

Evaluation of the developed hardwired mechatronic trainers as an educational device

Joseph C. Pepito*¹, Romeo P. Montecillo¹, Lelanie S. Cordero¹, Esperanza M. Del Fierro¹, Christine Omela V. Ocampo², and Kenneth A. Siglos³

¹Cebu Technological University, M.J. Cuenco Avenue Ave., Corner R. Palma St., Cebu City

²Cebu Technological University, Danao Campus, Danao City, Philippines

³Office of the Vice President for Research and Development, Cebu Technological University, M.J. Cuenco Avenue Ave., Corner R. Palma St., Cebu City

ABSTRACT

Mechatronics is a multidisciplinary discipline that refers to the skill sets required in the current, advanced computerized manufacturing industry incorporating electronics and mechanical engineering, computer systems, and advanced controls systems to products and processes. Mechatronics is a crucial foundation for the projected growth in manufacturing and automation. Cebu Technological University (CTU) - Main Campus offers a mechatronics program that aims to address the need for the future employment demand in industrial automation. The study aimed to assess the newly-developed hardwired mechatronic trainer- equipment needed for instruction to strengthen the quality of education. It employed a descriptive-normative survey method using a questionnaire duly evaluated by experts, including industry representatives, peers, and friends who have interests and experience in dealing with industrial automation.

Results suggested that the program professors met the educational and industry experience qualifications specializing in mechatronics or automation technology. Also, it showed that there is a significant difference ($P=.000$) between the perception of the students and professors on the trainer. The teachers and students may have different views in evaluating the innovation of the mechatronic trainers. However, they share the same hope: to have a well-functioning mechatronic trainer. Therefore, the development of an innovative mechatronics trainer is very effective in delivering relevant skills in mechatronics from the students' perspective, requiring both professors and students to fully utilize all laboratory facilities until they become familiar and used to have a complete understanding of the required knowledge and skills in mechatronics.

KEYWORDS: *Cebu, Mechatronics, Innovation, Trainer, CTU*

1 INTRODUCTION

Mechatronics is an integration of mechanical, electronic, software, and control theory engineering disciplines into a unified framework that improves technology design (Ali & Sabir, 2018). The term was derived from the observation of the synergy achieved through the integration of mechanical and electronic technologies (Stankovski et al., 2019). In this industrial revolution, mechatronics is an essential engineering discipline (Kuru & Yetgin, 2019) crucial to technology automation innovation, wherein mechatronics engineers and technologists are in great demand (Habib et al., 2021).

In teaching, especially in Bachelor of Science in Mechatronics, professors need to include production-relevant machinery, tools, and devices as instructional material for dynamic interaction with the students (Ibrahim et al., 2017). The mechatronic trainers are essential for teachers as instructional material that promotes effective instruction and communication to learners through the actual visualization of the mechatronics components (Arop et al., 2015; Kamińska et al., 2020; Yu et al., 2020). Further, the trainers are essential since mechatronics/ engineering education needs hands-on training and experience which increases the students' academic performance (Jadhav et al., 2017; Haughery, 2018).

CTU offers a Bachelor of Science in Mechatronics degree to respond to this demand for industrial automation technologists. The University has invested in infrastructure, tools, and equipment for the laboratory activities of the students to ensure developed and improved skills in industrial automation; however, the institution's resources are not enough for the sustainability of the program. High-quality mechatronics education is essential because there is a huge demand for competent mechatronics graduates (Irwin et al., 2021). Nevertheless, schools are struggling with the capacity of

*corresponding author: joseph.pepito@ctu.edu.ph

p-ISSN: 2599-4875 e-ISSN: 2599-4980

©Cebu Technological University, R. Palma St. corner M.J. Cuenco Ave., Cebu City, 6000 Philippines

the facilities to cater to the student's needs in their laboratory activities (Ak et al., 2018). Universities' teaching is challenged because future graduates need to be well prepared for the professional world (Eichinger et al., 2017).

Upon completing the mechatronics program, graduates should have professional, independent learning skills, controller design knowledge, numerical simulation and analysis, electronics, software development, and systems design (Berry et al., 2020). The industry qualifies mechatronic technologists to understand all mechanical, fluid power, electrical, and electronic componentry and how they combine into a system (Bishop, 2008; De Baerdemaeker et al., 2001; Barger & Gilbert, 2018).

This study was deemed to evaluate the developed trainer based on the perspective of professors and students. The study would identify the different perspectives of both teachers and students. It intended to develop a trainer that is a theoretical, practical, and skill-oriented resource, facilitating the learning acquisition of the students, which enhances their vocational-technical skills needed in the industry.

Objectives

The study mainly focused on the evaluation on the perception of the professors and students on the hardwired mechatronic trainer which aims to increase the learning and teaching productivity of the faculty and students of the Mechatronics department at CTU. Specifically, it gathered the following information: profile of the students and faculty of the mechatronics department; perceptions of the students and faculty on the hardwired mechatronics trainer; and impressions of the students and faculty on the hardwired mechatronics trainer.

2 MATERIALS AND METHODS

The study utilized the developmental research focusing on the assessment of the innovative hardwired mechatronics trainer using the ADDIE development model by Lee and Owens and flow-charting for the series of steps in the process (Lee et al., 2004). It employed a descriptive-normative survey method using the researcher-made questionnaire duly evaluated by some reliable industry partners, peers, and friends who have interests and experience in dealing with industrial automation. This study was conducted at Cebu Technological University-Main Campus on R. Palma St. corner M.J. Cuenco Ave., Cebu City. The Main Campus was selected as the research environment because of the increasing number of enrollees and students of the Bachelor of Science in Mechatronics program. The respondents were composed of 11 teaching personnel from the College of Technology handling subjects in BS in Mechatronics that personally experienced the

hardships in teaching because of the limited trainer for practical activities, and 36 student respondents. These students enrolled in BS in Mechatronics experience struggles in learning because of the limited trainer for practical activities.

Data collection was possible through a researcher made-questionnaire. The questionnaire was duly evaluated and validated by experts. It consisted of three parts: the first part composes the basic profile of the respondents. The questionnaire seeks relevant information like teaching experience, industry experience, educational background, and training for the professors. The students were also asked about their industry experience, years of studying mechatronics, and training. The second part of the questionnaire seeks to understand how the trainer provides the function skills in mechatronics. This part is divided into five segments. These are the skills that the trainer would bring to the learners' tool handling and maintenance, identification of pneumatic components and connections, electrical wiring preparation and connection, PLC programming and installation, and circuit training and commissioning. The last part of the survey determined the respondents' perspective regarding the importance of the trainer and how badly it is needed to enhance the education quality of the students. This part of the questionnaire wants to know about the respondents' perception of the application of mechatronics. Lastly, this part examines how the trainer would affect the students' skills.

Layout Laboratory Materials

The researchers made an inventory of existing laboratory materials, trainers, and other resources to know the current status of the Mechatronics Laboratory. It was found out that instructional material, particularly trainers for mechatronics, could not guarantee quality graduates in the mechatronics program. The existing ready-made trainer can only provide minimal skills since students need not measure, cut, splice, and attach terminal lugs before mounting in the terminal block.

Industry Perspective

The link between the industry and academe needs to be strengthened, especially in mechatronics-related areas, because awareness and acquisition of the skill sets are required by the industry (Ali & Sabir, 2018). The researchers made the questionnaire based on the information gathered from the industry partners and in-class observation. The industry partners' feedback stressed that student trainees (On Job Training) in their respective companies were more than qualified as mechatronics technicians. However, the students needed to improve their skills in fabrication through familiarization of components, preparation of materials, usage of tools, installation, and testing (Pepito, 2018).

Statistical Treatment

The gathered data from the 47 retrieved questionnaires were analyzed of their weighted mean. Moreover, the t-test with a p-value of 0.05. to determine the differences between ratings was also used.

Ethical Considerations

The study was conducted in accordance with the principles of the Helsinki Declaration and principles set forth by the Philippine Health Regulation Ethical Board (PHREB) and the Republic Act 10352 (Philippine National Health System Research Act of 2013) and CHED Memorandum Order no. 34 of 2007 has required the review of research endeavors involving human subjects. The study was approved by the college and department and informed consent was distributed to the respondents.

The research review application was made through filling out ethic review forms. In a PDF format the researchers submitted the research proposal, similarity index certificate, technical panel endorsement, informed consent forms and updated curriculum vitae of the authors. As required the author filled-out in excel file the risk assessment form, application form, and informed consent evaluation form.

Design and development procedures

The design is based on the information gathered both from industry partners and in-class observation. The industry partners' feedback stressed that student trainees (On the Job Training) in their respective companies were good enough to answer the need of mechatronics technicians except that they needed to improve their skills in fabrication through familiarization of components, preparation of materials, usage of tools, installation and testing (Pepito, 2018). Meanwhile, the researchers observed classes and found out that most of the students have difficulty understanding the functions of mechatronics components without demonstrating the actual unit because ready-made trainer can only provide very limited skills since students need not measure, cut, splice, and attach terminal lugs prior to mounting in the terminal block. They need materials that reinforce their theoretical knowledge which may lead to increased concept retention.

Figure 1 shows the process flow chart of developing a hardwired mechatronics trainer. The design trainer covered an industry-oriented competency indicators domain for mechatronics technology; these include the following: pneumatics control, sensors, electrical machinery control, programmable logic control, computer control, and system integration. Required materials were determined including the tools and equipment necessary for the construction of the trainer. Based on the layout, components were mounted to the board frame and tested as to their functionality. The

researchers tested all components to ensure the safety of using the trainer and the functionality of its mounted components. The test results showed that all these components have functioned accordingly and the wiring arrangement including the tightening of screws was all in place. This means that the developed mechatronics trainer is ready for external evaluation by the professors and students of the University.

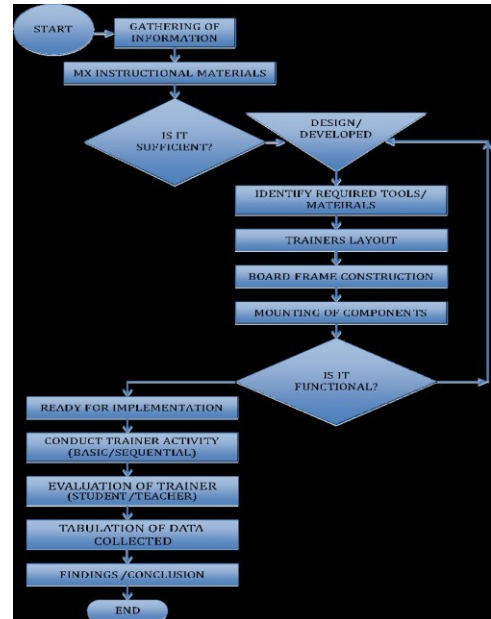


Figure 1: Design Development Flowchart

3 RESULTS AND DISCUSSION

The professors in Mechatronics Technology ranged from 26 to 50 years old, dominated by male respondents (64%), doctorate degrees (55%), and have teaching and industry experience. The professors' teaching Mechatronics Technology should have the appropriate educational background, training, and industry experience. The researchers found out that the professors are primarily engineers, have industry experience, and completed their graduate degrees.

The professors' knowledge on mechanics, electronics, control, and programming are necessary in order to efficiently teach students (Jimenez, 2018) (Table 1). The 36 student respondents are currently enrolled in the Bachelor of Science in Mechatronics Technology and have used the developed trainer. The students' training experience equipped them with the knowledge about their enrolled program's technicalities. The students' experience in mechatronics can increase their motivation, self-efficacy, and course rigor (Haughery, 2018) (Table2).

The trainer was designed for electro-pneumatics,

Table I: Demographic Profiles of the Professors Teaching Mechatronics Technology

Profile of the Professors		
Age	26 ≤ Age ≤ 50	
Sex	Male	64%
	Female	36%
Civil Status	Single	27%
	Married	73%
Educational Attainment	Doctorate Degree	55%
	Masters Degree	18%
	Doctorate Level	9%
	Master's Level	18%
Teaching Experience	Ten Years	36%
	Nine Years	18%
	Eight Years	9%
	Six Years	9%
	Three Years	9%
	Two Years	9%
	One Year	9%
Training	240 hours	55%
	200 hours	9%
	100 hours	18%
	80 hours	9%
	56 hours	9%
Industry Experience	20 Years	9%
	16 Years	9%
	6 Years	18%
	5 Years	9%
	2 Years	18%
	1 Year	9%
	No Exp	9%
	Prefer not to say	18%

programmable logic controller (PLC) and other

mechatronics circuit laboratory activities in the mechatronics program. It is composed of the input, process, and output mechatronics components. The trainer would be useful to the professors and students to show proper tool handling and maintenance as it is highly required in the industry. The innovative hardwired mechatronics trainer provided the industry setting in identifying and preparing the required mechatronics materials in performing laboratory activities (Jimenez, 2018).

Table II: Demographic Profiles of the Students who are Enrolled in Mechatronics Technology

Students Respondents		
Educational Attainment	2nd Year	78%
	3rd Year	22%
Training in Mechatronics	20 hours	56%
	4 hours	44%
Industry Experience	6 Years	3%
	2 Years	3%
	No Experience	94%

The mechatronics trainer has input (sensors), process (relays & relays), and output (valves, motors & lamps) components. The innovative hardwired trainer's components and connections can be easily identified to reduce confusion because these might affect the trainer's usability and students' learning process. The trainer must be user-friendly in the mechatronics laboratory, where there are various components and wired connections (Marzano et al., 2019).

The trainer should enhance the electrical wiring skills of the students because the wires are not ready-made, and the wires are manually connected. Laboratory activities including wiring are interesting to students which can be seen in their active participation in the laboratory. The trainer is believed to provide students with a quicker and better understanding of the subject and quickly develops the technical skills of the students required for hardwiring in mechatronics (Kucera, 2018).

The trainer should enhance the students' skills in PLC programming and installations, a very in-demand skill in the industry. The trainer also provides programming and installation of the models. The students will be immersed more on the actualization of their layouts. Programming skills could ensure quality graduates that could respond to automation technicians or experts (Ibrahim et al., 2018).

The trainer should provide skills that cannot be obtained using a ready-made trainer. Hands-on activities that involve industry-like experience are the main edge of the trainer. Hands-on activities in the newly developed trainer are robust; hence, it will help students perform better (Haughery, 2018).

The trainer was evaluated by both the professors and students is based on the five identified functional skills in mechatronics: tools handling and maintenance; pneumatic components identifications and connections; electrical wiring preparations and connections; PLC programming and installations; and circuit tracing and commissioning (Stankovski et al., 2009). The respondents have rated five benchmark statements to each identified skill based on the following category: strongly agree with the highest point scale of five up to the strongly disagree with the lowest point scale of one.

Finally, the students $x=4.4144$, $SD=0.45739$ and the professors $x=4.9073$, $SD=0.7604$ with an average weighted mean of 4.66 with a verbal description of strongly agree. However, the significant difference in the rating given revealed that the p-value of 0.000 is lesser than the 0.05 level of significance, which means rejecting the null hypothesis is the appropriate choice. Hence, there is a significant distinction in the rating given by the teachers compared with the students. The teachers and students may have different views in evaluating the innovation of the mechatronic trainers. However, they share the same hope: to have a well-functioning mechatronic trainer.

Impressions toward the improvement of the trainer

The researchers sought the respondents' impressions on the improvised trainer. Here, the respondents expressed their experiences and observations about the innovative mechatronics hardwired trainer and had the opportunity to enumerate the importance and the challenges they have encountered using the trainer.

Professor

The professors said that the trainer is efficient and very close to the real world of automation. The teaching of structure for technicians in mechatronics is displayed as an appropriate space for integrating knowledge related to engineering, electronic parts, control, and programming, to develop products to satisfy an increasingly competitive market in terms of technological-economic criteria (Jimenez, 2018). The trainer provides students with a quicker and better understanding of the subject and quickly develops the technical skills required for hardwiring in mechatronics (Kucera, 2018). Hence, this will lighten the task of the professors in discussing the topics. It is helpful to the mechatronics laboratory and is very user-friendly (Marzano et al., 2019).

The professors conveyed that the trainer would help

the students to have an understanding of mechatronics, together with excellent classroom motivation. The trainer would help by having a practical simultaneous class discussion. The trainer would also help the professor have more student exercises. It is also open to the concept of Internet of Things (Marzano et al., 2019); very relevant to mechatronics skills training; it shares the students' ability in hardwiring and ease of troubleshooting; a beneficial tool or device in the study of mechatronics; beneficial to teachers as well as students; and; outstanding trainer for mechatronics industry application. These skills are essential to the students as the industry advances. The University must take part in this advancement by providing quality graduates.

The professor also said that the trainer needs much attention because, during the execution, the professor needs to follow each terminated wire. The students should be attentive in tracing the wires to avoid confusion because of their complexity. Wiring is an essential skill for the students to master (Berry et al., 2020). In the recent case of the university the resources are scarce, hence, the learning and teaching process would be affected. In the laboratory setting where practical works are to be performed, students performed better when learning materials are available (Yu et al., 2020).

Wearing mechanical screws, stripping wires, familiarizing component ports, wiring safety, locating ports, and fluctuating internet connection are the common challenges in using the hardwire trainer. Their responses showed that familiarization with essential mechatronics components is quite challenging and yet very relevant to the required skills in dealing with the said technology. The adaptability of the students to the new methods and technology varies and depends on their existing skills or knowledge (Ak et al., 2018).

The professors' suggested having additional relays, analog inputs, and a PLC module as these are the components of the mechatronic trainer. The relays needed are those with two contractors, relays with eight and fourteen pins, and relays with four contractors. Relays are part of the PLC program that made conveying possible (Isiramen, 2018) including analog inputs and the PLC module.

Significant suggestions include a stable internet connection for a faster simulation of the projects. Internet connection is essential in mechatronics laboratories as it is needed in the software of the mechatronics system (Kuru & Yetgin., 2019). Safety is another factor to consider which includes covering and improving exposed terminal blocks. The mechatronics system should not cause hazards (Priesterjahn et al., 2011), especially to students during hands-on activities.

Professors were highly impressed and believed that the innovation of hardwired mechatronics trainers was very relevant in handling their laboratory classes in the mechatronics program. The device helps make their

lessons explicit to learners and enhances the quality of the learning experience for learning in many ways (Ijaduala, 1997; Usman, 2002). It also increases mechatronics skills and ensures quality graduates (Ibrahim et al., 2018).

Student

The students unraveled their impression on the hardwired trainer. The students said that the trainer would help them visualize the real-world application of mechatronics. The trainer allows them to use tools and equipment used in the industry. Visualization and interaction of the students with the equipment would help them learn (Kucera et al., 2018) faster and adequately. The students described it as an organized tool but very challenging in actual execution. The students who experienced using it help them to enhance their skills, capabilities, and ability to innovate (Haughery, 2018). The students are eager to learn more about the parts of the trainer. The student responded that a hardwired mechatronics trainer would promote meaningful learning discussions that eventually increase their mental retention during the discussion, especially in mechatronics technology. Instructional materials would make the teaching and learning process easy (Jimenez, 2018).

The students who had used the trainer had difficulty in arranging wires, making latch connection, designing circuit diagrams, installing wires, locating components ports, using two-wire sensor, identifying wire length, familiarizing components and understanding the whole trainer system. They suggested that to use and understand the wirings must be correctly labeled. To sum up most of the students have difficulties doing the wiring connections since they were used to having the ready-made materials that are easy to manipulate, however not similar to what the industry is utilizing. There are students who had a hard time adapting to the new technology (Ak et al., 2018).

Upgrading the component ports is one of the suggestions of the students. They also emphasize the need for more trainers to be produced to accommodate the whole student population. Single solenoid valves, relays that have more than two conductors, stepper motors, and other components are also needed to be provided by the University. They also want to have basic guidelines on safety precautions, manual for the trainers, and tags to label pneumatic components. Students should study the technical aspects of the course and the security measures that must be implemented for everyone's protection. More importantly, they said extra caution must be observed when using the trainer to avoid short circuits and regular cleaning of the trainer to maintain and increase the lifespan of the trainers. It also proved that students had learned the importance of safety in dealing with electricity by requiring cover to expose wire terminals. Hazards

should be minimized in a mechatronics system (Priesterjahn et al., 2011) by fixing exposed terminal logs and wires.

4 CONCLUSIONS AND RECOMMENDATION

The evaluation of the hardwired mechatronic trainer by the Cebu Technological University- Mechatronics Department's professors and students made a significant premise on utilizing tools that are utilized in the industry. It is validated on their impression on the hardwired trainer that it induces an effective learning and teaching process. Lastly the trainer must be continuously utilized by the students to help them learn on how to use the actual mechatronics components and relate to actual applications which would hone this skill to be industry-ready.

The learning process of the students could be improved through the use of the newly developed hardwired mechatronics trainer. This would be essential in producing high-quality graduates that would be competitive in the industry. Hence, the recommendation should be made to help the students and professors improve the teaching and learning process.

1. Provision of the mechatronics components. It is essential that the students are able to see and use mechatronics components for them to be knowledgeable and prepared for the industry. Hence, provision of the lacking mechatronics equipment to the laboratory would be considered essential.
2. Emerge the students in circuit modeling, simulation, and analysis. These are prerequisite skills for a mechatronics student. These skills must be instilled in the students to harness them to the need of the industry. Thus, professors should focus on teaching the students how to read circuit diagrams, identify mechatronics components and analyze wirings.
3. Improvement of safety measures. Safety must be the top priority during the wiring process, the professors and the students must be safe to avoid accidents. Thus, safety precautions must be properly discussed and practiced with students. Additionally, components must also be in good condition to avoid electrocution.

REFERENCES

- Ak, A., Topuz, V., Altıkardeş, A., & Oral, B. (2018). Development of a remote laboratory infrastructure and LMS for mechatronics distance education. *EURASIA Journal of Mathematics, Science and Technology Education*, 14(6), 2493-2508.
- Ali, S., & Sabir, S. (2018, November). Developments in

- Mechatronics Engineering Education and Its Current Status in Pakistan. In *2018 IEEE 10th International Conference on Engineering Education (ICEED)* (pp. 69-74).
- Arop, B. A., Umanah, F. I., & Effiong, O. E. (2015). Effect of Instructional Materials on the Teaching and Learning of Basic Science in Junior Secondary Schools in CrossRiver State, Nigeria. *Global Journal of Educational Research, 14*(1), 67-73.
- Barger, M., & Gilbert, R. (2018, June), New mechatronics Education Initiatives Paper presented at 2018 ASEE Annual Conference & Exposition, Salt Lake City, Utah. 10.18260/1-2--30839.
- Berry, C., Gennert, M., & Reck, R. (2020, June). Practical Skills for Students in Mechatronics and Robotics Education. In ASEE annual conference exposition proceedings. ISSN: 2153-5868. 10184531.
- Bishop, Robert H. (2008). *The Mechatronics Handbook: Mechatronic Systems, Sensors, and Actuators, Fundamentals and Modeling*. Second Edition: CRC Press.
- De Baerdemaeker, J., Munack, A., Ramon, H., & Speckmann, H. (2001). Mechatronic systems, communication, and control in precision agriculture. *IEEE Control Systems, 21*(5), 48-70.
- Eichinger, P., Hofig, B., & Richter, C. (2017, September). Education 4.0 for mechatronics—agile and smart. In *2017 International Conference on Research and Education in Mechatronics (REM)* (pp. 1-7).
- Habib, M. K., Nagata, F., & Watanabe, K. (2021). Mechatronics: Experiential learning and the stimulation of thinking skills. *Education Sciences, 11*(2), 46.
- Haughey, J. R. (2018). Mechatronics and Academic Success: Towards understanding the impacts of age, major, and technical experience. DOI: 10.18260/1-2—3080
- Ibrahim, M. Y., Kahandawa, G., Choudhury, T. A., & Mazid, A. M. (2017 February). Industry-led mechatronics degree development in regional Australia. In *2017 IEEE International Conference on Mechatronics (ICM)* (pp. 419-424).
- Ijaduala, J., 1997. The Effect of Instructional Materials on the Learning and Teaching of Economics.
- Irwin, J. L., & Minerick, A., & Sergejev, A. (2021, December), Innovative and Interdisciplinary Approach for Offering the Master of Science Degree in Mechatronics Paper presented at 2020 CIEC, Virtual.
- Isiramen, O. E. (2018). Design and implementation of an automatic conveyor sorting system (Doctoral dissertation, Murdoch University). <https://researchrepository.murdoch.edu.au/id/eprint/44957/>
- Jadhav, P. S., Mulla, A. M., & Jadhav, P. M. (2017). Blending ICT with Project based Learning for effective teaching and learning of Mechatronics. *Journal of Engineering Education Transformations, 30*(3), 47-51.
- Jiménez, R. (2018). Teaching Mechatronics Design: A Theoretical-Practical Approach. *International Journal of Applied Engineering Research, 13*(17), 13108-13117.
- Kamińska, Dorota; Zwoliński, Grzegorz; Wiak, Sławomir; Petkovska, Lidija; Cvetkovski, Goga; Barba, Paolo Di; Mognaschi, Maria Evelina; Haamer, Rain Eric; Anbarjafari, Gholamreza (2020). Virtual Reality-Based Training: Case Study in Mechatronics. Technology, Knowledge, and Learning, (), -. doi:10.1007/s10758-020-09469-z
- Kucera, E., Haffner, O., & Leskovský, R. (2018, January). Interactive and virtual/mixed reality applications for mechatronics education developed in unity engine. In *2018 Cybernetics & Informatics (K&I)* (pp. 1-5).
- Kuru, K., & Yetgin, H. (2019). Transformation to advanced mechatronics systems within new industrial revolution: A novel framework in automation of everything (AoE) *IEEE Access, 7*, 41395-41415.
- Lee, W. W., & Owens, D. L. (2004). Multimedia-based instructional design: computer-based training, web-based training, distance broadcast training, performance-based solutions. John Wiley & Sons.
- Marzano, G., Martinovs, A., & Ušča, S. (2019, June). Mechatronics education: needs and challenges. In ENVIRONMENT. TECHNOLOGIES. RESOURCES. *Proceedings of the International Scientific and Practical Conference* (Vol. 2, pp. 214-217).
- Pepito, Joseph C. (2018). Industry Feedback-Based Mechatronic Program Enrichment. *International Journal of New Technologies in Science and Engineering, Volume 5*, Issue 4. ISSN 2349-0780.
- Priesterjahn, C., Sondermann-Wolke, C., Tichy, M., & Holscher, C. (2011). Component-Based Hazard Analysis for Mechatronic Systems. 2011 14th IEEE International Symposium on Object/Component/Service-Oriented Real-Time.
- Rohde, Todd. (2008). *The Straight Dope on Mechatronics*. Yaskawa America, Inc. – Drive and Motion Division.
- Shivaprasad, B. S., Ravishankara, M. N., & Shoba, B. N. (2014). Design and implementation of seeding and fertilizing agriculture robots. *International Journal of Application or Innovation in Engineering & Management (IJAIEEM), 3*(6), 251-255.
- Stankovski, S., Tarjan, L., Skrinjar, D., Ostojic, G., & Senk, I. (2009). Using a didactic manipulator in mechatronics and industrial engineering courses.

IEEE Transactions on education, 53(4), 572-579.

- Stankovski, Stevan; Ostojic, Gordana; Zhang, Xiaoshuan; Baranovski, Igor; Tegeltija, Srdan; Horvat, Sabolc (2019). [IEEE 2019 18th International Symposium INFOTEH-JAHORINA (INFOTEH) - East Sarajevo, Bosnia and Herzegovina (2019.3.20-2019.3.22)] 2019 18th International Symposium INFOTEH-JAHORINA (INFOTEH) - Mechatronics, Identification Tehnology, Industry 4.0 and Education. 1–4.
- Usman, K. O., 2002. The need to retrain in service mathematics teachers for the attainment of objectives of Universal Basic Education (UBE). *The Journal of the Mathematical Association of Nigeria ABACUS* 27, (1): 37-44.
- Yu, Y., Ji, Z., Han, J., & Zhang, Z. (2020). Episode-based prototype generating network for zero-shot learning. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (pp. 14035-14044).