Bureau's efforts to serve the state by providing rigorous economic analysis and macroeconomic forecasting to business leaders and policymakers across the state. He received his PhD in Economics from the University of Tennessee.

Deskins' academic research has focused on economic development, small business economics, and government tax and expenditure policy, primarily at the US state level. His work has appeared in outlets such as Contemporary Economic Policy, Public Finance Review, Economic Development Quarterly, Small Business Economics, Public Budgeting and Finance, Regional Studies, Annals of Regional Science, Tax Notes, and State Tax Notes, as well as in books published by Cambridge University Press and the Lincoln Institute of Land Policy.

Deskins has testified before the United States Senate, the United States House of Representatives, and the West Virginia Legislature. He has delivered more than 100 speeches to business, government, and community groups and his quotes have appeared in numerous media outlets such as The New York Times, The Wall Street Journal, The Washington Post, Bloomberg, CNBC, National Public Radio, and PBS. He has served as principal investigator or co-principal investigator on more than $2 million in funded research.

Dr. Abhik Roy, West Virginia University

Abhik Roy is a professor educational psychology in the Department of Learning Sciences & Human Development (https://lshd.wvu.edu/) within the College of Education & Human Services at West Virginia University. Dr. Roy holds a Ph.D. in Program Evaluation with expertise in data science, visualization, and social network analysis and is an evaluator on multiple federal grants spanning both the National Science Foundation and the National Institutes of Health. He currently conducts research in (a) the use of machine learning to evaluate programs, (b) using predictive networks to assess change, and (c) deep learning architectures for text classification.

Dr. Karen E Rambo-Hernandez, Texas A&M University

Karen E. Rambo-Hernandez is an associate professor at Texas A & M University in the College of Education and Human Development in the department of Teaching, Learning, and Culture. In her research, she is interested in the assessing STEM interventions on student outcomes, measuring academic growth, and evaluating the impact of curricular change.

Understanding the Potential of a Holistic Cross-Disciplinary Project Experience in the Advancement of Professional Formation of Engineers

Introduction

The role of modern engineers as problem-definer often require collaborating with cross-disciplinary teams of professionals to understand and effectively integrate the role of other disciplines and accelerate innovation. To prepare future engineers for this emerging role, undergraduate engineering students should engage in collaborative and interdisciplinary activities with faculties and students from various disciplines (e.g., engineering and social science). Such cross-disciplinary experiences of undergraduate engineering students are not common in today's university curriculum. Through a project funded by the division of Engineering Education and Centers (EEC) of the National Science Foundation (NSF), a research team of the West Virginia University developed and offered a Holistic Engineering Project Experience (HEPE) to the engineering students. Holistic engineering is an approach catering to the overall engineering profession, instead of focusing on any distinctive engineering discipline such as electrical, civil, chemical, or mechanical engineering. Holistic Engineering is based upon the fact that the traditional engineering courses do not offer sufficient non-technical skills to the engineering students to work effectively in cross-disciplinary social problems (e.g., development of transportation systems and services). The Holistic Engineering approach enables engineering students to learn non-engineering skills (e.g., strategic communication skills) beyond engineering math and sciences, which play a critical role in solving complex 21st-century engineering problems. The research team offered the HEPE course in Spring 2020 semester, where engineering students collaborated with social science students (i.e., students from economics and strategic communication disciplines) to solve a contemporary, complex, open-ended transportation engineering problem with social consequences. Social science students also received the opportunity to develop a better understanding of technical aspects in science and engineering. The open-ended problem presented to the students was to "Restore and Improve Urban Infrastructure" in connection to the future deployment of connected and autonomous vehicles, which is identified as a grand challenge by the National Academy of Engineers (NAE) [1].

Methodology

The HEPE course was offered with the title, "Technology Innovation: Engineering, Economics, Public Relations." The class was composed of twenty-one students, where twelve students were majoring in engineering disciplines, seven students in strategic communications, and two in economics. For comparison purposes, the research team selected two traditional civil engineering courses, where the hypothesis was that the engineering students of HEPE course would gather higher levels of learning on non-technical professional skills compared to traditional groups of engineering students.

Comparisons between the HEPE and traditional groups were investigated by applying a Cross-Disciplinary Team Learning (CDTL) framework. The CDTL framework was developed by Lei [2], which has three-dimensions i.e., identification, formation, and adaptation. The identification dimension evaluated the readiness of students in forming teams with cross-disciplinary students and consisted of five constructs; (i) self-assessment (measures students' knowledge and their perceptions, interests, and levels of confidence in terms of working with a cross-disciplinary team), (ii) information seeking (measures the extent students are focused to gather information on the scopes and requirements of the HEPE and roles of team members), (iii) personal goal setting (assesses the ways students set personal

goals for the HEPE), (iv) strategic planning (measures students' planning for the HEPE), and (v) self-monitoring (measures the extent students self-monitor to achieve the HEPE outcomes). Formation dimension assessed engineering students' performances in team formation and functioning and consisted of nine constructs; (i) team goal setting (assess the clarity and appropriateness of team goals among students), (ii) role identification (measures the extent the engineering students identify the role of team members), (iii) trust (measures the level of trust of engineering students on team members), (iv) interdependence (measures the dependency of engineering students on team members), (v) peer feedback (measures number of times engineering students ask peer feedback), (vi) expert feedback (measures number of time engineering students ask expert feedback), (vii) communication and collaboration tools (measures the effectiveness of using communication and collaboration tools), (viii) awareness (assesses the awareness levels of engineering students of the learning outcomes of cross-disciplinary team members), and (ix) appreciation (assesses the extent engineering students appreciate team members). The adaptation dimension assessed the perspectives of engineering students to collaborate and align their goals with cross-disciplinary students. Adaptation dimension consisted of three constructs; (i) goal alignment (measures the alignment of individual goals to team goals), (ii) shared mental models (measures team members' ability to communicate and coordinate), and (iii) understanding (measures the extent engineering students became aware of, appreciate and apply cross-disciplinary knowledge over time). Each construct consists of multiple survey items. Three Institutional Review Board (IRB)-approved pre-, mid-, and post-semester surveys were administered to gather HEPE students' responses to the survey items. Similar three-stage surveys were administered among the traditional groups of engineering students. The questionnaire of these three surveys and details of the HEPE offering were presented in [3]. The research team gathered responses of seven and six students from the traditional groups 1 and 2, respectively. The analysis of variance (ANOVA) and one-sided t-test were used to investigate the difference in perceptions of the HEPE students among three stages of surveys as well as the difference in perceptions among HEPE and traditional groups of engineering students.

Results

Based on the analysis of survey responses, it was found that social science students in the HEPE course helped engineering students in identifying the comprehensive scopes and requirements of the open-ended problem and roles of cross-disciplinary team members. Engineering students in the HEPE course became more aware of the learning outcomes of social science disciplines in the context of solving engineering problems. In addition, a cross-disciplinary setting enabled engineering students in the HEPE course to seek higher feedback from peers and experts. The pre-survey revealed knowledge and perception similarities on the assessed constructs between the HEPE and traditional groups of engineering students. Between the HEPE and traditional groups of engineering students, the HEPE students showed higher interest in collaborating with the economics and strategic communication students in all three surveys. The mid-survey revealed that the HEPE students showed a higher average agreement level on the constructs of formation dimension (i.e., team goal setting, role identification, trust, interdependence, communication and collaboration tools, and awareness) compared to the traditional groups of students. The differences were significant for the team goal setting, trust, and awareness constructs ($p\text{-value} \leq 0.05$). However, the differences were reduced between HEPE and traditional groups in the post-semester survey. A similar finding was reported by Atadero et al. in terms of civil engineering students' diminished appreciation for diversity (i.e., working with students from diverse backgrounds) due to indirect intervention (e.g., absence of direct exchange of knowledge) [4]. In our HEPE offering, online instruction and group meetings in the second half of Spring 2020 semester due to COVID-19 pandemic might lead to decreased performances of HEPE students in terms of team goal setting, trust, and

awareness. The HEPE students showed higher average agreement on the goal alignment and shared mental model constructs in terms of working with a cross-disciplinary team than the traditional groups working in a team of engineering students only. In post-semester survey, a significant difference in agreement levels was observed on shared mental model construct between HEPE and traditional groups of students (i.e., average agreement levels were 4.18 for the HEPE students and 3.63 for both traditional groups, in a scale of 1 is strongly disagreed and 5 is strongly agreed).

Conclusions

The findings of the HEPE offering revealed the effectiveness of implementing a cross-disciplinary course setting in enhancing the team learning experience of the engineering students. In the pre-survey, the similarity between the HEPE and traditional groups was observed in most surveyed constructs. HEPE students showed better performances in the majority of assessed constructs in mid-, and post-surveys than the traditional groups of engineering students. Increased trust while working with cross-disciplinary students and higher awareness and appreciation of their learning outcomes are expected to help engineering students learn non-technical professional skills and work effectively in a collaborative environment. Overall, the findings gathered from this initial HEPE offering can provide early evidence to the engineering and broader higher education community in promoting similar HEPE course offerings to advance the professional formation of engineers. In future, the findings of HEPE course offering in Spring 2020 semester will be compared with the findings of the HEPE course offering in Fall 2020 semester to investigate the consistency of the findings. In addition, future research will implement the HEPE concept in traditional engineering courses and evaluate engineering student's learning beyond the conventional/technical skills.

References

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