Developing an Industry 4.0 Mobile Training Unit for Industrial Engineering Education

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Abstract
To remain abreast of the latest and ever developing technologies and paradigms of Industry 4.0, workers, students and trainers must continuously train and gain new skills and knowledge. Training content and methods are therefore required which effectively support knowledge transfer. From research previously carried out, via a questionnaire reaching over 200 participants, it has emerged that learners wanting to gain knowledge in Industry 4.0 topics have an active learning style. An active learning style means that learners learn best when they experience a situation and tend to retain and understand information best by doing something active with it such as in a laboratory or demonstration session. This coupled with the increasing difficulties of teaching and learning within industrial engineering education means that there is a need for an innovative solution to tackle this problem. This research work has therefore resulted in an Industry 4.0 mobile training unit which can complement the traditional training content and allow the learners to embark on a participative experience, hence leading to a more effective knowledge transfer.

Keywords: Industry 4.0, Engineering Education, Skills, Pedagogy, Demonstrator

Introduction

Developments relating to the Industry 4.0 revolution are driving technology and new concept development within industry at such a fast pace that even Higher Education Institution (HEI) educators are finding difficulties to catch up with these changes. Industrial engineering professionals need not only keep abreast of the latest industrial engineering technologies, but also learn new techniques and skills from the digital aspect, such as machine learning, Internet-of-Things (IoT), and cybersecurity concepts. These skills mismatches currently existing within HEIs imply that difficulties are being encountered in transferring knowledge effectively to a new generation of learners.

Furthermore, new paradigms of education are required to match the learning styles and preferences of a new generation of learners who are not necessarily engaged in the traditional “ex-cathedra” approach to knowledge transfer. From the research carried out as part of the ICARUS Erasmus+ project (icarusproject.edu.mt) it was concluded that learners wanting to gain knowledge in Industry 4.0 have an active learning style. This emerged as part of wider-ranging questionnaire which was distributed amongst over 230 participants with an industrial engineering background in various European countries. A predisposition to an active learning style means that they learn best when they experience a situation and tend to retain and understand information best by doing something active with it, such as in a laboratory or demonstration session.

It is here therefore being hypothesised that a new generation of learners within HEIs, who are accustomed to easy access to information via the internet, need to be engaged into gaining a deeper knowledge and understanding of industrial engineering concepts by being engaged in a real-time as well as participative use and demonstration of key-concepts and technologies.

In order to develop this active and engaging learning experience, training content and methods are therefore required which effectively support knowledge transfer. Therefore, the aim of this work is to develop an Industry 4.0 mobile training unit which could complement the training content and allow the learners to embark on a participative experience, hence leading to a more effective knowledge transfer.

Literature Review: A State of the Art of Training Systems for Industry 4.0

The concept of active learning within manufacturing is not a new one and has been discussed and approached differently within industrial engineering education. A number of approaches have been developed to encourage participative learning and effective knowledge transfer such as the learning factory concept. A number of these learning factory concepts have been well documented by Abele et al. (Abele et al. 2015) and can be used to address various requirements not strictly limited to education. One of the main concepts of the learning factory is that learners can train in a realistic training environment, as well as bringing the learning experience closer to an industrial scenario. An excellent implementation of this concept is presented by Matt et al. (Matt, Rauch, and Dallasega 2014) as the “Mini-Factory” at the Free University of Bolzano. This implementation demonstrates a number of industrial engineering concepts, from planning and assembly task analysis to robot programming and control. Another implementation of the learning factory within an educational environment is the “Automated Class Room” at the University of Applied Sciences Emden/Leer (Wermann et al. 2019). That said, learning factory approaches are typically limited to particular environments and do not allow for portability of a setup. Furthermore, their main objectives is to provide a hands-on learning approach in the lab, rather than providing a pedagogical approach to active learning in the classroom.

In a bid to improve training effectiveness researchers have also used Industry 4.0 technologies such as Virtual Reality and Data Mining to develop training systems (Roldán et al. 2019). In this case though, the approach is best suited for task training by operators within industrial environments, rather than targeted towards effective knowledge transfer of Industry 4.0 concepts in the HEI classroom. A number of works have also developed technology demonstrator type setups, but these are typically limited to a particular technology rather to provide training in over-arching Industry 4.0 concepts. One example of such an implementation is the robot process planning approach developed by (Erős et al. 2021). Whilst this is a good example of a technology demonstrator it is very limited to a particular application.

This literature review of the state of the art in training demonstrators for Industry 4.0 shows that there is a lack of portable demonstrators which effectively integrate training material in a range of applications and Industry 4.0 technologies. The aim of this research is therefore to develop an Industry 4.0 mobile training unit for effective and active industrial engineering education.

Research Methodology

In order to address this gap, and as part of the ICARUS project, an Industry 4.0 Mobile Training Unit is being developed. The systematic research methodology being employed is based on the User Centered Design Approach (Gulliksen et al. 2003). As shown in Figure

1, the first step of this approach is to adopt a structured approach to understand the user needs. For this work two types of users where considered. One set of user is the target of the training unit, i.e. the industrial engineering learner in an HEI. The other set of users are the trainers who will make use of the setup in a training environment. A set of design requirements are then developed based on user input in order to effectively develop a training unit which targets the actual user needs. This analysis of the requirements leads to the design of an Industry 4.0 Mobile Training Unit. The next and final step of this work will be to build the demonstrator and evaluate it with learners in a participative learning activity.

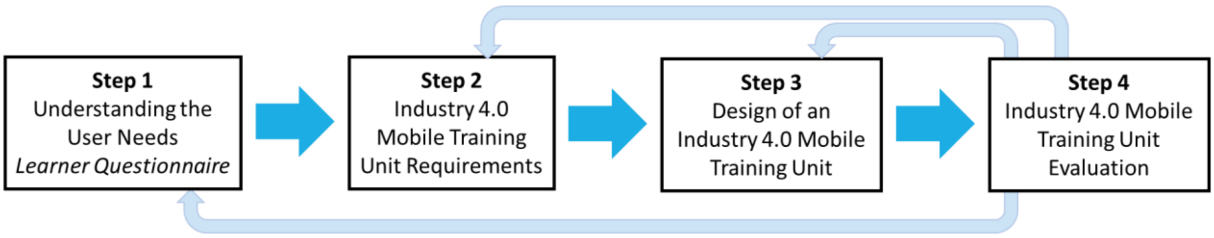

Figure 1: User Centered Design Approach

Mobile Training Unit Requirements

To understand better the user needs for a mobile training unit an online questionnaire was designed. This questionnaire which was distributed amongst a number of potential Industry 4.0 learners from European countries for a total of 231 respondents. The respondents overwhelmingly (96%) prefer an active training unit which allows them to interact in real-time with the technology.

Furthermore, a majority (63%) of the trainers responding to the questionnaire would also need to transport this mobile training unit not only within their own institution but also to other entities or to participate in specific training events. From these respondents the choice of vehicle to be used for transportation is a mix of private vehicles (40%) and rental vans (60%). These requirements provide an input in terms of the modularity and dimensions and weight of the training unit.

Based on an analysis of the questionnaire results as well as the aims of this project the specifications for an Industry 4.0 mobile training unit were drawn up. These are described in Table 1.

Active	The unit must allow active learners to interact in real-time with the setup during the learning experience.
Integrated	The Mobile Training Unit capabilities must be integrated/paired with the learning content on specific technologies/concepts.
Demonstrate	Topics such as Collaborative Robotics, Cyber Security and Data Integration and analysis needs to be implemented to allow for various Industry 4.0 approach and technology demonstration.
Transportable	The system must be transportable both internally and externally within the institution. Dimensions and weight therefore have to suite the transportation requirements.
Modular	Allow for a degree of modularity to allow customisability depending on the training or transportation needs.

Table 1: Specifications of an Industry 4.0 Mobile Training Unit

Results: The Design of an Industry 4.0 Mobile Training Unit

An Industry 4.0 mobile training unit was therefore designed in order to meet these specifications. This mobile training unit has been designed to demonstrate a number of Industry 4.0 technologies such as Collaborative Robotics, 3D Printing, Augmented Reality, Industrial Internet of Things (IIoT) and Artificial Intelligence. As shown in Figure 2 a UR3 robot by Universal Robots is used for the collaborative robotics aspect.

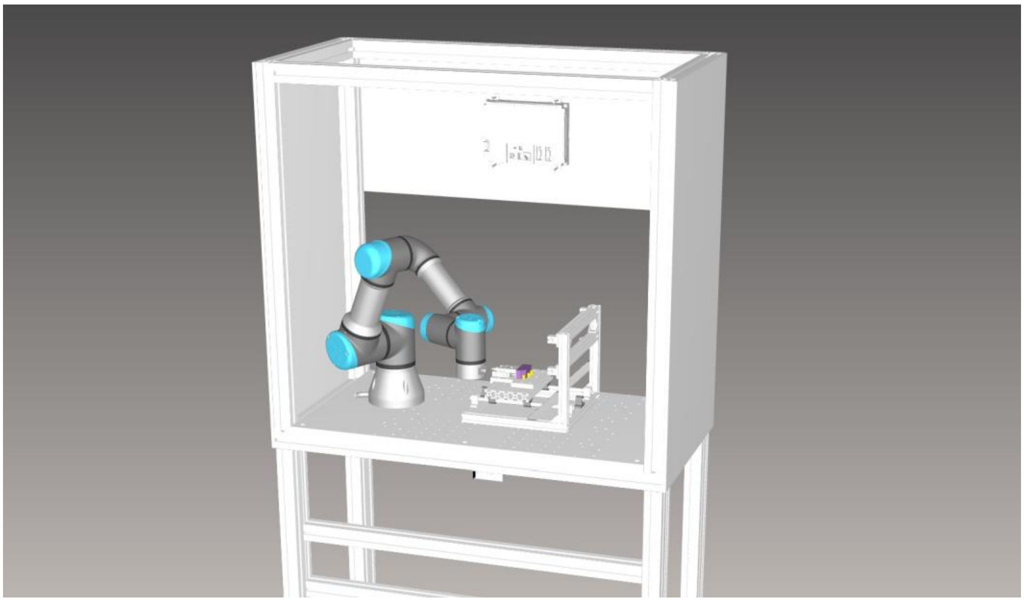

Figure 2: Concept of Modular Industry 4.0 Mobile Training Unit

This robot has been selected and is at the centre of this design as it can demonstrate a number of Industry 4.0 technologies and concepts including:

- Collaborative robotics and human robot interaction
- Robot programming and task planning
- Cybersecurity demonstrations and exercises
- Safety engineering methodologies and concepts

Further to the UR3 robot a desktop 3D Printer by Creality for the 3D printer. Industrial Ethernet protocols are used to connect the robot and 3D printer to a PLC (OMRON NX102). AR and VR models of the setups and products loaded onto the machine have also been developed in order to demonstrate the functionality of these technologies. These selections have been made to demonstrate the concepts of IIoT, data mining and cloud-based systems for real-time data collection and analysis from various PLCs and controllers via the OPC-UA communications protocol.

Discussion

The conceptual design solution as described in the previous section is the main contribution of this work. It is aimed at achieving the objective of this research, i.e. an Industry 4.0 mobile training unit for effective and active industrial engineering education. A number of Industry 4.0 technologies are implemented within the training unit, hence the aim of demonstrating a range of technologies is achieved.

The training unit is also coupled with the congruent training material for the different technologies and Industry 4.0 concepts such as AI, data mining, collaborative robotics, AR and VR. Both this Industry 4.0 training unit as well as the training material have also been developed as an open-source project, and these will be made available under an academic free license for other HEIs to develop and customise accordingly to their specific user requirements. Furthermore, as a systematic and guided approach, trainers can utilise the user centred design approach proposed by this work to customise the training unit to the specific needs and requirements of their industrial engineering learners, be these currently undergoing training in HEIs or as well in industry.

That said at this stage of this research the effectiveness of this training approach can still not be quantified and determined, since the actual training unit has not been implemented and tested within an actual training environment. Therefore, to confirm whether the overall aim and objectives of this research have been achieved this Industry 4.0 training unit would have to be used in a classroom set up to see whether not only have the design requirements been met, but whether the active training approach being proposed here is more effective than the traditional training methods.

A further note has to also be said about the actual design solution proposed here and the limitations of this research. As proposed by the user centred design approach the design solution is constrained or dependent on the users who were part of the study. Whilst a good sample size was adopted, it still could skew the design to a particular notion or direction, and hence lack generalisation for every training situation or user. There are still learners who prefer and perform better within a traditional approach to teaching were the student is more passive towards receiving knowledge and information from the professor. That being said, this approach to developing active training and pedagogical approaches aimed at increasing the effectiveness of knowledge transfer can be used as a guide for the development of innovative training practices.

Conclusion

Whilst as discussed in the previous section the Industry 4.0 training module here presented is still to be implemented and evaluated in a learning context, it is expected that this approach of integrating learning content with an active demonstrator will improve the effectiveness of the training content.

Furthermore, by making this setup portable it can be used within classrooms and everyday teaching, in order to demonstrate Industry 4.0 technologies to HEI students, as well as making it transportable to Industry for specific training sessions.

In future work this research will continue to develop new and innovative knowledge transfer approaches which will complement this test bed in order to move away from the traditional “ex-Cathedra” lecturing approaches used in HEIs, and implement active and participative training methods.

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