AN INVESTIGATION AND DEVELOPMENT OF HIGH LEVEL CONTROL ENGINEERING TRAINING PACKAGES FOR HIGHER EDUCATION AND INDUSTRY

Ali Elseddig Jwaid

A thesis submitted in partial fulfilment of the requirements of Nottingham Trent University for the degree of Doctor of Philosophy

College of Science and Technology
Nottingham Trent University

2016

ABSTRACT

This study investigates using the best technological pedagogical approaches for teaching in Higher Education (HE) in Science, Technology, Engineering and Mathematics (STEM), using Control Engineering as a case study. Five objectives directed the study: first, it examined tutors' understanding of integrated technology to pedagogy and content; second, it developed a self-assessment instrument of understanding integrated technology, content and pedagogy for tutors in HE; third, it examined approaches to selecting the content and developing the curriculum; fourth, it developed a teaching and learning framework for HE to meet the needs of students and the industrial sector; finally, it implemented and assessed this framework in real modules at Nottingham Trent University at undergraduate and postgraduate levels. The Technological Pedagogical and Content Knowledge framework (TPACK) guided this study and the instrument was developed to assess the tutors' understanding of the TPACK framework in HE.

The study used qualitative and quantitative approaches (mixed methods) under the post-positivist and constructivist paradigms (worldview). Through the use of purposive sampling, a total of 111 tutors and 120 students responded to the study. The questionnaires were used as a quantitative method, and semi-structured interviews, open-ended questions, observations and the literature review were used as qualitative methods. Quantitative data was analysed using the Statistical Package for the Social Sciences (SPSS). Principal Component Analysis (PCA) was used to check the validity of the instrument; Cronbach's alpha was used as a reliability measure; t-test, correlation and regression were performed to examine the effectiveness of implementing a new pedagogical HE framework which was developed based on TPACK.

The findings disclosed the validity of the TPACK framework in HE for control engineering teaching and indicated the likely benefits for HE STEM education in general; and they enabled the development of a self-assessment instrument for tutors in HE. The validity and reliability have been demonstrated in English; and the initial work on translation to Arabic is positive (originally, a case study was planned in Libya). The instrument helps to assess tutors in-service and pre-service training for Continuing Professional Development (CPD). This research proposes a training model within TPACK for tutors in HE, based on factor analysis (PCA) results, which clarify the most appropriate path to follow in particular training courses based on the real needs of the participant tutors. Finally, the research developed and investigated a new pedagogical framework (the AJ Framework) for teaching and learning in HE STEM and confirmed the effectiveness at BSc and MSc levels in control engineering.

This study recommends that training in TPACK and the AJ Framework would provide HE tutors with wider understanding of technology-enhanced teaching and learning. Also, that there is a need to integrate the student feedback system (student evaluation surveys for modules and courses) with the rest of the NOW system (Nottingham Trent Online teaching and learning Workspace). Potential areas of other future work are discussed.

Acknowledgements

In the beginning, I would like to thank Allah sincerely for all blessings and bounties, then I would like to extend my deep thanks and gratitude to all the people who contributed to enrich my knowledge and improve my competencies. First, I am grateful to my parents, their daily prayers and enormous efforts to make me who I am; I will never have been here without your extensive support, be it moral, financial and spiritual.

I would also like to extend my deep thanks and gratitude to my wife Amna who accompanied me along the happy journey of knowledge, and who wonderfully created the right atmosphere for me to bring this research to fruition, while my family were suffering from my absence from them. I would to thanks my kids Salima, Fatima, Seddig and Ahmed for their patience and support.

A big "thank you" goes to my wife's family; all my relatives; and friends. You were my social network that kept me and supported me during my PhD research.

I would like to convey my special thanks to my supervisors Dr Steve Clark and Prof Gren Ireson for their continuous support and guidance throughout the course of my PhD study. They have been excellent and supportive supervisors who not only guided me in my research but also helped me develop my professional career by supporting me to attend international conferences to present my work and to attend several training workshops. I would also like to extend my gratitude to my supervisor Prof Paul Evan for his wise input and guidance with regards to this research.

I would like to express my deep thanks and gratitude to Dr Kofi Appiah, who provided me with chance to implement my framework in his module, and Dr Robert Ranson my ATL, for his support, including attending international conferences.

Also, I would like to express my deep thanks of gratitude to Mr Mohammed Habbes, (Mr Ahmed Sweti and his wife), Mr Alzain Alzain, and Mr Khaled Haider for translation revision and back translations. Also, I would like to thank all of the academic, researchers, students, and industrialists who have assisted in this research in various ways.

Without encouragement and support from everyone above, this study would not have been completed.

Ali Elseddig Jwaid
August 2016
Nottingham Trent University, UK

Publications

Accepted for publication in IEEE Xplore

- **Jwaid, A.E.**, Clark, S. and Ireson, G., 2014, March. Understanding best practices in control engineering education using the concept of TPACK. In *Integrated STEM Education Conference (ISEC), 2014 IEEE* (pp. 1-6). IEEE.
- Alzain, A.M., Ireson, G., Clark, S. and **Jwaid, A.E**, 2016, December. Learning style instruments and impact of content: A qualitative study. In *Sustainable Technologies (WCST), 2016 World Congress on* (pp. 109-114). IEEE.
- Howedi, A. and **Jwaid, A.E**, 2016, December. Design and implementation prototype of a smart house system at low cost and multi-functional. In *Future Technologies Conference (FTC)* (pp. 876-884). IEEE.
- Alzain, A.M., Clark, S., Ireson, G. and **Jwaid, A.E**, 2016, December. A study of the reliability and validity of the first Arabic learning styles instrument (ALSI). In *Sustainable Technologies (WCST), 2016 World Congress on* (pp. 29-34). IEEE.

Accepted Journal paper

- Alzain, A.M., Clark, S., Ireson, G. and **Jwaid, A.E**, 2017. Learning Style Instruments: Impactions of Content. *The International Journal of Sustainable Energy Development (IJSED).*

In preparation (Journal papers)

- **Jwaid, A.E.**, Clark, S. and Ireson, G., Alzain, A.M., A Study of the TPACK framework in Higher Education in a School of Science and Technology.
- **Jwaid A.E**., Clark S., and Ireson G. "Novel framework for Teach Process Control Engineering by using The Concept of TPACK".
- **Jwaid A.E**., Appiah K., S. Clark, and G. Ireson. Testing AJ framework, implementation and evaluation for BSc embedded system module".

Other publications accepted for publication in IEEE Xplore

- Al-Shamma, N. and **Jwaid A.E**., 2016, December. Exploring the potential in utilising smartphones to aid in the treatment and management of inflammatory bowel disease. In *Future Technologies Conference (FTC)* (pp. 696-700). IEEE.
- Zubair, A., **Jwaid, A.E.** and Salih, A., 2016, December. Analysing denial of service attack traffic signature in IPv6 local network using correlation inspection. In *Future Technologies Conference (FTC)* (pp. 1008-1013). IEEE.
- Al-Shamma, N. and **Jwaid A.E.**, 2017, Intelligent Systems and Inflammatory Bowel Disease: Exploring the Potential for Outpatient Support, In *Computing conference.*
- Linn T., **Jwaid A.E.**, and Clark, S., 2017, Smart Glove for Visually Impaired, In *Computing conference*.
- Teyabeen, A. and **Jwaid, A.E.**, 2017, March. Sunshine Duration-Based Models for Predicting Global Solar Radiation. In *Computer Modelling and Simulation (UKSim), 2017 UKSim 19th International Conference*. IEEE.
- Teyabeen, A., Akkari F. A and **Jwaid, A.E.**, 2017, March. Power Curve Modelling for Wind Turbines. In *Computer Modelling and Simulation (UKSim), 2017 UKSim 19th International Conference*. IEEE.
- Teyabeen, A., Akkari F. A and **Jwaid, A.E.**, 2017, March. Comparison of Seven Numerical Methods for Estimating Weibull parameters for Wind Energy Applications. In *Computer Modelling and Simulation (UKSim), 2017 UKSim 19th International Conference*. IEEE.

Under review

- Teyabeen, A. and **Jwaid, A.E**, 2016. Mathematical Modelling, Simulation, and Validation of Photovoltaic Modules, Journal of Electrical Systems. (under-review).

List of abbreviations and variables

ADDIE	Analysis, Design, Development, Implementation and Evaluation model
AIPC	Applied Industrial Process Control
ATL	Academic Team Leader
BCS	British Computer Society
CCS	Controls Curricula Survey, IEEE Control Systems Society
CIT	College of Industrial Technology
CPD	Continuing Professional Development
CVI	Content Validity Index
EvaSys	Evaluation System, NTU uses to survey student feedback for modules.
FCIT	Florida Centre for Instructional Technology
FE	Further Education
FPGA	Field-Programmable Gate Array
HE	Higher Education
HEIs	Higher Education Institutions
HIEV	Higher Institute of Engineering Vocations
HIPT	Higher Institute for Polytechnics
ICT	Information and Communication Technologies
I-CVI	Item-Content Validity Index
IDE	Integrated Development Environment (for Arduino)
IEEE	The Institute of Electrical and Electronics Engineering

IET	The Institution of Engineering and Technology
ISD	Instructional System Design
IT	Information Technologies
JICEC	Joint Inter-College Ethics Committee
KMO	Kaiser-Meyer-Olkin
KTN	The Knowledge Transfer Network
LATi	Loughborough Advanced Technology innovation
LISCO	Libyan Iron and Steel Company
MOE	Margin of Error
MU	Misrata University
NOW system	Nottingham Trent Online teaching and learning Workspace
NSS	The National Student Survey
NTU	Nottingham Trent University
PBL	Project Based Learning
PCA	Principal Component Analysis
RQ	Research Question
SIPS	School Industrial Partnership initiative
SPSS	Statistical Package for the Social Sciences
SST	School of Science and Technology
STEM	Science, Technology, Engineering and Mathematics
TAM	Technology Acceptance Model
TEF	Teaching Excellence Framework

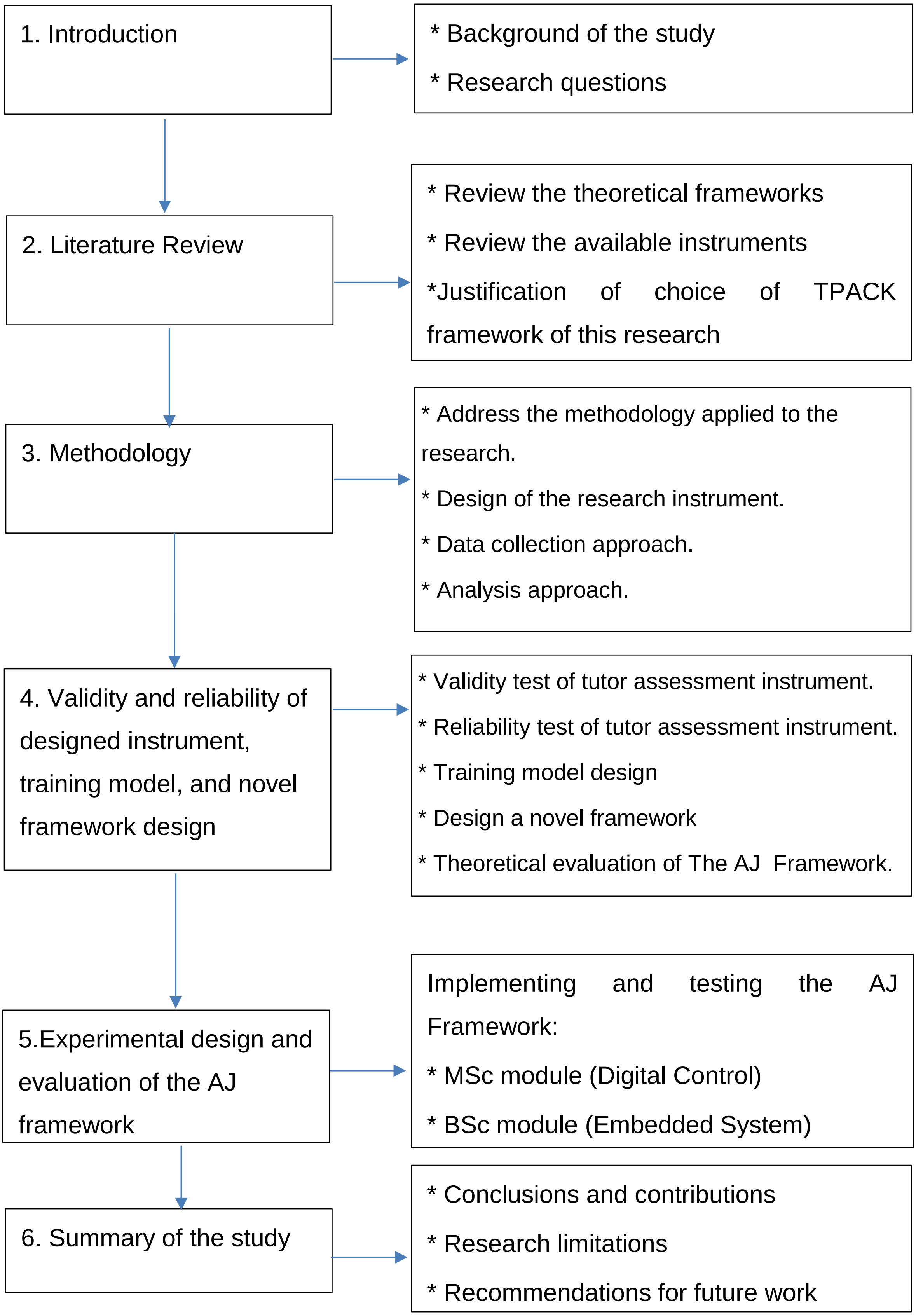
TEL	Technology-Enhanced Learning
TIM	The Technology Integration Matrix framework
TPACK domains	
TPACK	Technological Pedagogical and Content Knowledge
TPCK	Same TPACK, used in some references
TK	Technological Knowledge
PK	Pedagogical Knowledge
CK	Content Knowledge
PCK	Pedagogical Content Knowledge
TCK	Technological Content Knowledge
TPK	Technological Pedagogical Knowledge
The AJ Framework	Ali Jwaid’s Educational framework developed based on the TPACK framework
TPACK HE	Technological Pedagogical and Content Knowledge for Higher Education

Contents

List of Figures

List of Tables

Structure of the Thesis



1. Chapter one: Introduction

This chapter provides an introduction to the study, including a research statement, aims and objectives. It also covers the challenges, potential and rationale of the research, and a synopsis of the PhD thesis.

There are many researchers working to enhance teaching in engineering subjects: universities, colleges, industry and professional bodies (e.g. IEEE, IET). Also, there are many research projects in university Education departments covering theoretical pedagogical approaches in STEM teaching. This work attempts to examine the much smaller overlap between these two significant areas.

The focus in this research is improving formalised pedagogical approaches for practical use in HE level control engineering teaching and training. The researcher is a control engineer who has experience in UK and Libyan Higher Education (HE) alongside industrial experience in Libya.

1.1 Background of using technology in Higher Education

The importance of education is obvious for all, to achieve a better life. It is an aim that all can strive to achieve, at any level. The HE level is a significant element for human development, society and industry.

In the last two decades, use of technology has been growing fast in both educational (Garrett, 2014) and commercial institutions (R. C. Clark & Mayer, 2016; Zaharias & Poylymenakou, 2009). The use of technology as an educational tool, for example, has been adopted within companies where the “continuous education and training” of employees for human resource purposes “is critical to an organization’s success” (Zaharias & Poylymenakou, 2009, p.1).

Technology-Enhanced Learning (TEL) solutions can potentially offer a learning environment which acknowledges a student’s individual differences and thus aid in delivering tailored support which enables the learner to acquire the desired knowledge and skills at a time, place and pace that is appropriate for their own particular circumstances (Aljojo, 2012). In countries such as Malaysia, ICT has been adopted in education, both within the public and private domain, in an attempt to alleviate the pressures placed on the education system (Lye, 2013) and it was found that the use of ICT in education was shown to aid student engagement and encourage better interaction between the student, their instructors and their peers. That is not to say that the use of ICT in education is not devoid of challenges. Poor system design, a lack of technological support and unstable internet connections risk hindering the educational experience, while the use of technology was seen to lead to some plagiarising work (Lye, 2013).

Teaching in HE relies on a diverse range of knowledge, the foundation of which is rooted in both pedagogical comprehension and mastery of the content. In addition to pedagogical and content knowledge, the incorporation of technological knowledge has been gaining traction, paving the way for an educational framework in schools advocating Technological, Pedagogical and Content Knowledge (TPACK) (Ashe & Bibi, 2011). The TPACK framework aims to provide teachers with the concept of effective design of technology enhanced learning (Mishra & Koehler, 2006).

Advancements in modern technology has encouraged the development of teaching strategies which incorporate the use of technology in HE (Huffman, Whetten, & Huffman, 2013), thus necessitating the need for adopting technological knowledge within a teaching framework. There is, however, a lack of research into how TPACK can be implemented within HE (M. C. Herring, Meacham, & Mourlam, 2016). The success of TPACK within pre-university education warrants an investigation into the potential adoption and effectiveness of TPACK in HE. Therefore, this research assesses the practical application in control engineering HE courses of use of the TPACK framework.

1.2 Research Statement (Problem Statement)

Most control engineering HE courses are designed based partly on ad-hoc methods, by using technology often with little consideration of pedagogical methods. Fox (2002) stated, “I argued that the question was no longer whether educational institutions should embrace the new technologies, but where to use them and how they should be used to best advantage”. Technology offers the probabilities of improved learning environments but the number of questions has increased about effectiveness, accountability, implementation and facilitation of technology in teaching and learning focus, learning style and pedagogy (J. Campbell & Oblinger, 2007).

Lye (2013, p.295) mentioned that "Technology brings opportunities to the educational fields but it comes with unsolved challenges to the teaching and learning process". Many researchers argue that, successful Information and Communications Technologies (ICT) implementation in education necessitates adjustment of module content for the selected technology and pedagogical approach (Rienties, Brouwer, & Lygo-Baker, 2013).

The cost of establishing traditional control systems and robotics study programs usually runs into many thousands of pounds. As a result, many undergraduate and graduate institutions especially in developing countries are unable to establish these important programs in their curriculum. Therefore, questions remain on how can we make sure that using common educational microcontroller, equipment and simulations software meet the educational and industrial needs (Balogh, 2010; Candelas et al., 2015; Ricks, Jackson, & Stapleton, 2008).

In regards to the selected framework, 'TPACK', for this study (see Section 2.3), the TPACK instruments in use, at present, have been unable to establish an acceptable level of discriminant validity of the TPACK constructs (L. Archambault & Crippen, 2009; L. M. Archambault & Barnett, 2010; Schmidt et al., 2009; Smith, 2010). It is clear that teaching control engineering subject area needs to be investigated, especially with the TPACK framework. Therefore, based on the above statements the following research questions have been set:

1.2.1 Research Questions

The research questions are divided into general research questions and specific research questions, as follows:

i. General research questions

1- How can TPACK be used to improve teaching and learning in HE? (Test the validity and reliability of the TPACK framework in HE)]
2- How can a validated TPACK self-assessment instrument be produced?
3- How can the validated instrument be applied to Continuing Professional Development (CPD) training courses?
4- How can TPACK training models be adapted to accommodate tutors?
5- What is the impact of implanting a TPACK framework on tutor performance?

6- What is the impact of implanting a TPACK framework on student engagement and performance?

ii. Specific research questions

1- How effective is a TPACK framework in enhancing student engagement and performance?
2- Do correlations call into question whether or not technology content (TCK), technological pedagogy (TPK), and technological pedagogical content knowledge (TPACK) are distinct domains?
3- How can we improve the accommodate of industrial needs?
4- What are the best strategies that can be used to optimise tutor and student performance in HE?
5- Which TPACK domain should the CPD trainers start with to improve in-service tutors?

1.3 Research Aims

This research explored how to improve teaching and learning in Science, Technology, Engineering and Mathematics (STEM) subject areas in HE with the main focus on control engineering, by using a modified TPACK framework to fit HE and industrial needs.

1.4 Research Objectives

The purpose of this research in using TPACK is to investigate the theoretical and practical application of both software and hardware technology tools alongside the underlying pedagogy and its associated application, in control and the embedded systems subjects; which are heavily based on mathematics and programming. In addition, students and engineers need to be taught theoretical knowledge and given guidance on how to apply this knowledge in practical ways.

The researcher implemented this study in the Computing and Technology department of Nottingham Trent University (NTU), by undertaking a pedagogical improvement project (research) with a focus on a Digital Control and an Embedded Systems module as core subjects in MSc Electronic Engineering; and BSc Computer System curriculums, respectively.

The research investigates ways of improving the approaches to teaching and training of design in control and embedded systems, which may be processed to produce an efficient framework using the following objectives:

- Analysis of current practice and literature of using technology in general and TPACK in specific;
- Development of new models based on the above;
- Design of a research TPACK instrument to collect feedback from participants;
- Analysis of collected data; and adapt new models as appropriate.

An initial objective was to work towards a further case study within Libyan HE, which due to unforeseen circumstance was not possible. More details about selecting Libya as a case study are described in section 1.9.

1.5 Original Contribution to Knowledge

This research is the first reported investigation into the use of TPACK for improving control engineering related subjects in HE.

This research broadly evaluated and assessed the outcomes and impacts associated with TPACK pedagogical approaches to teaching control engineering in HE. Pedagogical principles were integrated into a Digital Control module and an Embedded Systems module.

This research examined (in a Digital Control and an Embedded Systems module) the suitable techniques that can be used to produce teaching and training packages to improve the quality of student engineers, aligned in particular to industrial needs. This involved investigation of how tutors and trainers exploit computer-based technologies in supporting the learning of control and/or embedded systems modules at university and in HE level industry training. This research examined how pedagogical approaches associated with these technological tools are adapted to both the cognitive and physical resources available in the classroom/training setting.

A novel framework (the AJ Framework) was developed within TPACK to provide tutors the suitable pedagogical knowledge to select appropriate technology and content to enhance student performance and achieve industrial needs.

The AJ Framework was investigated for teaching and learning in HE, and effectiveness was confirmed at BSc and MSc levels in control and embedded systems modules.

The research has also contributed to the knowledge by producing a new TPACK instrument for HE tutors, and tested its validation and reliability.

The research has developed the first translated version in the Arabic language of a TPACK HE instrument, and validated the translation.

This research proposes a training model within TPACK for tutors in HE, which clarifies the most appropriate path to follow in particular training courses based on the real needs of the participant tutors.

1.6 The challenges in control and embedded systems education

Successful teaching and learning of control and embedded systems programming and hardware interfacing is challenging for several reasons. For example, the new version of microcontrollers have complex systems, with handbooks of more than a thousand pages. It takes a long time to become familiar with a microcontroller family in the detail necessary for course integration; a time-consuming task for a teacher or trainer (Reese & Jones, 2010).

Control topics have been covered in the Control Curriculum Survey (CCS) published by IEEE Control Systems Society (Cook & Samad, 2009); also, many textbooks (Bequette, 2003; Cheng, 2013), and several papers (Méndez & González, 2010).

Embedded systems are used in control applications and the curriculum needs in regards of embedded systems have been covered in the Computer Science Curriculum ACM/IEEE 2004 (Shackelford et al., 2006), ACM/IEEE 2013 (Sahami, Roach, Cuadros-Vargas, & LeBlanc, 2013) and ACM/IEEE2016 (Durant et al., 2014; Hodges, 2016). However, the increasing number and complexity of real world applications require the need for deeper understanding of embedded systems. The theoretical curriculum does not necessarily give students the chance to learn beyond the basic and predictable nature of digital embedded systems. A curriculum designed solely for the practical use of these systems may fail to address these key issues. Thus, it became necessary to teach engineering students to learn at the appropriate levels, and to have more detailed knowledge of theory and applications of embedded devices (Kuan, Tseng, Chen, & Wong, 2016; Ricks et al., 2008). Therefore, it is an essential duty for HE to update the contents of what they teach with respect to industrial needs. It is not an easy job (challenge) for the universities as Åström (2012) states that “we started teaching control and delivered the first course, then we learned a bit more, then we made a new more narrow course, then we learned more, then made a new even narrower course…. and so on. The courses become more and more specialized and this issue causes educational challenges as the specialist students need awareness of the subjects they interact with” (Jwaid A.E, Clark S, & Ireson G, 2014).

1.7 The potential of improving the content of Control and Embedded Systems modules

Generally, what industry needs from engineering graduates, in addition to practical skills, is evolution. The dynamic nature of embedded systems make the contents of modules shift (adjustment). Thus, more assessment is required to measure student performance (Ricks et al., 2008). On the other side, a student with a traditional control background would know about control algorithm design and analysis, but might not understand important issues that constrain the computational implementation of these algorithms. These issues go well beyond sampling and quantization taught in a typical course on digital control systems (Freudenberg & Krogh, 2005).

Indeed, a design team for an embedded control system application will require expertise that extends across traditional disciplinary boundaries. Skills required include (Freudenberg & Krogh, 2005; Marwedel, 2011; Wu, Liu, & Yin, 2015):

- Sensor calibration and resolution
- Interfacing actuators
- Real-time operating systems and systems-level interrupts
- Multi-threading and handling exceptions

As a result of continuous adjustment of the module content, there is a demand to design a framework to solve the challenges of industrial needs and at the same time be aware of pedagogical concepts.

1.8 The rationale for designing a new teaching framework

From a pedagogical perspective, traditional pedagogical strategies use lectures and textbooks, describing the system with laboratory exercises and a demand for full-time tutor supervision; which is often less motivating, as designing Embedded Systems modules with traditional pedagogical strategies can lead to unsatisfactory results (Freudenberg & Krogh, 2005; Lilja, Ollikainen, & Laakso, 2003; Méndez & González, 2010). Therefore, there is a need to design non-traditional pedagogical strategies. A wide range of HE institutions use blended learning strategies to teach control topics in engineering subjects (Méndez & González, 2010). Pedagogical blended learning strategies take advantage of technological advances to shape online learning and traditional (face-to-face) learning (Graham, Allen, & Ure, 2005). Many HE institutions use online courses and programmes (van Rooij & Zirkle, 2016) which increase the opportunity of optimising the advantage of both, face-to-face and online learning environments. The challenge is surrounding the design and development of a blended learning sound pedagogy online course (Graham et al., 2005; van Rooij & Zirkle, 2016).

This research tested a new pedagogical framework for HE to improve the progress of students, by accommodating the best of both learning environments (face-to-face and online learning) at the same time as taking into account the industry needs.

There is an existing framework that synthesizes technology and pedagogy with the content: the TPACK framework. It is a successful pedagogical framework, which introduces the effect of using technology in education (L. Archambault & Crippen, 2009; Graham, 2011; M. Herring, Mishra, & Koehler, 2014). (Graham, 2011) argues, “The technological pedagogical content knowledge (TPACK) framework has the potential to provide a strong foundation for future technology integration research. A strong TPACK framework can also provide theoretical guidance for how teacher education programs might approach training candidates who can use technology in content-specific as well as general ways” p.1959. Furthermore, many researchers recommend using the TPACK framework in HE teaching (Rienties et al., 2013). Therefore, after research the TPACK framework was selected to investigate the development of control and embedded systems teaching in HE.

1.9 The Libyan Higher Education (HE) system

As mentioned in Section 1.4 Research Objectives, the researcher's initial intention was to study the HE system at NTU as a case study of a developed country, then adapt and transfer it to Libya as a case study of a developing country. Thus, this section gives a brief overview of the Libyan HE system, and the motivation to select Libya to investigate and develop engineering HE.

In Libya, HE is categorized into three types of tertiary institutions: Universities, Technical Faculties and Higher Technical and Vocational Institutions.

A motivation of developing teaching in engineering HE in Libya in general, and control engineering and embedded systems in particular, is that Libya has many factories, oil fields and other service agencies, and needs qualified control engineers to solve their problems. To prepare them, suitable equipment and facilities are needed for teaching and training. All of these currently have high costs, because they often need high-level expertise and expensive training hardware and software, mainly imported from overseas (Abrahamson, 2004).

The previous and current political and economic circumstances in Libya not only disturbed the country's whole infrastructure but also gravely affected HE, which led to serious challenges being faced by the engineering education, some of these are listed below (Abod-her, 2013; Jwaid A.E et al., 2014; Rafik, Treadwell, Triki, Gupta, & Najah, 2010; Tamtam, Gallagher, Olabi, & Naher, 2011):

- Reliance on traditional approaches of learning.
- Absence of technology in learning and teaching.
- Deficiency of the material assets essential to execute the learning programs initiated by universities and higher education institutions (HEIs).
- Lack of effective strategic planning in universities and (HEIs).
- Deficiency of training programs for some teaching staff, essential for their development.
- Lack of expertise in the academic staff to effectively use modern technologies in teaching.
- Less than ideal collaboration and coordination between training centres and higher educational institutes.

The ongoing Libyan war and the associated political problems meant it was not possible to carry out most of the intended case study work in the country. Therefore, more work design, testing, and implementation was carried out at NTU. The established case studies are detailed in recommendation for future work in sub-section 6.3.4, p.171.

1.10 Synopsis of the PhD Thesis

How? " To Improve, Enhance and make HE sustainable?"

TEACHING SCIENCE AND ENGINEERING IN HE BY USING TECHNOLOGY

Why? "HE is a critical component of human development worldwide."

PhD study

As main aim of this research to improve teaching and learning in HE STEM, thus we need to focus on the context of learning which includes: Teaching, curriculum and assessment

Phases	**Phase one: Teaching** Assess teachers' understanding of integrating technology into the content and pedagogy	**Phase two: Content (curriculum) design**	**Phase three: implementation and assessment**
Objectives	Developed the instrument to be more appropriate for teachers in HE. Target groups: * In-service teachers at NTU, UK * In-service teachers at Misurata HE, Libya * Test validity and reliability of this developed instrument. * Comparing between them and give suggestions for improvement * Design Training Model.	Design and choose the content Make it fulfil the requirements of students: * Improve employability, or * Enhance their positions in their current job like MSc students and BSc students from partnership programmes. * Developed a framework that is clear for teachers in universities to follow and increase the quality of student learning and their performance.	Assessed tutors to fulfil the conditions in TPACK framework, by: Observation by peer. Student (understanding, engagement, performance, marks, and their feedback). Getting feedback from industrial sector through: * Industrial Liaison Forum * Knowledge Transfer Network * Industrial feedback through placement and career department in the university.
Methodology	CVI, pilot study, {quantitative research} statistical analysis, PCA, Cronbach Alpha, and. Arabic translation validation steps.	Theory development (building theoretical framework, first of all, identify essential variables, theoretical analysis. Quantitative research, CVI, and PCA. Collecting feedback from module leaders, course committee meeting, feedback from BSc, MSc students in Sandwich programme).	Implemented on: MSc module: Digital Control, three times and compare. BSc Module: Embedded Systems. Collected feedback from module leaders following our framework, observation, Students feedback.
Findings	Achieve validity and reliability – find a relation between domains. From results of PCA, we came up with a TPACK training model. This model gave solutions for the disagreement about which domain we should start with.	* Developed a novel "AJ Framework", implemented, validated, and evaluated. * Developed a training model for HE tutors. * Developed the first Arabic instrument for TPACK.	* Implementing the AJ Framework gave good effectiveness. * Improved student engagement. * Improved observation feedback for tutor and student engagement and performance.

Figure 1.1 The schematic representation of the workflow undertaken in the current PhD study

2. Chapter Two: Literature Review

2.1 Introduction

This chapter reviews the related literature and provides contextual background to the chosen framework of this research. It outlines TPACK related work in terms of instrument design and use of TPACK in HE. It describes the industrial needs in terms of pedagogy for the control and embedded systems subject area.

2.2 Teaching and learning models/frameworks:

This part overviews some of available teaching and learning frameworks which can be used to improve control engineering related STEM pedagogy. There are several teaching and learning frameworks discussed in the literature, in this section we tried to review the available frameworks, which use technology as a core domain.

Teaching in control engineering related STEM requires the use of many different types of knowledge. Including pedagogical and content knowledge, however, the technological knowledge has been attracting attention (Abdulwahed & Nagy, 2012).

2.2.1 Technological Pedagogical and Content Knowledge (TPACK)

The TPACK framework was described by Mishra and Koeher (2006) based on the concept of Pedagogical Content Knowledge (PCK) of Shulman (1986). Whilst Koehler and Mishra have both attempted to define and measure TPACK, the framework is still not regarded as being completely understood (Angeli & Valanides, 2009). To date, the explanations of TPACK and its associated constructs, that have been provided, do not allow for readers, or researchers in the field, to reach a consensus as to what is (or indeed, what is not) an exemplar of each construct (S. Cox & Graham, 2009). However, this work on TPACK has had an influence on the educational technology field. The TPACK framework has inspired teachers and tutors to re-assess their knowledge and use of technology in the classroom; including the description of TPACK instruments, and their use and validation (S. Cox & Graham, 2009). This study aims to apply PCA as a means of interpreting correlated components, thereby providing opportunities for researchers to better understand the TPACK model through statistical methods and qualitative methods (see Chapter 4).

2.2.2 The Technology Integration Matrix (TIM) framework

The Technology Integration Matrix (TIM) was developed by the Florida Centre for Instructional Technology (FCIT) throughout the 2005/2006 school year. FCIT used the ‘No Child Left Behind Act’ fund to create TIM (Murtaugh, 2011).

TIM clarify how teachers can use technology to enhance learning for ‘K-12’ level students, which covers pre-university education: kindergarten, primary and secondary school (Management Association, 2013).

“The TIM incorporates five interdependent characteristics of meaningful learning environments: active, constructive, goal directed (i.e., reflective), authentic, and collaborative. The TIM associates five levels of technology integration (i.e., entry, adoption, adaptation, infusion, and transformation) with each of the five characteristics of meaningful learning environments. Together, the five levels of technology integration and the five characteristics of meaningful learning environments create a matrix of 25 cells as illustrated Appendix ” (Florida Center for Instructional Technology, 2011).

2.2.3 The Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) has been developed by extending reasoned action theory (Davis Jr, 1986). “TAM is an information systems theory that represents how the user accepts and uses technology. The theory suggests that when users are presented with a new technology, their decision on how and when to use will depend on two belief constructs. One, the degree to which a person believes that using a particular system would enhance his or her job performance, the degree to which a person believes that using a particular system would be free from effort” (Kisanga, 2015, p.80).

The main purpose of TAM is to provide the foundation for outlining the influence of external variables on internal beliefs and behavioural intentions; and attitudes (Davis, Bagozzi, & Warshaw, 1989; Kisanga, 2015).

2.3 Justification of choosing the TPACK framework of this research

The literature shows that TIM framework has been designed to be used directly for school level. However, it included interesting features and guidelines for teachers to integrate technology in their teaching approaches, which motivated some researchers as (Kruger & Bester, 2014) to study the impact of it (TIM framework) at university level. Thus, these positive features have been already included in the TPACK framework (J. Harris & Hofer, 2009; J. Harris, Mishra, & Koehler, 2009; J. Harris et al., 2010; Mishra, 2014), where they mention the importance of identifying suitable activity types for learning specific topics.

In regards to the TAM model many researchers have studied this model (Cheon, Lee, Crooks, & Song, 2012; Ngai, Poon, & Chan, 2007; Park, 2009) including our colleague Dalton (Kisanga, 2015). As the aim of this research not only to test the used technology, but also to test and improve the content and link it to industrial needs with the respect of pedagogical aspects, which is not available in TAM model, thus the TAM model is less suitable for this research. The TPACK framework studies all these domains: content, pedagogy and technology.

Chai *et al.* (2013) argue, “Survey studies of other educators beyond K-12 in HE setting should be carried out to understand their notion of TPACK. This is especially so for the faculties in HE as they are likely to be the most important people to help form the pre-service teachers’ TPACK”.

As this research is designed to study the effectiveness of TPACK in HE. The strength of the framework and the areas that need more investigation have been covered as following:

2.3.1 Strength of the TPACK framework

TPACK has proved to be an interesting framework because it synthesizes technology and pedagogy with content in a way that has proved to be very helpful in the research literature (J. Harris et al., 2009; M. Herring et al., 2014; M. Koehler & Mishra, 2009; M. J. Koehler, Mishra, Kereluik, Shin, & Graham, 2014; Mishra & Koehler, 2006; Schmidt et al., 2009). It is a successful pedagogical framework, which introduces the effect of using technology appropriately in education (L. Archambault & Crippen, 2009; Graham, 2011; M. Herring et al., 2014). Graham

(2011) argues, “The technological pedagogical content knowledge (TPACK) framework has the potential to provide a strong foundation for future technology integration research. A strong TPACK framework can also provide theoretical guidance for how teacher education programs might approach training candidates who can use technology in content-specific as well as general ways”.

Archambault & Barnett (2010) stated, “TPACK is potentially useful, especially when conceptualizing how the affordances of technology might be leveraged to improve teaching and learning”. Furthermore, many other researchers recommended using the TPACK framework in teaching (Angeli & Valanides, 2009; L. M. Archambault & Barnett, 2010; Ashe & Bibi, 2011; Ay, Karadağ, & Acat, 2015; Cavanagh & Koehler, 2013; S. Cox & Graham, 2009; Garrett, 2014; Graham, 2011; J. Harris & Hofer, 2009; M. C. Herring et al., 2016; Jwaid A.E et al., 2014; Kafyulilo, 2012; Khan, 2011; M. J. Koehler et al., 2014; Koh & Chai, 2014; Mishra & Koehler, 2006; Rienties et al., 2013; Schmidt et al., 2009; So & Kim, 2009; Tømte, Enochsson, Buskqvist, & Kårstein, 2015; Yurdakul et al., 2012).

2.4 The concept of TPACK

TPACK, which is a modern pedagogical approach, is a “framework to understand and describe the kinds of knowledge needed by a teacher for effective pedagogical practice in a technology-enhanced learning environment”. The TPACK framework model essentially consists of seven domains, which are (1) Content Knowledge (CK), (2) Pedagogical Knowledge (PK), (3) Technology Knowledge (TK), (4) Pedagogical Content Knowledge (PCK), (5) Technological Content Knowledge (TCK), (6) Technological Pedagogical Knowledge (TPK), and (7) Technological Pedagogical Content Knowledge (TPACK). Of these seven domains, CK, PK and TK are the core domains whilst the other four are complementary domains. The three core domains are described below (Jwaid A.E et al., 2014; Mishra & Koehler, 2006).

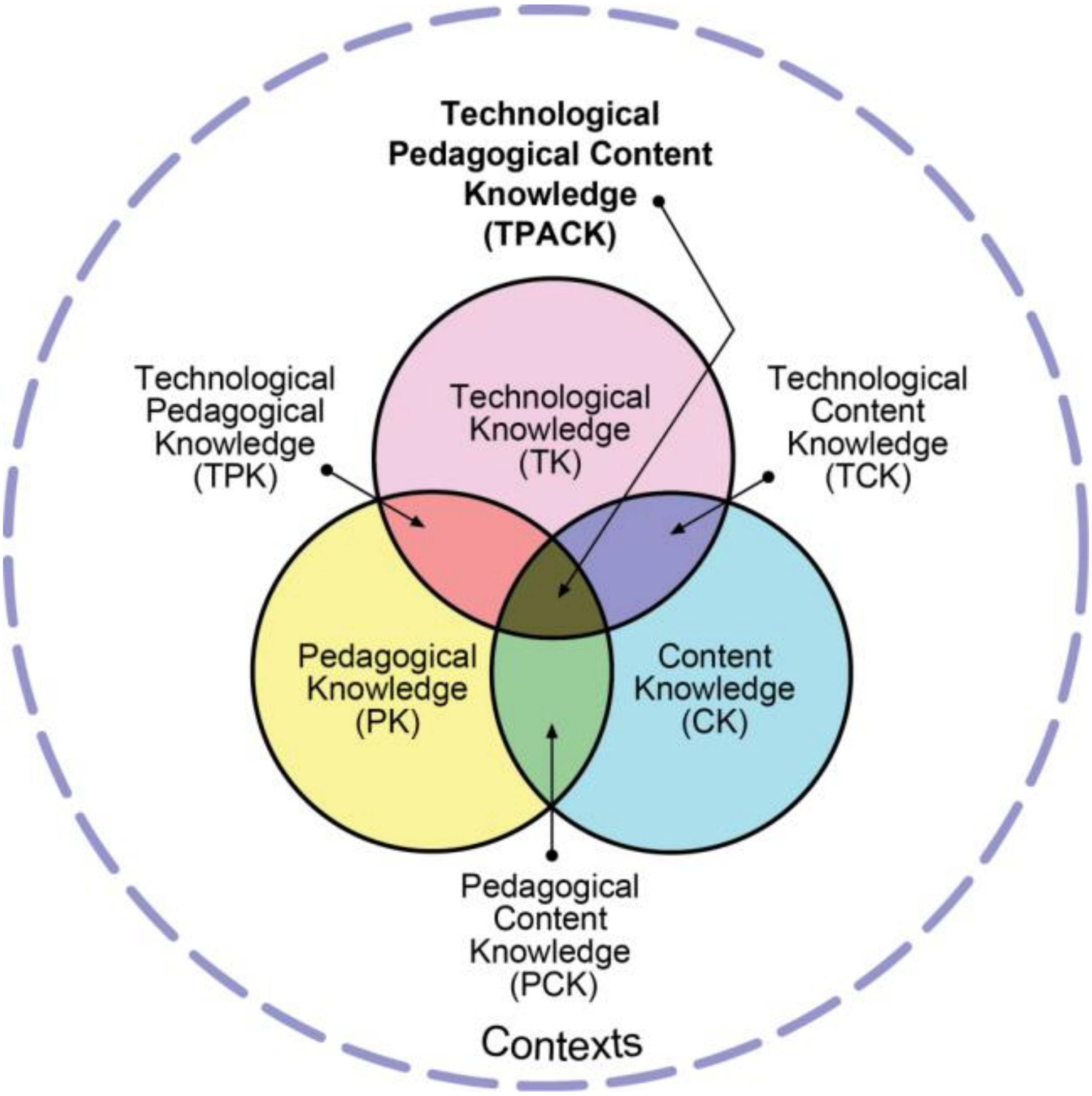


Figure 2.1 The TPACK Framework (M. Koehler & Mishra, 2009), from http://tpack.org.

The definition of each domain is shown below:

"1. Technology Knowledge (TK) refers to the knowledge about various technologies, ranging from low-tech technologies such as pencil and paper to digital technologies such as the Internet, digital video, interactive whiteboards, and software programs".

2. Content Knowledge (CK): the "knowledge about actual subject matter that is to be learned or taught" (Mishra & Koehler, 2006, p. 1026). Teachers must know about the content they are going to teach and how the nature of knowledge is different for various content areas".

3. “Pedagogical Knowledge (PK): refers to the methods and processes of teaching and includes knowledge in classroom management, assessment, lesson plan development, and student learning.

4. Pedagogical Content Knowledge (PCK): refers to the content knowledge that deals with the teaching process (Shulman, 1986). Pedagogical content knowledge is different for various content areas, as it blends both content and pedagogy with the goal being to develop better teaching practices in the content areas.

5. Technological Content Knowledge (TCK): refers to the knowledge of how technology can create new representations for specific content. It suggests that teachers understand that, by using a specific technology, they can change the way learners practice and understand concepts in a specific content area.

6. Technological Pedagogical Knowledge (TPK): refers to the knowledge of how various technologies can be used in teaching, and to understanding that using technology may change the way teachers teach.

7. Technological Pedagogical and Content Knowledge (TPACK): refers to the knowledge required by teachers for integrating technology into their teaching in any content area. Teachers have an intuitive understanding of the complex interplay between the three basic components of knowledge (CK, PK, TK) by teaching content using appropriate pedagogical methods and technologies” (Schmidt et al., 2009).

Mishra & Koehler (2006) said “TPCK is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students’ prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones.” (Mishra & Koehler, 2006, p. 1029).

The processes involved in the formation of TPACK, through bringing technology into content and pedagogy, is highly complex and challenging, involving a multistep developmental procedure (Jwaid A.E et al., 2014).

As mentioned above there are many reasons to select TPACK as a framework (see Section 2.3, p.15). However, TPACK for HE needs also to be linked to industrial needs (Chai, Lim, & Tan, 2016; Jwaid A.E et al., 2014). So, after developing a TPACK framework including an industrial focus, an improved framework developed in this research is called the 'AJ Framework', and which will be covered in Chapter 4.

2.5 TPACK related work

The TPACK framework was established by Mishra and Koehler (2006) as a model to measure and evaluate the content, pedagogy, and technology knowledge.

Messina & Tabone (2012, p. 1018) argue, "There is a growing number of research projects aimed at implementing TPACK". Mishra (2011) mentioned to the increasing extent and speed of TPACK cited works in doctoral theses, journal, and conference published articles. There publications concern different aspects, including research and studies; such as: strategies to develop the TPACK framework; measurements of teacher TPACK knowledge in different subject areas, such as maths, science, English, psychology, IT, etc.; using TPACK for professional, development in in-service teacher training programmes; and introducing the TPACK framework for pre-service teachers in university courses (Chai et al., 2013; Chai et al., 2016; Garrett, 2014; Messina & Tabone, 2012; Mishra, 2011).

In addition to the original structure of the TPACK framework, other models have been created such as: TPACK-deep (Yurdakul et al., 2012); TPACK-ICT (Angeli & Valanides, 2009); and TPACK-Practical models (Yeh, Hsu, Wu, Hwang, & Lin, 2014) which bring different interpretations to the framework (Ay et al., 2015). However, all of these models are designed for school teachers not for HE tutors.

It is clear that the word 'implementing TPACK' is used widely to include different purposes and at different levels, therefore, the methodology is often different from one research project to another, based on that.

2.5.1 Methodologies for TPACK related work

Theoretical methodology definitions and more details on methodology will be presented in Chapter 3. This section will review the methodology in TPACK related work.

Researchers used different methodologies to study and analyse TPACK: some used quantitative methods, some used qualitative methods, and few researched using mixed methods.

Chai *et al*. (2013) reviewed TPACK literatures in May 2011. This review classified 74 peer reviewed journal papers and divided them into 55 data driven research articles and 19 non-data driven research articles. In addition, they found among the data driven research 13 papers used quantitative methods, 31 papers used qualitative methods, and 11 papers used mixed methods.

In terms of the non-data driven 19 papers, 9 are classified as worked examples, 1 on an editorial paper and 9 papers are classified as theoretical papers, for instance, TPACK constructs and ICT integration was theoretically studied (S. Cox & Graham, 2009; Graham, 2011; T. C. Hammond & Manfra, 2009; J. Harris et al., 2009)).

Several studies have been published after May 2011 when Chai *et al.* identified TPACK literatures. Thus, this research reviewed more recent TPACK literature and included PhD theses, MSc dissertations, and conference papers identified until August 2016.

For instance, various new research used quantitative methods (Ay et al., 2015; Garrett, 2014; M. Herring et al., 2014; Koh & Chai, 2014; Mouza, Karchmer-Klein, Nandakumar, Ozden, & Hu, 2014; Pamuk, Ergun, Cakir, Yilmaz, & Ayas, 2015; Polly & Orrill, 2016; Tai, Pan, & Lee, 2015; Tømte et al., 2015; Yurdakul et al., 2012). They used statistical analysis such as correlation, t-test, factor analyse, internal validity, regression, and Cronbach alpha to analysis the TPACK framework and understand the constructs, definition and borders between domains. Some researchers studied the instrument validation (L. M. Archambault & Barnett, 2010; Kopcha, Ottenbreit-Leftwich, Jung, & Baser, 2014; Laborda et al., 2014; Schmidt et al., 2009; Smith, 2010). More details about instrument design will be covered in sub-section 2.5.2 'Instruments '.

Some researchers used qualitative methods, including interview, or/and observation, (for example (S. Cox & Graham, 2009; Olofson, Swallow, & Neumann, 2016) used interviews as a research method to collect data). Some used a case study approach (Almås & Krumsvik, 2008; An & Shin, 2010; Boschman, McKenney,

& Voogt, 2015; Doering & Veletsianos, 2008; T. Hammond & Manfra, 2009; Hofer & Swan, 2008; Khan, 2011; Manfra & Hammond, 2008; Schul, 2010a; Schul, 2010b; E. Wilson & Wright, 2010); others used qualitative methods to survey teacher views of using ICT and referenced it to TPACK constructs by using artefact evaluation of an online course website (Banas, 2010; Ozgun-Koca, 2009); others used document analysis by reviewing journal papers and projects reports (Polly, Mims, Shepherd, & Inan, 2010); a systematic review method (Tondeur et al., 2012); a focus group approach to study implementing tablets in secondary schools (Bekirogullari et al., 2014); intervention studies research methods to improve pre-service and in-service teacher TPACK understanding - these studies examined course effectiveness and studied employment of the TPACK framework to structure CPD programmes for in-service teachers and professional development for pre-service teachers (Akkoç, 2011; L. Archambault, Wetzel, Foulger, & Kim Williams, 2010; Bowers & Stephens, 2011; Groth, Spickler, Bergner, & Bardzell, 2009; J. B. Harris & Hofer, 2011); using observation followed by interviews (Schmidt-Crawford, Tai, Wang, & Jin, 2016); finally, observed and analysed the discussion through audio record of meetings (Ling Koh, Chai, & Tay, 2014).

Regarding mixed methods, the literature includes several researchers who used mixed methods to study the TPACK framework (Angeli & Valanides, 2009; Doering, Veletsianos, Scharber, & Miller, 2009; Graham, Borup, & Smith, 2012; Greenhow, Dexter, & Hughes, 2008; Khan, 2011; M. J. Koehler & Mishra, 2005; Mishra & Koehler, 2006; Mouza et al., 2014; Ozmantar, Akkoç, Bingolbali, Demir, & Ergene, 2010; Tømte et al., 2015).

Finally, the work which was classified as non-data driven, as some researchers studied theoretically TPACK contracts and ICT integration (S. Cox & Graham, 2009; Graham, 2011; T. C. Hammond & Manfra, 2009; J. Harris et al., 2009).

2.5.2 Instruments

Developing TPACK instrument for HE was among the objectives of this research, as mentioned in Section 1.4, and the validity of the developed instrument will be covered in Section 4.3. Thus, reviewing the relevant literature is the first step to this objective. Alongside the growth of the TPACK framework, several survey instruments have been designed to assess and measure teacher knowledge of

TPACK. The base of these instruments was a questionnaire on a Likert-type scale. It is important to mention here that from the literature the authors used different terminologies to describe the TPACK instrument, such as self-assessment questionnaire, self-report survey and survey instrument.

Reviewing the literature, we found the instrument which was developed by Schmidt et al. (2009) was used earlier and widely, cited by 663 articles from Google Scholar and 309 documents using Scopus (in 04/08/2016).

The Schmidt et al. (2009) instrument included 47 items. This instrument has been adapted by Lee and Tsai (2010) to 30 items and to 29 items by Doukakis *et al.* (2010) which was used to assess computer teacher TPACK understanding.

Archambault and Crippen (2009) developed an instrument that included 24 items for online teachers. Graham et al. (2009) developed a TPACK instrument for science teachers which included 30 items, which was adapted afterwards to include 31 for mathematics teachers. Chai *et al.* (2010) developed a preservice survey instrument to develop preservice teacher TPACK through ICT courses, this instrument included 18 items. While Sahin (2011) included 47 items for preservice English language teachers.

(Koh & Chai, 2014) designed their instrument by including 36 items for preservice and in-service teachers. This study used cluster analysis to gain insight into the different teacher perception of the development of TPACK after undertaking ICT design activity. This study enhanced the linkage between theory and practice of the TPACK framework.

The Ay *et al.* (2015) instrument included 22 items, this study examined the construct of TPACK framework for teachers at schools level (pre-university). This study is a “TPACK-Practical: Examination of its validity in the Turkish culture via structural equation modelling”. Statistical analysis used item discrimination, correlations, Cronbach's alpha and confirmatory factor analysis.

The research in this thesis also developed a TPACK instrument for HE. This will be covered in Sub-sections 3.7.2 and 3.7.3.

2.5.3 Using TPACK in HE

There is lack of HE research in TPACK development (M. C. Herring et al., 2016). as mentioned earlier in Section 2.6.

Literature was obtained from a number of main publication databases including Science Direct, IEEE Explore, ProQuest, Google Scholar and NTU library.

The TPACK developments in HE mostly focus on school pre-service teachers (Mouza et al., 2014) and some focus in “leadership structures that promote the development of TPACK, and for faculty development for both teacher education and non-teacher education faculty” (M. C. Herring et al., 2016).

Cox (2009) in her research studied the conceptual side of the TPACK framework by interviewing university professors and primary school teachers, so the study was not HE only, rather it was a conceptual analysis in order to obtain definitions and evidence for the TPACK framework’s component constructs. Cox described TPACK definitions and boundaries having been somewhat fuzzy, and the result of her research that using simplified definitions “ helped to emphasise the boundaries between the constructs and to support the new model of TPACK.” (S. M. Cox, 2008, p.101).

In a brief publication, Ashe & Bibi (2011) mentioned the importance to study the implications of the theoretical perspectives of the TPACK framework for empirical study. They mentioned two necessary research areas needed more investigations:

“ 1. Explaining the nature of TPACK.

2. Understanding how technology can change the context of learning and how that change can affect student thinking.”

Rienties *et al.* (2013) have studied tutors in HEIs and their perceptions of TPACK in the Netherlands, by using an online tutors training program survey instrument that was used to measure pre-test and post-test.

(Lye, 2013) has done research for “private higher education institution group in Malaysia that implementing the Technological, Pedagogical, and Content Knowledge (TPACK)” which used a questionnaire survey instrument to highlight the online teaching and learning challenges faced by academic staff and pedagogical skills training program needs. He stated: “there is no single technology solution that can be applied to every academic staff, every subject, or even every teaching and learning methods" (p. 296). He concluded that ICT brings some advantages such as increasing convenient time for learning, the engagement rate and encouraging teamwork.

(Garrett, 2014) used the TPACK instrument to measure TPACK in HE. The author in this research recommended to implement TPACK in teaching in HE, and suggests that observation and evaluation as future practice should be used to validate the TPACK framework in HE.

As the research in this thesis aimed to investigate the effectiveness of TPACK in control engineering and similar STEM related studies. It is clear from the literature this HE subject area has not been fully covered before.

2.6 The TPACK framework and areas needing more research in the TPACK framework

Although, the TPACK framework is a powerful and useful framework which could be used to enhance teaching, however, Koehler et al. (2014) mentioned that "the TPACK framework remains a topic ripe for research". Many researchers described the TPACK framework as beneficial and problematic at the same time (L. M. Archambault & Barnett, 2010; S. M. Cox, 2008) because of unclear definitions and constructs of frameworks domains and the boundaries between them are somewhat fuzzy. Cox (2008) stated "While I believe that this study has helped to clarify the TPACK framework, there remain areas that are as yet unexplored or not fully understood. These areas should prove fruitful for future research on the TPACK framework." p.101. Archambault & Barnett (2010) mentioned the difficulty of separating out each of the TPACK domains. Therefore, they argued, based on Cox & Graham (2009) that "This makes it difficult to implement knowledge from a framework that is yet to be fully defined which limits its practical application. This is an important area for future research, including detailed examples of TPACK as it pertains to teacher practice" (L. M. Archambault & Barnett, 2010, p.1661).

Later on, Graham (2011) did a critical study of the TPACK framework constructs and he concluded, theoretically, that constructs in the TPACK framework are integrative and he described the definitions with less boundaries between the framework domains. In addition, he suggested that "researchers must work together to shore up weaknesses in the clarity of TPACK construct definitions and in articulating ways that the constructs are related to each other. In particular, researchers must clarify the boundary conditions that enable one element in the framework to be distinguished from adjacent elements. ” (Graham, 2011, p. 1959).

Chai *et al.* (2013, p.41) stated: “We would argue that more surveys that compare pre- and in-service teachers TPACK could be helpful in identifying the gaps in their TPACK and teacher educators can then plan how to support the continuous development of TPACK”. Therefore, this current research took this step by comparing pre- service and in-service tutor in HE, to contribute in this area, where there is dearth of research in this important stage (M. C. Herring et al., 2016).

In addition, Chai *et al.* (2013, p.41) argue that “Survey studies of other educators beyond K-12 in higher education setting should be carried out to understand their notion of TPACK. This is especially so for the faculties in higher education as they are likely to be the most important people to help form the pre-service teachers’ TPACK”. Thus, there is need for practical study to investigate this theoretical analysis, also there is lack of available TPACK research in HE level in general (Garrett, 2014; M. C. Herring et al., 2016) and control and STEM related subject areas in particular. Therefore, as a result of review of the TPACK framework, the researcher has been motivated to investigate the effectiveness of using it to develop teaching in control and STEM related subject areas in HE.

2.7 Student Learning Style

Students typically have different learning styles due to the variety of their needs and abilities, where some may prefer some approaches over others (Alzain, Clark, & Ireson, 2014).

Some students are auditory learners, while others are kinesthetic or visual learners. Auditory learners learn by reading or listening to lectures. Kinesthetic learners learn by doing. Visual learners learn visually by means of graphs, picture and charts. Students can prefer one, or more of learning styles. Because of these different learning styles, it is important for tutors to integrate into their teaching activities related to each of these learning styles so that all students are able to achieve the learning outcome of the module (Vaishnav, 2013).

2.7.1 Learning style of students in school level and HE level

The main difference between school level and HE is that students need to be self-motivated in HE. There is no-one here to prompt them, as the situation in school, also the students should be more independent learning (UoB, 2017).

Field, Duffy, & Huggins (2014) quoted "Being independent at university means that you are responsible for managing your studies, your time and yourself. In high school, you might be used to teachers reminding you when work is due, telling you what and when to study, and checking your progress. University learning requires you to learn and complete assignments independently, plan your workload, meet deadlines and organise your time. This level of self-management can be a challenge. Some students thrive; others find it difficult to adjust at first".

The role of the tutor in HE is to organise, facilitate, deliver lectures, and supervise labs. In terms of assessment tutor support student learning by providing an early formative assessment (HEA, 2014).

To integrate technology into teaching approach, different student learning styles should be considered, and this require from the tutor in HE have knowledge of integrating technology and pedagogy also use some strategies such as tutor- online discussion boards and organised study buddies (HEA, 2014).

2.7.2 Learning style and the TPK domain

TPK rationales are rooted in the use of general teaching strategies, were also identified specific examples of how tutors candidates used their knowledge of general learner characteristics such as learning styles, preferences, developmental abilities, etc. (Graham et al., 2012).

TPACK is a relatively new framework, which has not been tested before in HE. Thus in this research, we tried to implement and evaluate the monitoring and evaluation features of TPACK in HE, which were already used in pre-university levels, as shown in chapter 5.

2.8 Control Engineering related STEM education

A recent survey conducted by MathWorks in collaboration with YouGov discovered that 60% of STEM employers believe that there is a skill gap in the UK within their respective fields (Andrew, 2013; Mathworks, 2013). The threat of a widening skills gap in the UK is further verified by the UK Commission for Employment and Skills (UKCES) (UKCES, 2015), and the Department for Industry, Business , Innovation & Skills (Johnson, 2016).

The “STEM Skills Gap Report” found that, out of the 300 employers and 2 leading academics surveyed, 59% of businesses and 79% of academics fear a lack of skilled candidates leaving education able to meet the employment needs of their industry. The report also found further need for greater collaboration between academia and industry in order to address the shortfall and meet the rising demand. A key discovery of the research found that often the approach to teaching STEM at university level isn’t always conducive to the needs of employers (Mathworks, 2013).

The report presented a number of key findings pertaining to the extent of the skill gap, attitudes toward academic and industrial collaboration and the varying opinion on how to address the shortage (Andrew, 2013; Mathworks, 2013). The findings are summarised below:

2.8.1 The extent of the skills gap:

- Over 60% of academic and business leaders, 68% and 61% respectively, believe that is a skill shortage which could take in excess of 10 years to address.
- Over 80% of academic and business leaders, 89% and 83% respectively, believe that the skill gap is a risk to the UK’s competitiveness in the world economy.
- Over 50% of academic and business leaders believe that investment in STEM education, both in further and higher education, is inadequate when compared to other countries.

2.8.2 Industry and academia collaboration:

- Out of the universities and businesses polled, the majority agree that more could be done to mitigate the skills gap through better collaboration between academia and industry. 52% of employers and 64% of academics fear that industry does not work closely enough with universities.

- A large number of businesses (63%) believe that industry should have greater involvement and contribute more to the STEM curriculum within the UK, a notion met with far less enthusiasm among universities with only 46% welcoming such a contribution.
- Of the academics who welcome greater industry involvement all advocate for the provision of workplace experience for STEM students. Furthermore, 82% of academic respondents would welcome industry experts to give talks at their university.

2.8.3 Different approaches to closing the gap:

- The majority of businesses (61%) believe that there needs to be a greater emphasis on project based learning within STEM subjects so as to engage students in scientific and engineering exercises which are relevant to real world problems. This however is an opinion not shared by academics, of whom on 34% would agree to just an approach.
- The majority of businesses (56%) believe that students will fail to reach their full potential in their given field without Project Based Learning (PBL), a sentiment only shared with 37% of the academics.

In Mathworks analysis of the report, Dr. Coorous Mohtadi asserts that one is able to arrive at two important conclusions; firstly far more must be done to encourage students to pursue a STEM subject in higher education, secondly the various STEM curricula must adapt to the needs of industry taking into account that students will one day need to address problems that are yet to be known with technologies that have not yet been invented. More needs to be done to gain a better understanding of what is required for graduates to succeed in the workplace. The current educational paradigm must align itself with the needs of industry so as to better equip students with the skills required to enter the workforce and to progress in their careers. Business and academic opinions on how to address said issue appear to be in conflict, what is clear however is that greater collaboration is needed between industry and academia so as to address the STEM skills gap which poses a threat to the UK’s future economic prosperity (Mathworks, 2013).

2.9 Links with industrial practice and world affairs

Closing the skills gap comes by including more industrial practice in the university curriculum, and let students deal with real life problems before their graduation. This will give students deeper understanding. “It is initiated by students’ authentic quest to understand the world they live in. Students are encouraged to articulate their ideas about what they are inquiring and to subsequently work on these ideas to achieve deeper understanding, employing not just true/false criteria but also criteria related to the usefulness of the ideas. Adopting such a constructivist approach, students are engaged in knowledge work directly. This formed the foundation for them to become knowledge workers for the twenty-first century. ”(Chai et al., 2016).

Thus, linking university with industrial practice and world affairs will align to industrial needs and would make students more effective in their jobs.

2.10 Areas of possible investigations

According to the rapid changes in the technologies within all subject areas in general, and in engineering subject area in particular. Therefore, updating the contents of the curriculum is a big requirement in achieving the target of universities. Universities provide the society with qualified graduates who serve the requirements of their jobs.

The implementation of technology in education requires pedagogical modification (Ertmer, 2005; Ertmer & Ottenbreit-Leftwich, 2013; Jwaid A.E et al., 2014; M. Koehler & Mishra, 2009; Schmidt et al., 2009). The demand for establishing a new teaching framework to follow for seeking of sustainability in HE is mentioned in Chapter 1 (see Section 1.8, p.9).

2.10.1 Digital Control Module

Digital Control is defined as applying the control theory within engineering discipline for designing systems with predictable behaviour. Devices output performance being measured by using sensor/s and controlled. Input actuator can be controlled by giving sensors measurements (Cheng, 2013).

2.10.2 Embedded Systems Module

An embedded system is defined as a system including a core computing part which is used for specific applications rather than the general purpose of the computer (Marwedel, 2011; Ricks et al., 2008).

There are several reasons for choosing Digital Control and Embedded Systems modules to implement a TPACK framework. Firstly, the significant interest in control and embedded systems applications because the digital control and embedded systems have become a part of our daily lives, because they form the essential component in many common devices. Digital control and embedded systems represent a large part of the digital technology market, such as automotive technology, telecommunications, astronomy, military applications, data communication industries and office automation (Freudenberg & Krogh, 2005). Secondly, the complexity of teaching embedded systems, because it requires various interdisciplinary skills in various subjects such as maths, physics, software and hardware. Consequently, this requires skills beyond these traditionally taught in the subject in electronic engineering (Ricks et al., 2008; Wu et al., 2015).

Implementing the framework in teaching a Digital Control and an Embedded Systems modules will be covered in Chapter 5.

These two modules were chosen because of the availability and the helpful module leaders who agreed to implement the study with these modules. Moreover, the researcher is experienced as a control engineer and a tutor in this subject area in HE.

2.11 Summary

This chapter presented the available technological pedagogical frameworks, and the justification of selecting the TPACK framework in this study. Also, this chapter provided the definitions of TPACK domains. Furthermore, TPACK related work was reviewed in terms of TPACK instruments, as a research background for Chapter 4, and using TPACK in HE, as a research background for Chapter 5. Finally, it illustrates why STEM education in engineering needs to be linked to industrial requirements and presented research gaps.

3. Chapter Three: Methodology

3.1 Introduction

The preceding chapter addressed the literature related to the increasing influence of technology on the pedagogy in engineering HE modules.

This chapter will address the methodology applied to the research, including the design of the research instrument, data collection and the approach to analysis.

In order to choose the most appropriate methodology for any research, it should start with understanding the purpose of the research. In general, within the way in which the research questions has been asked that will lead answers to be either an exploratory, or descriptive, or explanatory form of case study (Hamilton & Corbett-Whittier, 2012; Newby, 2010; Saunders, 2011; Yin, 2011).

An exploratory study is initial research, which attempts to search for patterns within collected data and develop a model, which represents the data. It answers the question of ‘what’. It assesses phenomena in new situations/scenarios (Yin, 2011). Descriptive study is a step to acquire further information on specific features of a subject-matter. This demands theory to make sure that the collecting data process is in a correct direction. Also a descriptive case study answers the question of ‘what’, however, it is used to describe the effect of particular issue, or might be used to reflect complete descriptions of what can be considered to study. The third type of case study is explanatory, which is used to explain ‘why’ or ‘how’ a particular issue happens or happened (Yin, 2013).

Beyond case studies, various methods have been referred to by educational researchers (Lodico, Spaulding, & Voegtle, 2010; Newby, 2010) . The differences are based on which aspects we evaluate. In education there are four major aspects, built upon the elements, which are: student, teacher and facilities. These four aspects are: student learning, teaching methods, teacher training, and classroom dynamics (Collins & O'Brien, 2011; Newby, 2010; Ramsden, 2003).

Research can be built on both empirical and non-empirical approaches or a combination of the two. The ways of knowing, or foundations of understanding, in research, are divided in the empirical and non- empirical approaches as shown in Figure 3.1 Foundation of understanding (Kervin, 2006). Non- empirical research is based on theory: logic (common knowledge) and authority. While the empirical approach is based on seeking evidence and experience: experimental or observational data collection. The empirical approach includes some domains used for evaluation, such as: inductive and deductive, quantitative, and qualitative (Black, 1999; Kervin, 2006). Quantitative and qualitative domains will be covered later in this chapter, see Section 3.2.2.

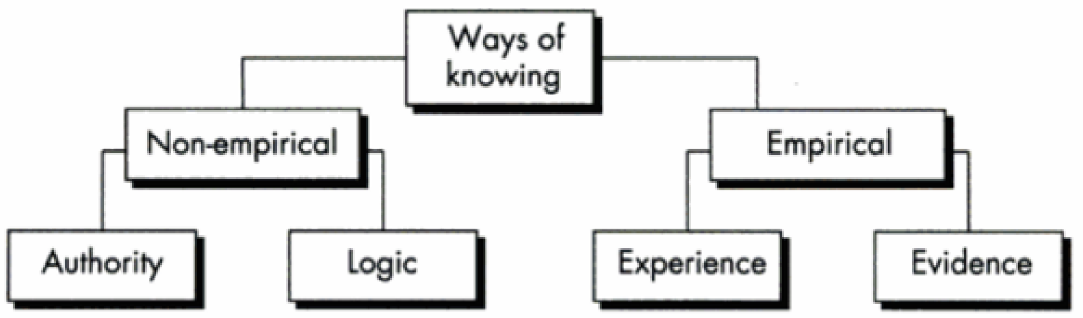


Figure 3.1 Foundation of understanding (Kervin, 2006)

Inductive and deductive domains both "approach to the relationship between theory and research", (Bryman, 2012). An inductive approach begins with observations, which lead to formulate theory, following research, through conjecture and hypothesis (Goddard & Melville, 2004). In other words, an inductive approach generates theory from the research (Bryman, 2012). A deductive approach refers to hypothesis development based on existing theory, and then respectively, to test the validity of hypothesis consumption by design of the research strategy (Y. K. Singh & Bajpai, 2008; J. Wilson, 2014).

3.2 Research Methodology and Methods

This section presents the definition of methodology and methods and the difference between both.

Methodology is defined in Oxford English Dictionary as "a system of methods used in a particular field". This definition clarifies that the concept of methodology covers procedures of data collection and analysis processes, without covering conceptual thinking (Newby, 2010). This will be expanded when we talk about paradigms in next section. Research methodology specializes in compilation of research tools and applying suitable rules of research. There are some frameworks used in methodology such as case studies and ethnography (Newby, 2010).

Method in educational research refers to the range of approaches which can be used as a tool for data collection, also how to interpret data to describe, explain, or/and predict educational phenomena, or results (L. M. Cohen & Manion, 2011; Creswell, 2014).

So to summarize, as (Newby, 2010) stated: “research methodology is concerned with the assembly of research tools and application of appropriate research rules. Research methods are the research tools themselves, for example questionnaires, observation, statistical analysis” p.51.

3.3 Paradigms in research

A paradigm in research is a philosophical perspective defined as a model, or a way of examining social phenomena, which supports researchers in determining what they have to examine, how they shall examine it, and how they shall interpret the results (Bryman, 2012; Saunders, 2011). On the other hand, (Newby, 2010) mentioned the definition of paradigm from the Oxford English Dictionary as “a conceptual model underlying the theories and practice of a scientific subject.” p.44. The paradigms give a thinking way to understand a subject in a research area and how to process it (Newby, 2010). It focuses on supporting researchers to be more specific in terms of what ought to be researched and studied, and how it should be performed, and finally how results ought to interpreted (Bryman, 2012). Thus, it is useful for researchers to use paradigms for effectively understanding the world surrounding them (Bryman, 2012; Newby, 2010). Paradigms involve values of research environment, concepts and assumptions, which are considered in conceptual thinking as a higher level than methodology, as has been covered early in this chapter. (Newby, 2010) considers the term paradigm as described by the well-known analysis approaches: quantitative, qualitative and mixed methods. Additionally, how these approaches work to connect the way in which a researcher thinks about selecting a suitable subject area to be investigated, and which output of research can be depended on. Briefly, paradigms connect the philosophy of research and the research practice (Newby, 2010). There are different types of paradigms, which will be covered in more details under components involved in research approaches in section 3.5.1.

It is important to highlight the different opinions of using terms for paradigms. Some authors use the term worldview instead of paradigm (Creswell, 2014). (Creswell, 2014) mentioned that some authors use epistemology and ontology as (Crotty, 2012), or conceived on a large scale research methodology (Neuman, 2009).

3.4 Research approaches

Research approaches mean research plans and procedures, which include a sequence of assumptions to address elaborate methods of collecting, and analysis of data, moreover interpretation of analysis results. So we can define a research approach as a research plan which involves numerous decisions. The general decision includes selecting which appropriate approach should be conducted for studying a certain topic. The researcher ought to build the selection of approach decision on: firstly, the nature of the research problem, and on the three components which are important to approach any research, which includes philosophical assumptions, research methods, and research design (Creswell, 2015; Newby, 2010).

Traditionally, research approaches are divided into quantitative research, qualitative research and mixed methods. It is important to examine them briefly, and how they can be used to investigate the research questions.

3.4.1 Quantitative research

Quantitative research is an approach, which uses statistical techniques to examine a phenomenon, systematically. Basically, the quantitative research is the collection of data and the analysis of them, and addressed conclusions based on the analysis; seeking to refine, accumulate and develop a scientific knowledge base. Some authors (D'Cruz & Jones, 2013; Marlow, 2010; Schofield, 1993) consider that quantitative research can be used as a collecting instrument; in addition, there is a possibility of generalized findings (Newby, 2010). Quantitative approaches are robust, strict and persuasive.

The character of quantitative research can be succinctly summarized as the identification and explanation of pattern and order.

3.4.2 Qualitative research

Qualitative research is an approach used to describe quality and kind of subjects, which are difficult to be described by statistical techniques. Primarily, qualitative research refers to exploratory research. The qualitative research is mainly used to understand the implicit motivations and different views. Moreover, it provides deep inspection into the matter as well as: underpinning the idea of improvements and hypotheses for potential quantitative research. There are different techniques to collect qualitative data such as: semi-structured or unstructured interview; focus group; or participant observation (Bryman, 2012; Neuman, 2009; Wyse, 2011). Qualitative approaches infer conclusions, logically, from evidence by assembly of them from relevant resource to determine patterns and order. Qualitative approaches are robust research for extracting information in-depth; also, because it takes in account the emotions, relationships, and all other evidence to make complete sense of the subject area (Newby, 2010). These approaches do not require big sample sizes (as quantitative approaches), furthermore, a defined quota can be achieved by choosing the respondents (Bryman, 2012; Neuman, 2009; Wyse, 2011).

3.4.3 Mixed methods research

Mixed methods research is an approach used to describe combining the two approaches above: quantitative and qualitative approaches. The researcher employs both collection data approaches, quantitative and qualitative data (Bryman, 2012). The main objective of the mixed research methods is to address a specific research question from whatever related angle, and if necessary to take advantage of combining previous research of investigation perspective. Mixed methods are often used in complex education research, but have to deal with the requirements of each approach. However, mixed methods gather the strengths of both approaches, in-depth, more efficient as qualitative approaches offer, and quantitative researches add predictive power (Newby, 2010).

Essentially, a mixed methods approach bridges the limitations of one method, to help researchers, based on strengthening the other method (Denscombe, 2014). For instance, a qualitative research approach can study a few individuals, which lose any statistical determination; on the other hand, in quantitative research approaches the individual's knowledge gets less attention in terms of in-depth understanding (V. P. Clark & Creswell, 2011). The nature of integration of a quantitative research approach with open-ended questions and semi-structured interviews provides a comprehensive understanding of the research problem comparing to use only one approach (Biesta, 2012; Creswell, 2015; Creswell, 2014). There is no space here to go through the evidence of the benefits of using mixed methods in social science in general, and for educational research in particular, but this is well detailed elsewhere (Biesta, 2012; Bryman, 2012; V. P. Clark & Creswell, 2011; L. M. Cohen & Manion, 2011; Creswell, 2014; Denscombe, 2014; Newby, 2010; Riegler, 2012).

3.5 Components involved in research approaches

As mentioned in the previous section, the important components for selection of a research approach are philosophical assumptions, research methods, and research design. The comprehensive research approach is the plan of conducting a research or proposing the design of the plan, which includes intersection between these three components, as shown in Figure 3.2, that represent a research framework. When researchers plan a study to implement the approach in practice, they are required to think across the philosophical paradigm assumptions that they use in the study, and relate the research design to these paradigms, and the particular research procedures or methods.

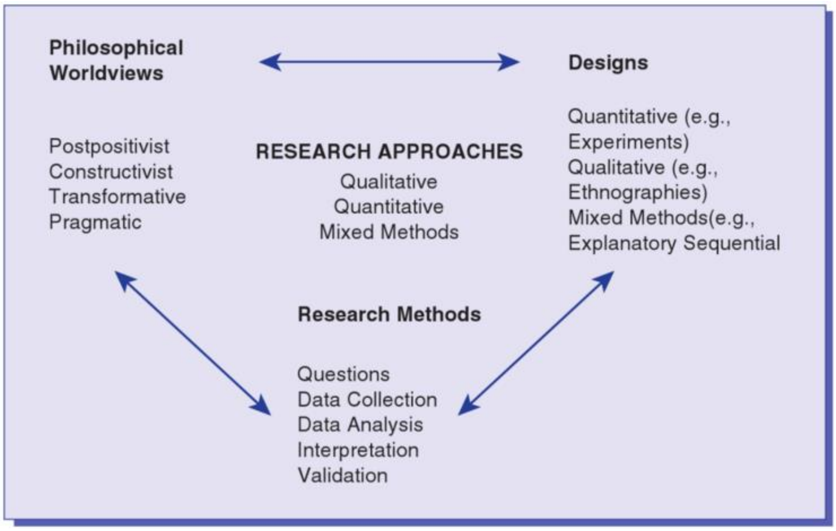


Figure 3.2 A framework for Research (Creswell, 2014)

3.5.1 Philosophical paradigms (worldviews)

Creswell (2014) advises researchers to make explicit the bigger philosophical ideas for a research plan or proposal preparation of what they adopt. That can explain the reasons why they selected among the three approaches (quantitative, or qualitative or mixed methods) for their research, by addressing the following:

- Propose the philosophical paradigm (worldview) in the study.
- Identify the basic ideas of the selected paradigm.
- Explain how the paradigm shaped their approach to research.

There are different types of paradigms such as post-positivism, transformation, constructivism and pragmatism (Creswell, 2014).

This study uses post-positivist and constructivism paradigms as the most appropriate for this research.

i. Positivism and post-positivism paradigm

Firstly, positivism is based on the idea that scientific knowledge is the true knowledge of the world, and it is categorized by the testing of hypotheses which are developed from existing theory (Creswell, 2014; Saunders, 2011). Thus, the post-positivism paradigm comes after positivism to represent the thinking. That is the traditional form of research has been represented by the assumptions of post-positivism paradigm, which are mainly true as an approach for quantitative research. Post-positivists think that the values, knowledge and experience of the researcher can influence what is observed so try to avoid these biases that can affect positivist investigations.

(Creswell, 2014) defined post-positivists as “reflect a deterministic philosophy about research in which cause probably determine effects or outcomes. Thus, the problems studied by post-positivists reflect issues that need to identify and assess the causes that influence the outcomes, such as found in experiments” p.245. Post-positivism includes these elements: determination, theory verification, empirical observation and measurement, and reductionism (Creswell, 2014). In the post-positivism paradigm, the observer (researcher) ought to be independent (Ramanathan, 2009).

ii. Constructivist

Constructivists focus on how bodies of knowledge come to be, and how ideas are constructed by human interactions and decisions (Cynthia D'Angelo et al., 2009; Riegler, 2012). It is mainly considered as an approach for qualitative research (Creswell, 2014). A constructivist seeks to increase the breadth of understanding of the situation (Ramanathan, 2009). Constructivism includes these elements: understanding, theory generation, social and historical construction and multiple participant meanings (Creswell, 2014). The researchers are considered as part of what will be observed (Ramanathan, 2009).

3.5.2 Research designs

The second major element in the research framework, as shown in Figure 3.2 is a research design. This element provides specific direction for procedures in the stage of research design, by identifying strategies of inquiry within research approaches (Creswell, 2014).

For instance, a quantitative design could proceed as an experimental research design, or a research survey. Qualitative design could be a case study or phenomenological research which involves conducting interviews. Mixed methods approaches could combine different quantitative and qualitative research aspects (Creswell, 2014; Newby, 2010).

3.5.3 Research methods

Research methods is the third element in the research framework, which are concerned with data collection forms, analysis techniques, the proposed interpretation by researchers for their studies, and how they can validate it. It will be useful for the researchers to highlight and organize all data collection possibilities: such as if the type of questions will be close-ended questions or open-ended questions or both; the analysis statistical or text based, and so on, as section 3.4 covered the three methods: quantitative, qualitative and mixed methods) (Creswell, 2014; Newby, 2010).

Finally, after talking about a framework for research and its main three elements, using this framework gives researchers methods to select an appropriate approach for their subject area. Starting with the research problem, then using a philosophical paradigm, after that employing the strategies of inquiry in the research design stage, finally, employing the selected research methods (Creswell, 2014).

3.6 Justification of this research approach

This section presents the reasons for selecting the research approach for this research, by following the framework for research shown in Figure 3.3.

The purpose of this research is to explore whether using the TPACK framework in HE increases the quality of students and teachers learning and teaching, and university-industry links. Non-empirical and empirical approaches have taken place in this research for reviewing TPACK related work. In addition analysis of secondary data has been done in order to acquire detailed knowledge of the subject, to identify and recognize gaps in the use of TPACK in HE.

Therefore, this research uses the post-positivism philosophical paradigm, since the research verifies the TPACK framework theory and ability of implementing it in HE. The research develops hypotheses based on existing theory, which is considered as a deductive approach (Newby, 2010). Also because the research uses survey research and experimental research as a quantitative design, so the research method uses a questionnaire as an instrument to collect data, and statistical analysis and interpretation. All of this falls under (categorised as) a quantitative approach.

In addition, this research uses a constructivist philosophical paradigm, because the research observes the performance of the tutors and the students, to understand the impact of implementing TPACK framework on their performance. Case studies were conducted as a qualitative inquiry of the research design. So the suitable research methods are observation and interview for collection of data from individuals, analysis of the text and interpretation of the patterns. Furthermore, this research uses an inductive approach to generate theory of a novel framework to increase the quality of graduates; by linking the university approach with industrial sector needs. All of this falls under (categorised as) a qualitative approach. Thus, the most appropriate methodology that fits the needs of this research inquiry is an exploratory case study.

Consequently, this research overall uses the mixed methods approach with a view to provide an inclusive analysis for the research problem. The researcher used quantitative and qualitative approaches to collect data, then analysed them separately, after that combined the results for interpretation. For the quantitative approach, self-assessment questionnaires were used as an instrument to assess teacher understanding of the TPACK framework. Also an EvaSys questionnaire has been used to collect student feedback about the module, teaching strategies, assessment, and general comments.

The justification of choosing mixed methods approaches in this research relied on the nature of the research question needs. So by using a quantitative approach, which is considered as a deductive approach, for collecting data, offers the ability to examine the phenomena of using TPACK to enhance teaching and learning, systematically. Use of qualitative methods offers the investigation of implicit motivations and different views, which are considered as an inductive approach, for collecting data to build theory for a framework linking university and industry needs to improve graduates, tutors and the research aspects. Figure 3.3 summarizes the justification of this research approach.

3.7 Research design stages.

A research design is a blueprint for conducting research stages, which is used to define the approach for data collection and analysis, also for the approach to interpret and validate the results. This section addresses the process of research design, including the research methods approach used for each stage, and a strategy of inquiry will be covered in this section.

3.7.1 Literature review and selecting an appropriate teaching framework

The previous work of using technology in HE was reviewed by addressing literature from main resources such as books, journals, and conference papers. The secondary data has been analysed to gain in-depth knowledge in the subject area, and identify gaps in using technology to enhance teaching and learning in HE. It was used to examine the theory of each piece of research and to compare and contrast among them as covered in Chapter 2. This leads to the choice and design of instruments and a framework to increase the quality of teaching and learning in control engineering teaching HE. In terms of research approaches this stage followed a constructivist paradigm, non-empirical, qualitative approach.

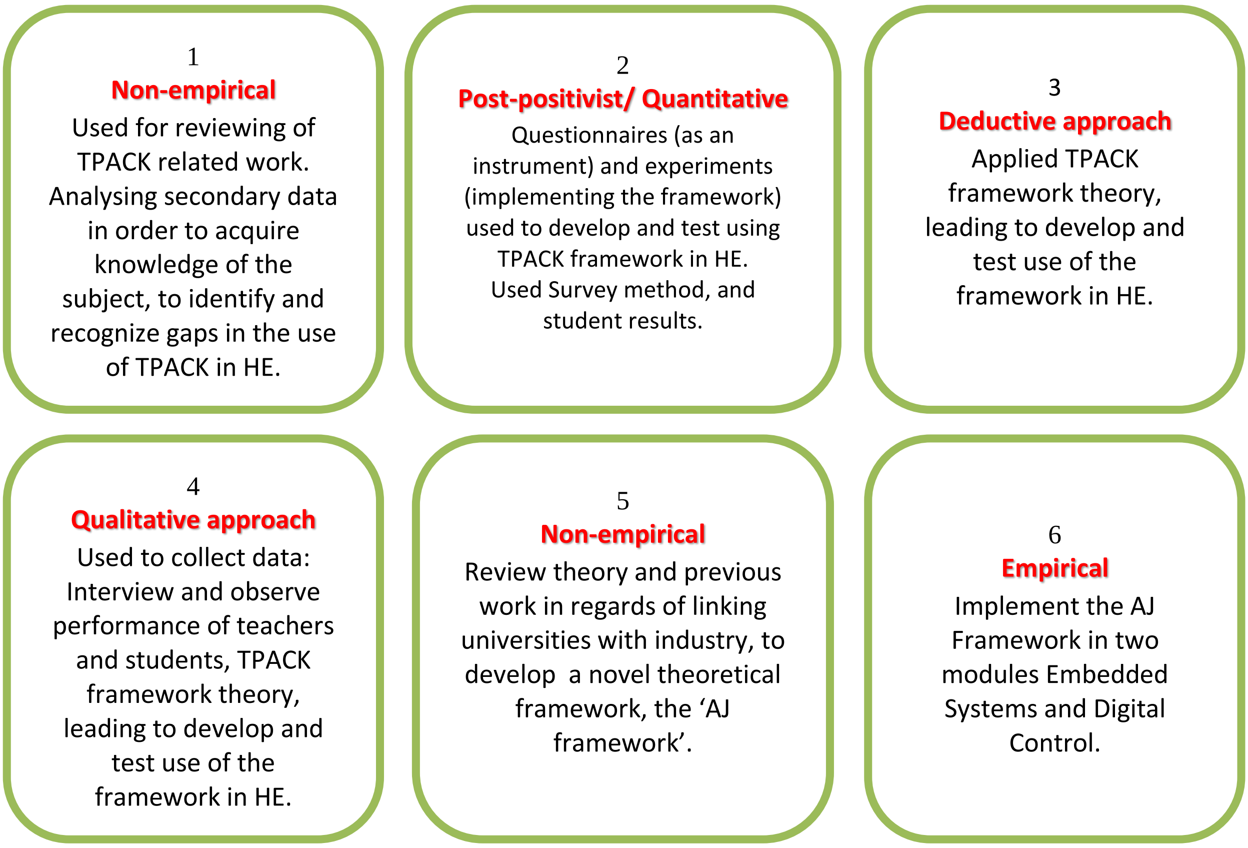


Figure 3.3 Justification of this research approach (Philosophical Approach)

3.7.2 Selecting an appropriate TPACK instrument to assess teacher understanding

For studying the understanding of teachers in HE using the TPACK framework, many of the previous researchers used surveys as an instrument to assess teacher understanding of integration of technological pedagogical and content knowledge, (as mentioned in section 2.5 ‘TPACK related work’). Using a survey as research design in this stage is an appropriate design because it enables verification of TPACK theory. The selection process of the suitable teaching framework has been conducted as follows:

- Reviewed previous TPACK instruments in the literature then compare and contrast among them; studied the theory of each, including their results (see Sub-section 2.5.1 p.19 and 2.5.2, p.21).
- Selected Schmidt’s questionnaire instrument as the main instrument (Schmidt et al., 2009) and obtained permission of use by contacting the main author, Dr Schmidt, for questionnaire design (see sub section 3.7.3, p.42).

To implement the suitable research approach for this stage, the post-positivist paradigm was considered as the best paradigm in terms of the philosophical paradigms; and the methods of collecting, analysing, interpreting and testing validity are quantitative methods by using a survey as an instrument.

3.7.3 Questionnaire design

Questionnaires used as data collection research methods (as it classified in sub-section 3.5.3, p.39) have been considered as useful instruments for information collection in general social and education methodology (Black, 1999; Creswell, 2015; Kumar, 2014; Neuman, 2009; Y. K. Singh & Bajpai, 2008; Wyse, 2011), and specifically in TPACK studies by (L. M. Archambault & Barnett, 2010; Garrett, 2014; Smith, 2010; Tai et al., 2015).

i. TPACK HE , and AJ questionnaire instrument design

Development of TPACK instrument for HE had six phases. First of all, the selection of an appropriate instrument by reviewing literature and assessment the selected instrument was the TPACK self-assessment tool developed by (Schmidt et al., 2009) (see sub-section 3.7.2, p.42). Phase two was developed by modifying some items of (Schmidt et al., 2009) to make it more appropriate for HE. Phase three involved adding other selected items which have been mentioned in other two instruments; (Koh & Chai, 2014) and (Sahin, 2011) to make the instrument cover all aspects of all seven domains of TPACK. At this stage the questionnaire included 47 items (see sub-section 4.3, p.58). Phase four was adding 16 items for improving university links to industrial needs, that made the AJ Questionnaire include in total 63 items. Phase five introduced content validity from experts in the relevant HE pedagogical area, for more procedure steps (see Sub-section 3.9 p.56) and for results (see sub-section 4.3.4, p.62). Phase six involved reliability testing more procedure steps (see sub-section 3.9, p.56) and for results (see sub-section 4.4, p. 65).

This instrument includes open-ended questions as well, to give the participants freedom to express their opinion, which provides richer research data through qualitative input.

The TPACK HE scale's item development were guided by the seven domains constructs of (Mishra & Koehler, 2006) conceptual framework. A Likert scale of 5 points give 1 point for 'Strongly disagree' up to 5 points for 'strongly agree'.

Seven separate sub-scales of the TPACK HE scale were constructed based on the TPACK framework the three main domains and the four intersection domains as defined (see Section 2.4, p.16) as shown in (Figure 2.1, p.17) . Each sub-scale included a number of questions as follows:

- Content Knowledge (CK) (3 items);
- Pedagogical Knowledge (PK) (14 items);
- Technological Knowledge (TK) (5 items);
- Pedagogical Content Knowledge (PCK) (6 items);
- Technological Content Knowledge (TCK) (3 items);
- Technological Pedagogical Knowledge (TPK) (9 items);
- Technological Pedagogical Knowledge (TPACK) (7 items).

The purpose of including 47 items was to make sure all aspects of each sub-scale (domain) were included.

The AJ questionnaire included the eighth domain, which is linking to the industrial needs. Thus, eight separate sub-scales were constructed based on the TPACK framework as well as joint points with industrial needs (see Section 4.7, p.72) and as shown in (Figure 4.6, p. 74. and Figure 4.7, p. 75). As a result 8 items were added in the eighth sup-scale (AJ domain) and 6 items added to all sub-scales except PCK. Because PCK has not got direct links to technology and industrial needs.

The AJ questionnaire included item development as follows:

- Content Knowledge (CK) (4 items);
- Pedagogical Knowledge (PK) (15 items);
- Technological Knowledge (TK) (6 items);
- Pedagogical Content Knowledge (PCK) (6 items);
- Technological Content Knowledge (TCK) (4 items);
- Technological Pedagogical Knowledge (TPK) (10 items);
- Technological Pedagogical Knowledge (TPACK) (8 items);
- Industrial links to HE (AJ framework) (8 items).

ii. EvaSys, students feedback questionnaire instrument design

Regarding the EvaSys questionnaire (Evaluation System surveys student feedback for modules) survey instrument, this questionnaire has been designed, reviewed and validated by experts of learning and teaching in NTU. The questionnaire was distributed to students and it is not compulsory for students to participate.

EvaSys included 25 items. A scale of 5 points Likert by giving 1 points for ‘definitely disagree’ till 5 points for ‘definitely agree’. The analysis was focused on five main aspects:

- Teaching on the module.
- Assessment and Feedback (Formal and Informal).
- Module Organisation and Resources.
- School Specific Questions.
- Overall Satisfaction.

Each of these aspects included open-ended questions (see Appendix A).

3.7.4 Translate the TPACK HE instrument to the Arabic language

Investigation of the TPACK framework in developing countries is one of the research aims, and the selected case study was Libya. So, the instrument questions were translated to the Arabic language. The translation was reviewed by two bilingual participants, both of whom have experience in computer and engineering teaching in HE. (more details see section 4.7, p.72)

The questions have been reviewed by an expert in the Arabic language who has 30-years of experience in education. He verified the questions structure and meaning from both sides linguistically and pedagogically, and he agreed them.

After that, back translation took place from two independent professional bilingual experts who were not involved in the earlier translation into Arabic. The results of back translation was good, as both back translations gave same meaning, as shown in Appendix A.

3.7.5 Study area

This study has been conducted at two different places: UK as case study of a developed country and Libya as a developing country. In order to compare between both, and to suggest to transfer the experience.

i. Developed country

The study was conducted at NTU at the School of Science and Technology (SST). This school includes departments in computing and technology, chemistry, biology science, sport science, maths and physics (see Sub-section 4.3.3, p.61)

ii. Developing country

The study was conducted at Libyan Higher Education Institutions (HEIs), including Misrata University (MU), College of Industrial Technology (CIT), Higher Institute of Engineering Vocations (HIEV) and Higher Institute for Polytechnics (HIPT), in subjects: computer and technology, engineering, biology, and maths.

From the industrial sector, managers and trainers of a Training Centre of the Libyan Iron and Steel Company (LISCO) were interviewed, to study and investigate their strategies and investigate training gaps in HE. Finally, they gave suggestions based on feedback after reading earlier findings of this research.

3.7.6 Sample type

Sampling the population is used to represent a segment of a target population in a certain study and allows the researcher to obtain information and conclude the findings of the study and use them to predict prevalence of probable behaviour of all population or any impacts of some factors (Kumar, 2014).

i. Developed country

Teachers and students were considered the main respondents in this research in the study which took place in a developed country. The research aims to investigate the impact of the TPACK framework on teacher performance and the influence of implementing this framework in student performance. Teachers play the main role in the education of students to impact strongly on the success of education process. Feedback from the industry sector was considered to get more information with which to support the proposed framework.

ii. Developing country

Tutors were considered the main respondents in this research. They were surveyed in a developing country by participation in a self-assessment instrument. In addition, people from the industry sector were interviewed to get more information to support the proposed framework.

3.7.7 Sample size

As known, especially in quantitative methods, the larger the sample size means more accurate findings (Kumar, 2014). This section will present the estimated population and the approaches used.

i. Developed country

The research took place in two phases: Instruments validation and reliability; and AJ framework implementation and evaluation.

a. AJ and TPACK HE questionnaire instrument

For the quantitative approach, the population of the target group was 169 academic tutors from 8 departments in the SST at NTU. 57 tutors participated in this study (see Sub-section 4.3.3, p.61).

The confidence level usually is wanted to be fairly high: 75%,85%, 90%, 95% or 99%. In this study 90% was selected to be confidence level as recommended by (Teigen & Jørgensen, 2005). And to calculate the Margin of Error (MOE) of obtained sample size 57 tutors use the formula in Equation 3.1 (Antonius, 2003; LeBlanc, 2004).

$$MOE = Z\sqrt{\frac{p(1-p)}{n}\frac{N-n}{N-1}} \qquad \textit{Equation 3.1}$$

Where:

$\mathrm{Z}=$ The confidence interval constant

$\mathrm{p}=$ The population proportion

$\mathrm{n}=$ The sample size

$\mathrm{N}=$ The population size

The standard confidence intervals Z for confidence level 90% used in statistics are 1.645 and the maximum probability of p (the population proportion) is 0.5 (H. Singh, 2015).

$$MOE = 1.645 \times \sqrt{\frac{0.5(1-0.5)}{57} \times \frac{(169-57)}{(169-1)}}$$

$$MOE = 0.089$$

Margin of Error(MOE) is 8.9%. This seems like a reasonable value.

b. AJ framework implementation and evaluation.

For the qualitative approach, firstly, observation procedures included two tutors in two modules; an MSc Digital Control module and a BSc Embedded Systems module. Secondly, all the student engagement and performance was observed in the module, tutor performance was observed and interviews were conducted. For the quantitative approach, student marks and attendance data were collected. The study took place three times in the MSc Digital Control module, and one time in the

BSc Embedded Systems module. Table 3.1 shows the actual number of students participated in this study.

In the Digital Control module the three cases are as shown in Table 3.1. It is clear that 100% of the students participated, however, the population proportion itself is small, so considered statistically insignificant, which led to deal with them as qualitative data.

Table 3.1 Students participated ratio in the AJ implementation

Empirical research, AJ framework implementation	**Students**	**Assessment sample size**	**Participants ratio**	**EvaSys feedback**	**Participants ratio**
Digital Control Module, First implementation	7	7	100%	7	100%
Digital Control Module, Second implementation	6	6	100%	6	100%
Digital Control Module, Third implementation	6	6	100%	6	100%
Embedded Systems Module, First implementation	50	50	100%	22	90%

In regards of the Embedded Systems module the population proportion is 50 students which is statistically accepted because the normal distribution and confidence level is 100% for students assessment, and where the sample size is more than 30 that is considered acceptable statistically because of the normal distribution (L. M. Cohen & Manion, 2011).

However, in terms of students feedback through the EvaSys instrument the situation is different, because students are free to participate or not, as participation is not compulsory, so the total participants number was 22 students (40%). So, for this sample size MOE can be calculated by using the same formula in Equation 3.1.

MOE was 13.4%, based on 90% confidence level. Nevertheless, by comparing with related work in assessment and evaluation in HE, although only 40% of students agreed to give feedback, this ratio is not too bad comparing with other related publications, for example Watt, Simpson, McKillop, & Nunn (2002) got only 33.3% response rate.

ii. Developing country

For the quantitative approach, the population of the target group was estimated to be 150 academic tutors who teach in the SST departments from MU and other HEIs. The population is not a certain number because of the political situation and the war in the country disrupted the research.

By using Equation 3.1 based on a 90% confidence level the MOE was 12.6%, however, the sample size was the best that could be done (see Section '6.3 Recommendations for Future Work based on Research Limitations', p.168). especially, for the ongoing situation in Libya as mentioned in Section 1.9, p.10.

For the qualitative approach, the head of the Training Centre of LISCO in Misurata was interviewed, also a focus group with 10 teachers who are teaching in this centre, in computing and electrical and control engineering and the technical teaching of the English language for technicians and engineers working in the Factories of this company.

The AJ framework was presented and discussed in the 7th workshop on April 2014. This included 96 higher Institutes in Libya participated in this workshop. The results and discussions of this workshop will be presented in Chapter 4.

3.7.8 Sample procedures

Since the research target group is a particular subset, a selective sample (purposive sampling) technique was used to gather responses from teachers working in teaching in HE in STEM subject areas and from the students. The reason for using purposive sampling is because it is a non-probability sampling technique which is most effective when there is a need for studying a certain area with 'inside experts' within the subject area. The purposive sampling can be used with quantitative and qualitative methods (Tongco, 2007).

For the quantitative methods, a survey instrument was distributed to tutors (in-services teachers) and PhD students (pre-services teachers) of the SST at NTU. The survey instrument was distributed to tutors (in-services teachers) of MU and HEIs in the City of Misrata - Libya, to examine the developing country case.

In terms of qualitative methods, the observations and interviews targeted the teachers on selected modules and students who took these modules in the SST.

For the developing country case, the methods included a focus group with higher Institutes teachers, and Training Centre of LISCO. In addition, interviewing the head of developing department in administration of HEIs, National board of technical and vocational education/ Libya, as well as an interview with the head of Training Centre of LISCO was done.

3.7.9 Developing the framework

The literature review of previous work was used to construct the framework. The framework was adapted based on the TPACK theory and the added parts from what the researcher found to make it more appropriate for HE with links to industrial needs. This results in a new framework called the 'AJ Framework' which is considered as a developed framework, by covering the domains of the AJ Framework in lesson plans, content, and used technology for each module (see Chapter 4 and Chapter 5). This approach is considered as a non-empirical approach.

To achieve development on the TPACK framework, different research methods were designed and used for data collection.

i. Questionnaire design

This research method was covered in sub-section 3.7.3, p.42. In addition, the correlation relationship between each domain with an AJ Framework added item was calculated (see sub-section 4.11.1, p.79).

ii. Interview design

Experts in HE were interviewed, the interviews were designed as semi-structured interviews. The questions were asked about using technology in HE and how to update the content, teaching strategies, and technology including meeting industrial needs.

The following list provides the experts in SST who were interviewed to know about school approaches, regulations, and their reasoning:

- Module leaders/tutors
- School Teaching and Learning Coordinator
- School Quality Manager

- Courses Managers (how the module fits in the course)
- Academic Team leaders (ATLs)

iii. Observation design

Observation is used broadly for collecting data. It is an approach which offers the researcher a chance to collect live data from live situations. This makes the researcher inductive and see things, which might happen in real situations (L. Cohen, Manion, & Morrison, 2013).

Tutor and student performance and student engagement were observed. The researcher attended all lecture and lab sessions, also, audio records were taken.

The importance of conducting observations of students is:

- Provides feedback to tutors and students regarding types of pedagogic issues, in order to enhance performance for the next stages.
- Provide a baseline against which to evaluate the level of success of the educational process.
- Provide a baseline against which to assess the level of success of instructional intervention.

Observation research methods were used to evaluate and assess the effects of the AJ framework on tutor and student performance alongside industrial needs (through formal meetings, and through filling feedback forms). This stage sustains and supports performance improvements for the subject in HE (see sub-section 5.2.1).

iv. NTU teaching support facilities

The following NTU facilities are used extensively in this research and have been used to apply the AJ framework as context and/or research data sources (www.ntu.ac.uk):

NOW (including TURNITIN: plagiarism detection program used by NTU)

The Student Dashboard which is a system used to monitor students' engagement. It measures students' attendance, using the NOW (Nottingham Trent Online Workspace) system, access to module material, library use and access to university buildings.

Banner (student online results database): the system used for releasing students results, where each student can see their results.

Common Assessment Regulations: "processes of assessment in place which enable every student to demonstrate the extent to which they have achieved the intended learning outcomes of the award. The main purposes of assessment are to judge the students' achievement of learning outcomes and to safeguard threshold academic standards. Appropriate assessment also informs teaching, facilitates and shapes learning and engagement and supports the development of graduate attributes."

School Policies with respect to students and staff:

"Support students and make sure that they have the knowledge with the purpose of attendance monitoring and they "have the opportunity to engage with all of the course's learning outcomes." And provide equality considerations and who they can contact if the face any problems.

Some NTU HR policies (especially peer observation of teaching):

The observation polices apply to all teaching and learning facilities in classes; lectures, tutorials, seminars and laboratories.

3.8 Design experiments

In education, design experiments (it is also called design-based research) are considered as an effective methodology to study tutor and student development Design experiments is post-positivism paradigm used to study learning in context through study of teaching tools and strategies; and the systematic design (Angeli & Valanides, 2005).

In terms of experiment design, implementation and evaluation, the ADDIE model was used as Instructional System Design (ISD), as shown in Figure 3.4. ADDIE includes five phases Analysis, Design, Development, Implementation and Evaluation. It is used by instruction designers to build performance tools and effective training (Morrison, Ross, Kemp, & Kalman, 2010).

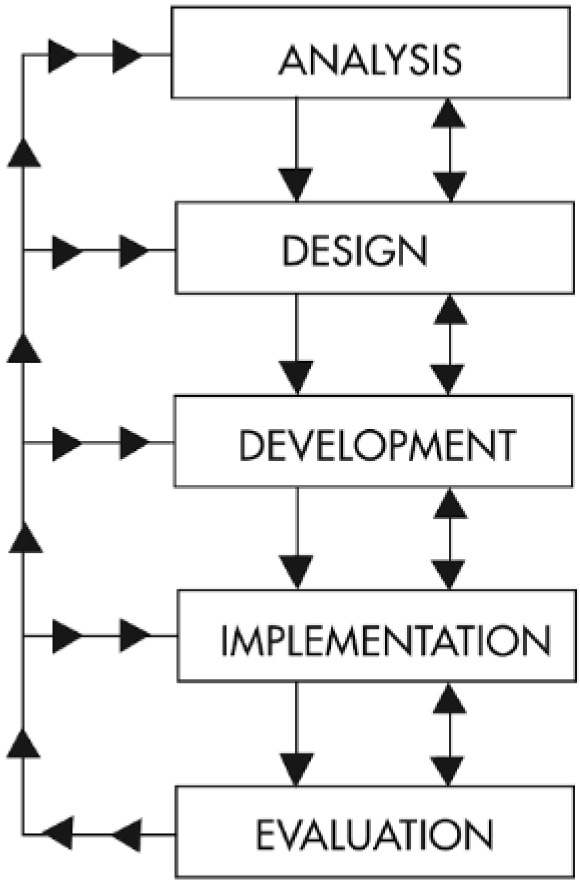


Figure 3.4 ADDIE Model (Kovalchick & Dawson, 2004)

ISD is “a technology which incorporates known and verified learning strategies into instructional experiences which make the acquisition of knowledge and skill more efficient, effective, and appealing” (Merrill, Drake, Lacy, Pratt, & ID2 Research Group, 1996, p.2).

The ADDIE model is widely used as ISD. The constructivist paradigm helps to shape instructional theory (Cunningham & Duffy, 1996).

Analyse: in this phase, the tutor analyses gathered information about the student level, student learning style, module overall aims, and learning outcomes. Then the tutor classifies to make the content (this covers the CK domain) more applicable (this covers the PCK domain).

Design: The tutor designs the module objectives in detail, and plans teaching strategies by identifying the activities required from students, in order to achieve modules aims and learning outcomes, based on the analyse phase. This phase could cover all TPACK domains.

Develop: Tutor creates the designed activities. This phase might include PK, PCK, TPK, TCK and TPACK domains depending on the requirements of activities.

Implement: The fourth phase involves implementing the developed content (CK) and teaching strategies (which might cover PK, PCK, TPK, and TPACK domains). This phase gives tutors a chance to test all materials and define if they are suitable for the intended students.

Evaluation: In this final phase, the tutor makes sure that content and teaching strategies achieved the desired aims. It includes formative and summative assessment forms. This phase could include PK, PCK, and TPK domains.

The ADDIE model is an iterative process ISD, which offers to the tutor chance to assess teaching and learning elements in each phase and revise them any time if necessary. More details are provided in Section 5.2.

An iterative design methodology was used to evaluate the effectiveness of the AJ Framework.

3.8.1 First implementation of the framework in the Digital Control module

As the research aims to investigate and develop teaching and learning in HE in STEM subjects, so there is a need to observe the implementation of the TPACK framework in a real course. The study took place three times in an MSc Digital Control module, and once in a BSc Embedded Systems module.

In the MSc Digital Control Module, the module content is divided into two parts: in the first part we taught by a conventional teaching strategy, and second part we applied the TPACK framework and students were assessed by giving them an assignment for each part. We got feedback from the students and the tutor about which strategy they found better and why, as illustrated in Figure 3.5. To test the impact of using TPACK we compared the score of each student for each part as shown in Figure 3.6. Moreover, we noted the student understanding and interaction with specific learning activities. Student feedback took place and changes were made to the module and they were implemented for the next year. In terms of a selected approach, this stage used a constructivism philosophic paradigm, for research design; it is an experimental design, and both quantitative and qualitative methods are integrated by collecting data, observing and interviewing the students and the tutors.

Figure 3.5 Getting student feedback

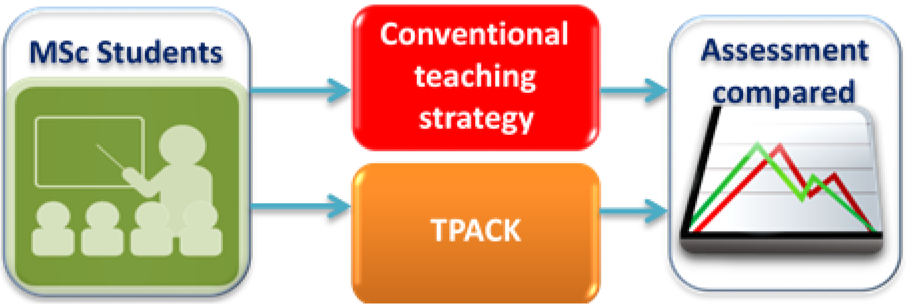


Figure 3.6 Compared assessment

3.8.2 Second implementation of the framework in the Digital Control module

The second time of implementation of the framework took place in the following year. Again the framework was implemented as the first time; additionally we used the feedback of last year's implementation. In this year another tool was used which is the student dashboard (now.ntu.ac.uk) as Technological Pedagogical Knowledge (TPK). The student dashboard is a system used to monitor student engagement. It measures students' attendance, using the NOW online system, access to module material, library and access to university buildings. A student from the first implementation who was on placement this year, was interviewed and we got more feedback about industrial needs. The tutor was interviewed again several times.

3.8.3 Third implementation of the framework in the Digital Control module

The final implementation of the framework took a place in the following year. The framework was implemented, as last time, and the feedback of last year was considered. In this year the industry feedback took place and the content was updated based on that.

3.8.4 First implementation of the framework in the Embedded Systems module

The framework was implemented in BSc level in an Embedded Systems module. The content of the module was updated to meet the needs of the industrial sector. All lectures and labs were observed and weekly feedback was taken. The performance of the students, their marks, and feedback was compared with the previous year. This included many formal and informal interviews and meetings with the tutor.

3.9 Validity and reliability

The researcher was involved in some teaching sessions in Digital Control module, so might that caused bias. To achieve validity and reliability some methods and statistical techniques were used. For more details, see Chapter 4.

- Experts in teaching in HE reviewed the questions of the instrument.
- Content Validity Index (CVI) was used to test the validity of each question within the instrument, CVI is widely used to evaluate quantitative methods (Aljojo, 2012).
- A pilot study was conducted with 10 tutors in HE to examine the clarity of the questions on the instrument.
- Principal Component Analysis (PCA) was used to test validity of the instrument.
- Cronbach Alpha was used to test reliability.
- Test and retest was used to achieve repeatability.

3.10 Data analysis and interpretation procedure

As the research was conducted by using mixed methods, both approaches, quantitative and qualitative, have data analysis procedures.

3.10.1 Quantitative data analysis procedure

For quantitative data analysis, statistical techniques were applied. An analytic strategy was applied by the statistical program, SPSS version 22 (http://www.ibm.com/analytics/us/en/technology/spss/), to analyse the responses to the questionnaire. SPSS was used to test the validity and reliability as mentioned in previous section. PCA as factor analysis techniques was used to test validity of the data. The purpose of PCA is to reduce a large set of observed variables into a comparatively smaller number of components. This method helps researchers determine a level of construct validity (Lackey, 2008). It is used here to produce a new training model for teachers in HE based on the theory of the TPACK framework, (see Chapter 4). For reliability, the Cronbach alpha test was conducted to determine the reliability of collected data (Hartas, 2015).

3.10.2 Qualitative data analysis procedure

The interviews and observations were turned to text by using thematic analysis. Thematic analysis is used to find out patterns or themes within the data, and it commonly used in to associate with research questions and describe phenomena (Braun & Clarke, 2006; Bryman, 2012).

3.11 Ethical considerations

Collecting information requires informing participants, getting their consent, and making sure they are willing to allow researchers to use the data collected from them, to be considered as ethical (Kumar, 2014). Thus, the researcher considers the entitlement of privacy of participants and of all other ethical issues: personal data, informed consent, confidentiality and anonymity overall time whether during collecting data or after that (Brooks, Te Riele, & Maguire, 2014).

Ethics research clearance (Appendix D) was obtained from the Joint Inter-College Ethics Committee (JICEC) in Art & Design and Built Environment/Arts and Science, Nottingham Trent University. The consent form has been signed by all of the respondents who participated in the study.

3.12 Summary

This chapter examined the research approaches, philosophical paradigms, designs and methods of this research. In addition the methods of data collection and the research approaches were justified based on each research problem and research design stages, procedures of analysis and interpretation the findings, and validity and reliability and ethical consideration were presented.

4. Chapter Four: Validity and reliability test of tutor assessment instrument, training model and the AJ teaching framework.

4.1 Introduction

This chapter presents three sub-areas: Validity and reliability testing of the tutor assessment instrument, developing a training model and developing a novel HE teaching framework (the AJ Framework).

4.2 Assess tutor understanding of integrating technology to the content and pedagogy

This section presents the assessment approach to assess tutor understanding and perception of the TPACK framework.

4.3 Validate the TPACK HE instrument

As mentioned in sub-section 2.5.2, there are many instruments that have been used as a self-assessment tool to measure tutor knowledge of TPACK. This section presents the instrument validity test following the steps described earlier (see Section 3.9, p.56).

The TPACK HE questionnaire instrument, of 47 items, was developed (see sub-section 3.7.3, p.42) for this study adopting questions developed from previous studies (Koh & Chai, 2014; Sahin, 2011; Schmidt et al., 2009).

Although these earlier questionnaires have been validated, additional validation was carried out since the designed questionnaire in this study mixed items from different previous questionnaires and adapted them to fit the HE context.

Construct validity was established through the use of pedagogy experts reviewing the instrument. Seven experts in teaching in HE reviewed the questions of the instrument.

A pilot study, using face-to-face assessment was also carried out with 10 participants (more details in section 4.3.2).

4.3.1 Computing a content validity index (CVI) of the instrument

This section illustrates the method, which was used to provide interpretable content validity for the readers.

The questions of the instrument were reviewed by 7 experts in teaching STEM subjects in HE.

An Item-Content Validity Index (I-CVI) was calculated; if the expert gave 3 or 4, the item will be considered, if less it will not. The mean (Proportion) will be calculated for all the items by summing experts rate of each item and dividing by the total number of items as showing in Equation 4.1 . I-CVI is recommended to be not lower than 0.879 on average (Polit & Beck, 2006).

$$I - CVI = \frac{\sum\sum Experts\ rate\ of\ each\ item}{Number\ of\ Items}$$ *Equation 4.1(Proportion of I-CVIs)*

Table 4.1 Ratings on a 47 Items Scale by Seven Experts: Items Rated 3 or 4 on a 4-Point Relevance Scale

Item	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Number in Agreement	Item CVI
1	3	4	4	4	4	4	4	7	1.00
2	4	4	3	4	4	4	4	7	1.00
3	3	4	4	4	3	4	4	7	1.00
4	4	4	4	4	4	3	2	6	0.86
5	3	4	4	4	4	3	4	7	1.00
6	4	3	4	3	4	4	4	7	1.00
7	3	3	4	2	4	4	4	6	0.86
8	3	3	4	4	3	4	4	7	1.00
9	3	3	4	3	4	3	4	7	1.00
10	3	4	4	3	4	3	2	6	0.86
11	4	4	4	4	4	4	2	6	0.86
12	2	3	4	4	3	4	3	6	0.86
13	4	3	4	4	3	4	4	7	1.00
14	4	4	3	4	4	4	4	7	1.00
15	4	4	4	4	4	4	4	7	1.00
16	4	4	4	4	4	4	4	7	1.00
17	3	4	4	4	3	4	4	7	1.00
18	3	3	4	3	4	1	2	5	0.71
19	3	3	4	3	3	1	2	5	0.71

Item	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Number in Agreement	Item CVI
20	2	2	4	3	3	1	3	4	0.57
21	3	2	3	1	3	1	2	3	0.43
22	2	3	3	4	4	1	2	4	0.57
23	4	4	4	4	4	4	4	7	1.00
24	4	4	4	4	4	3	4	7	1.00
25	3	4	3	4	4	2	3	6	0.86
26	3	4	3	4	4	2	3	6	0.86
27	3	4	4	4	4	2	3	6	0.86
28	3	4	4	4	4	2	3	6	0.86
29	4	4	4	3	4	3	4	7	1.00
30	3	4	4	4	4	3	4	7	1.00
31	4	4	4	4	4	3	4	7	1.00
32	4	4	4	4	3	3	4	7	1.00
33	4	4	4	4	3	3	4	7	1.00
34	4	3	4	3	3	3	3	7	1.00
35	3	3	4	3	3	3	4	7	1.00
36	3	3	4	4	3	1	3	6	0.86
37	3	3	4	3	3	1	3	6	0.86
38	2	3	3	3	3	1	2	4	0.57
39	3	2	4	2	3	1	3	4	0.57
40	4	3	4	4	3	4	4	7	1.00
41	4	3	4	4	4	4	4	7	1.00
42	3	3	3	3	4	2	3	6	0.86
43	4	3	4	4	3	3	4	7	1.00
44	4	3	4	3	4	4	4	7	1.00
45	2	3	3	2	4	4	4	5	0.71
46	3	3	3	3	4	4	4	7	1.00
47	4	4	4	4	4	4	4	7	1.00
Proportion Relevant:	0.89	0.94	1.00	0.91	1.00	0.70	0.83	Mean expert/ Proportion (I-CVIs)	0.90
								S-CIV/UA (Universal Agreement)	0.57
								Total Agreements	27

As shown in Table 4.1, the I-CVI is 0.90 which in bigger than 0.78: that indicates validity is achieved.

4.3.2 Pilot study

A pilot study was conducted at Nottingham Trent University with 10 participants, using face to face assessment. Participants were encouraged to answer and give feedback as honestly as possible, particularly for ambiguous or misleading words, phrases or imprecise questions. One participant confused similar questions and thought that there are repetitions in the Pedagogical Knowledge (PK) domain and Pedagogical Content Knowledge (PCK) domain:

"Question 29: I am familiar with common student understandings and misconceptions." And "Question 42: Without using technology, I can address the common misconceptions my students have for my first teaching subject."

This led to the use of sub headings in the questionnaire for each sub-scale of TPACK domains to make it clearer and to avoid confusing the participants in the main study.

4.3.3 Sample size of the academic tutors from SST, NTU

The participants were mostly male, with 45 responses (78.9%) against 12 (21.1%) female. This is consistent with the population distribution of the target group (72% male and 28% female). The age was ranged in four blocks, three blocks from 27 to 43 and a block of 43+. The biggest age sample in a block was 44% for ages over 43. The responses were from every department in the SST, including the highest number of participants from the Computing and Technology team (32 tutors, which contributed 56.1% of the responses), see Figure 4.1. 80.9% of staff have stated they have attended teaching and pedagogy training courses.

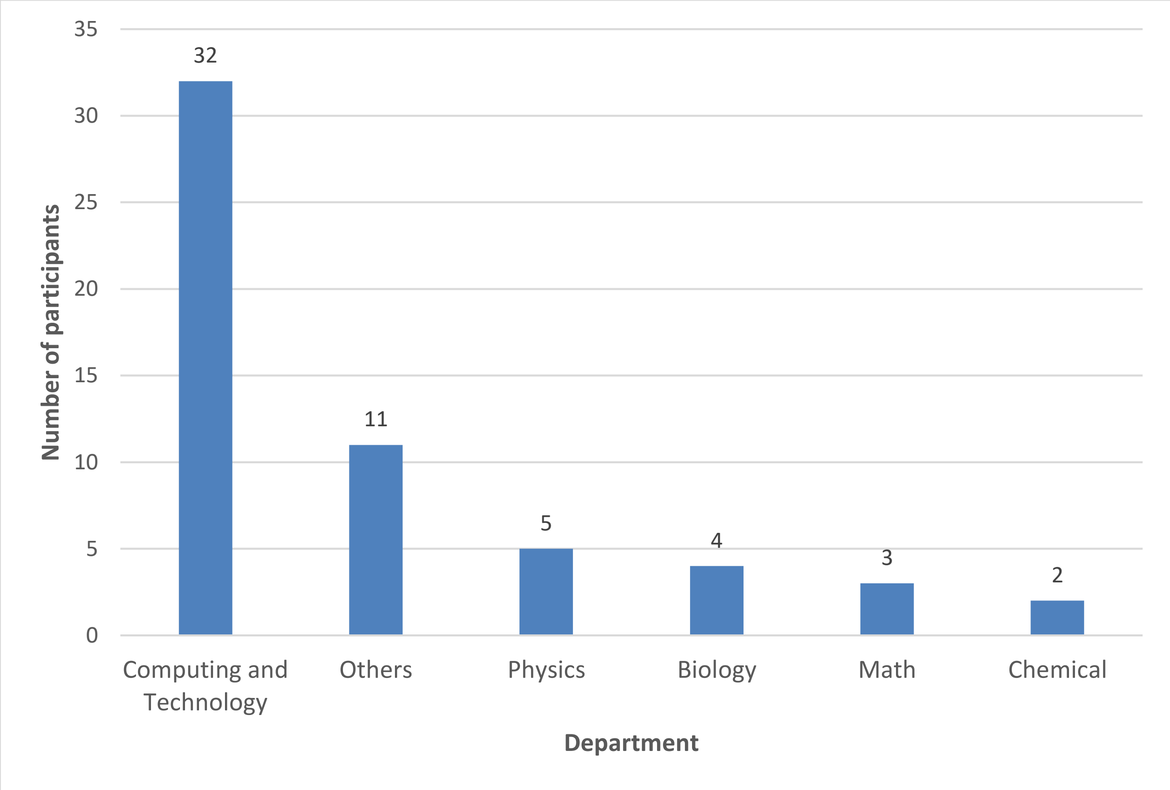


Figure 4.1 Participant numbers from each department (NTU)

4.3.4 Test the validity of the instrument (construct validity)

The 47 items survey was then subjected to Principal Component Analysis (PCA). To validate that the data set is appropriate for component analysis, the Kaiser-Meyer-Olkin (KMO) sampling adequacy value was measured. The KMO value was calculated as 0.59, which is beyond the minimum satisfactory value of 0.5 required to proceed to PCA (Kamel, 2010). As the KMO value was between 0.5 and 0.7, this indicated an acceptable sample size (Kaiser, 1974; Kamel, 2010; Phelan, 2008). Also the Bartlett's Test of Sphericity value was found to be significant at $p<0.001$ (Bartlett, 1954; Müller, 2013). The correlation matrix showed many correlations greater than 0.3 (see Table 4.2 Part of Correlation Matrix**)**. The correlation matrix is considered as suitable for PCA, as one of the factor analysis techniques, if some correlations are $r=0.3$ or greater (Pallant, 2010). By achieving all of these requirements, performing PCA component analysis is regarded as suitable for the data set.

Table 4.2 Part of Correlation Matrix

Correlation	CK10	CK11	CK14	PK16	PK17	PK18	PK19	PK20
CK10	1.000	0.615	0.477	0.582	0.330	0.279	0.332	0.421
CK11	0.615	1.000	0.353	0.379	0.228	0.244	0.351	0.305
CK14	0.477	0.353	1.000	0.348	0.298	0.300	0.363	0.400
PK16	0.582	0.379	0.348	1.000	0.667	0.487	0.504	0.322
PK17	0.330	0.228	0.298	0.667	1.000	0.602	0.622	0.391
PK18	0.279	0.244	0.300	0.487	0.602	1.000	0.638	0.276
PK19	0.332	0.351	0.363	0.504	0.622	0.638	1.000	0.362
PK20	0.421	0.305	0.400	0.322	0.391	0.276	0.362	1.000

The component loadings for items lower than 0.50 have been ignored in this analysis, with a view to focus on the higher value, important items (Hair, Black, Babin, Anderson, & Tatham, 2006).

PCA revealed the presence of eleven components with eigenvalues greater than one. However six of them have less than three items, which is considered unacceptable (L. A. Clark & Watson, 1995). Also, the scree plot, indicates the change (or elbow) is after the third component (see Figure 4.2). Moreover, the total variance for each component should attribute at least 5% (Netemeyer, Bearden, & Sharma, 2003). Therefore the analysis has been repeated using only the three components meeting these requirements.

This analysis confirmed the existence of three separate components within the survey, using the eigenvalues rule, known as the Kaiser Normalization, as indicated by the components with eigenvalues greater than one. The amount of variance explained by the three components was 54.973% (see Table 4.3) which exceeded the 50% minimum considered acceptable (Dunteman, 1989).

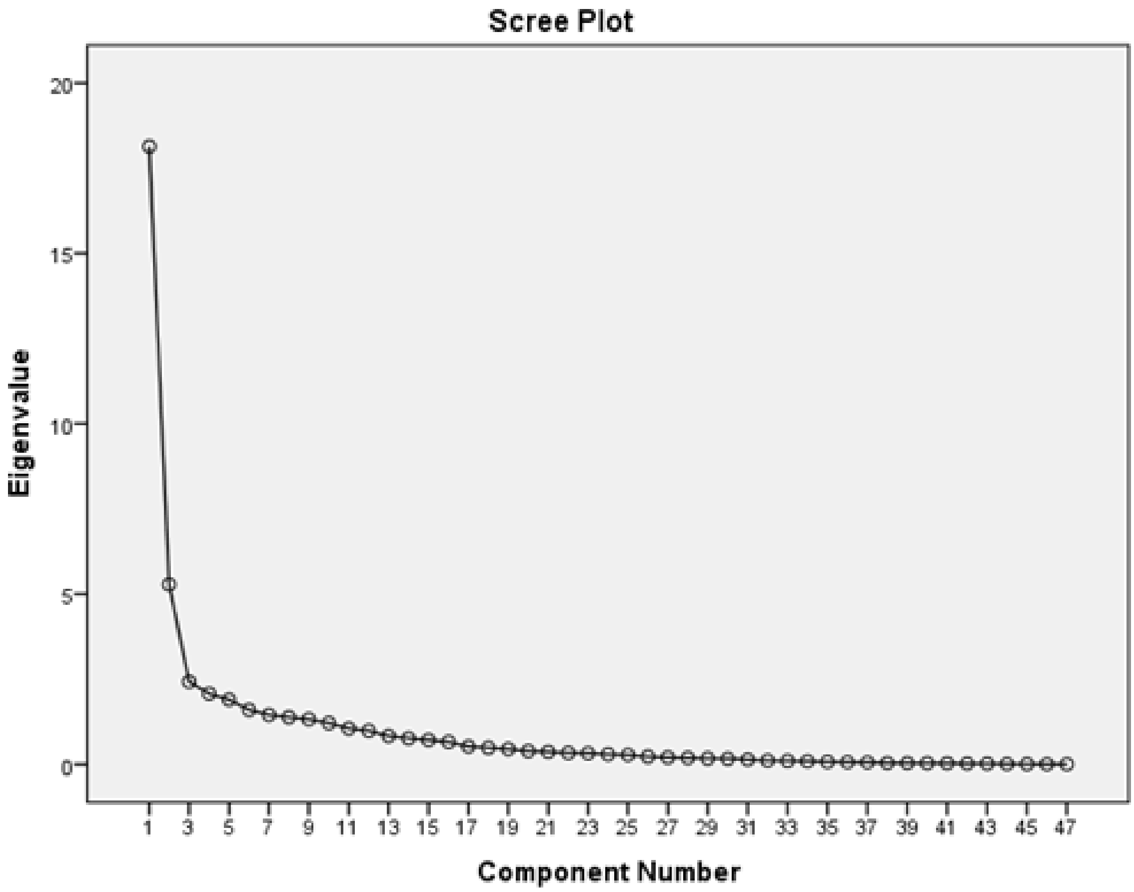


Figure 4.2 Scree Plot of TPACK instrument of 47 items

Table 4.3 shows the eigenvalues, the total variances, and the cumulative variance for each of the three components found as a result of PCA. The eigenvalue of the first component is 18.132 with the highest variance as 38.579% of the total variance explained. The second component's eigenvalue is 5.280 with 11.234% total variance explained. The third component's eigenvalue is 2.425 and the total value explained is 5.161%.

Table 4.3 Total variance explained after rotation

Component	Eigenvalues	Percentage of Variance (%)	Cumulative Variance (%)
1	18.132	38.579	38.579
2	5.280	11.234	49.813
3	2.425	5.161	54.973

4.4 Test the reliability of the instrument

For the survey item's reliability determination, values of internal consistency (Cronbach's alpha) were computed for each subscale. The values in Table 4.4 are shown against descriptive statistics, with alpha values from 0.92 to 0.72, demonstrating high internal consistency reliability (Hartas, 2015). Cronbach's alpha not only depended on correlation between the items but also, depended on number of items, so more items mean more reliability (Streiner, Norman, & Cairney, 2014). As seen the CK and TCK got the lowest value with 3 items, however, the reliability is still within accepted range.

Table 4.4 Summary of descriptive statistics and Cronbach alpha values for each domain (English Version)

Domain	Number of survey items	Mean	Standard deviation	Cronbach's alpha
Content	3	4.43	0.61	0.72
Pedagogy	14	4.22	0.70	0.92
Technology	5	4.22	0.86	0.84
Pedagogical content	6	4.14	0.53	0.87
Technological content	3	4.31	0.71	0.84
Technological pedagogy	9	4.07	0.77	0.91
Technological pedagogical content	7	3.89	0.85	0.89

4.5 Designing a training module for tutors in HE

As a result of the PCA, three components represented the TPACK framework (see Figure 4.3). These components are named in accordance with the literature as follows: Technology Integration (TK, TCK, TPK and TPACK); Pedagogy related (PK and PCK); and Pedagogical Content Knowledge (PCK, CK and PK). PCA measured the highly correlated items and from the response of the participants it can be reported that there is clear connection between Technology and all other domains which include technology; TK, TCK, TPK, and TPACK. The responses also reported pedagogy items connected with Pedagogy and PCK. Finally the third component reported is the strong connection between PCK without technology and the content knowledge domain:

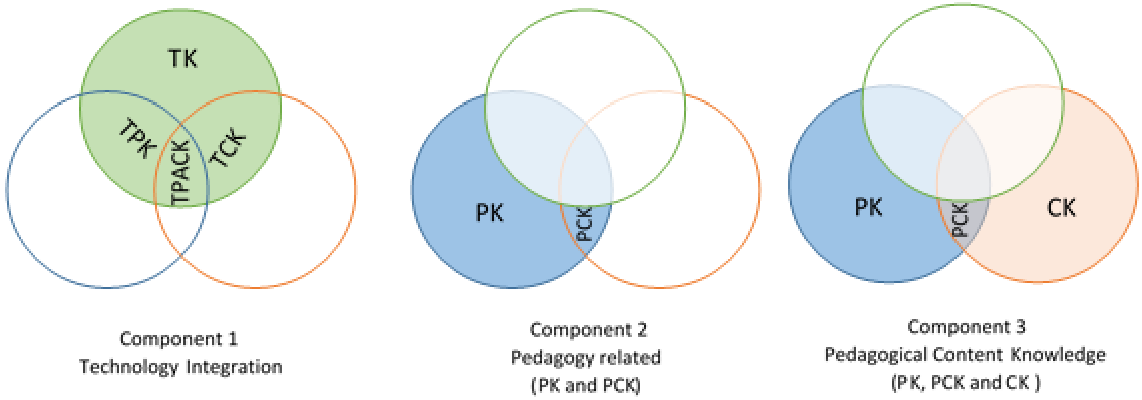


Figure 4.3 Components with covered TPACK domains

Table 4.5–4.7 illustrate how the survey items, loaded by factors, as indicated by the rotated component matrix, converged in five iterations. The communalities for each item are also presented.

Table 4.5 Rotated component matrix – Component 1: Technological pedagogical and content knowledge.

Rotated Component Matrixa		
Survey item	Subscale	Component 1
I can use appropriate technologies (e.g. multimedia resources, simulation) to represent the content of my teaching subject.	TCK	.820
I have the technical skills to use computers effectively.	TK	.814
I know about technologies that I can use for understanding and delivering my content area.	TCK	.776
I can learn technology easily.	TK	.775
I can choose technologies that enhance the teaching approaches for a lesson.	TPK	.762
I can choose technologies that enhance students' learning for a lesson.	TPACK	.749
I can choose technologies that enhance the content for a lesson.	TPACK	.742
I can evaluate the appropriateness of a new technology for teaching and learning.	TPK	.739
I know about the technologies that I have to use for the research of content of my teaching subject.	TCK	.734
I know how to solve my own technical problems when using technology.	TK	.723
I can use strategies that combine content, technologies and teaching approaches in my coursework in my classroom.	TPACK	.708

Rotated Component Matrixa		
Survey item	Subscale	Component 1
I think critically about how to use technology in my classroom.	TPK	.652
I can adapt the use of the technologies to different teaching activities.	TPK	.648
I can design inquiry activities to guide students to make sense of the content knowledge with appropriate ICT tools (e.g. simulations, web-based materials).	TPACK	.647
I am able to facilitate my students to use technology to find more information on their own.	TPK	.646
I can design lessons that appropriately integrate content, technology and pedagogy for student-centered learning.	TPACK	.624
I can teach lessons that appropriately combine content subject “content area”, technologies and teaching approaches.	TPACK	.596
I am able to use collaboration tools (e.g. Google Sites, Google Doc).	TK	.595
I can provide leadership in helping others to coordinate the use of content, technologies and teaching approaches at my school and/or district.	TPACK	.591
I can create self-directed learning activities of the content knowledge with appropriate ICT tools (e.g. Blog, Webquest).	TPACK	.567

Table 4.6 Rotated component matrix – Component 2: Pedagogical Knowledge.

Rotated Component Matrixa		
Survey item	Subscale	Component 2
I can adapt my teaching based-upon what students currently understand or do not understand.	PK	.794
I can assess student learning in multiple ways.	PK	.761
I can adapt my teaching style to different learners.	PK	.743
I am able to stretch my students’ thinking by creating challenging tasks for them.	PK	.734
I know how to assess student performance in the classroom.	PK	.691
I know how to organize and maintain classroom management.	PK	.688
I am able to guide my students to adopt appropriate learning strategies.	PK	.677
I am able to help my students to monitor their own learning.	PK	.630
I can select effective teaching approaches to guide student thinking and learning.	PCK	.603
I am able to select appropriate and effective teaching strategies for my content area.	PCK	.580
I am able to help my students to reflect on their learning strategies.	PK	.535
I can use a wide range of teaching approaches in a classroom setting.	PK	.524

Table 4.7 Rotated component matrix – Component 3: Pedagogical and Content Knowledge.

Rotated Component Matrixa		
Survey item	Subscale	Component 3
Without using technology, I know how to select effective teaching approaches to guide student thinking and learning of the subject matter for my first teaching subject.	PCK	.775
Without using technology, I can address the common misconceptions my students have for my first teaching subject.	PCK	.744
Without using technology, I can help my students to understand the content knowledge of my first teaching subject through various ways.	PCK	.682
Without using technology, I can address the common learning difficulties my students have for my first teaching subject.	PCK	.656
I can think about the content knowledge of my first teaching subject like a subject matter expert.	CK	.584
I am able to plan group activities for my students.	PK	.570
I am confident to teach the content knowledge for my first teaching subject.	CK	.559
I have sufficient content knowledge in my first teaching subject.	CK	.502

4.6 Discussion of the designed training model for tutors in HE

Theoretically and practically, the TPACK framework has been structured for effective use of technology in order to establish integrated technology in teaching. Nevertheless research has emphasized that there is still a need to illuminate, comprehend and expand the TPACK framework (Yurdakul et al., 2012).

The TPACK framework is obviously helpful from an organisational perspective. (Mishra & Koehler, 2006) state “The TPCK framework, we argue, has given us a language to talk about the connections that are present (or absent) in conceptualizations of educational technology. In addition, our framework places this component, the relationship between content and technology, within a broader context of using technology for pedagogy.” (p. 1044). Despite this, the results of the PCA showed that it is hard to separate the domains. This result matches with earlier research (L. M. Archambault & Barnett, 2010, p.1656) “measuring each domain is complicated and convoluted, potentially due to the notion that they are not separate.”.

Graham (2011) has described the construct values for TPACK and related it to technology integration as a widely used term. This study presented the most important component as Technology Integration, which gathers domains that include all the technology elements; this is in line with what Graham (2011, p.1958) claimed: “One example of how the added constructs can increase value is in distinguishing TPACK from Technology Integration in a more clear, robust way. The TK, TPK, and TPCK constructs are of particular importance to researchers of educational technology”.

The second component, pedagogy related, includes ten items of PK and also includes two items of PCK: (PCK39) I can select effective teaching approaches to guide student thinking and learning; (PCK38) I am able to select appropriate and effective teaching strategies for my content area.

Finally, the third component described three domains, PCK, CK and one item from PK and all PCK items, in this component, mentioned clearly “without using technology” that evidence the separation of technology elements into the first component.

(Graham, 2011) mentioned that the relation between constructs in TPACK is really descriptive: hypotheses might predict the relative value of various approaches to the development of the TPACK framework in addition to the influence of teachers with strong PCK, TPK or TPACK in terms of student learning measurements.

There are some hypotheses for in-service instructors (Graham, 2011), as this research focuses on lecturers in Universities. These include:

- Learning content-specific pedagogies and supporting technologies simultaneously is more effective.
- Beginning with PCK and moving to TPACK because of previous experience with content-specific pedagogies.

It could be possibly said that the second hypothesis is the most supported in this work, based on the PCA. Two components; pedagogy related and the pedagogical content knowledge presented the importance of starting with pedagogical knowledge (stage 1), then moving gradually towards the border between pedagogy and pedagogical knowledge, then moving to PCK (stage 2) and the third component (interpreting the relationship of the items in this component).

After moving to the technology integration component (stage 3), there is a question that was asked by (Koehler, Mishra, Kereluik, Shin, & Graham, 2014):

which is the most effective process for in-service trainers in Universities to move from TPK to TPACK?

Within Table 4.4, which presented the domain means, the technology integration component, TCK has got the highest mean (4.31) of the four technology sub-components and TK is second highest with (4.22). These mean scores indicate that tutors report that their knowledge is very strongly related to their ability to use standard sets of appropriate technologies to represent the content. On the other hand, the TPK mean was 4.07 and TPACK was the lowest at only 3.89. These result support what Cox (2008, p.69) imply that tutors in HE have stronger TCK and less TPK.

Thus, it appears that trainers should have more concentration on TPK than TCK, in other words: it is essential to have knowledge of the general capability of technology in teaching and learning settings then move to the TPACK domain (S. Cox & Graham, 2009), because "of the cognitive overload associated with learning new technologies and content-specific pedagogies all at once." (Graham, 2011, p.1959).

Figure 4.4 summarizes the suggested stages for an in-service tutor training model. As indicated above, based on the research literature and the factor analysis (PCA) results of this study, the first stage starts with pedagogy then moves to PCK as a second stage, finally the third stage, which is more complicated, starts with TPK then moves to TCK and ends with TPACK. In other research, the order of stage 3 may differ and depending on the lowest mean of TPK and TCK, from use of the instrument, the stage should start with the sub-component with the lower mean.

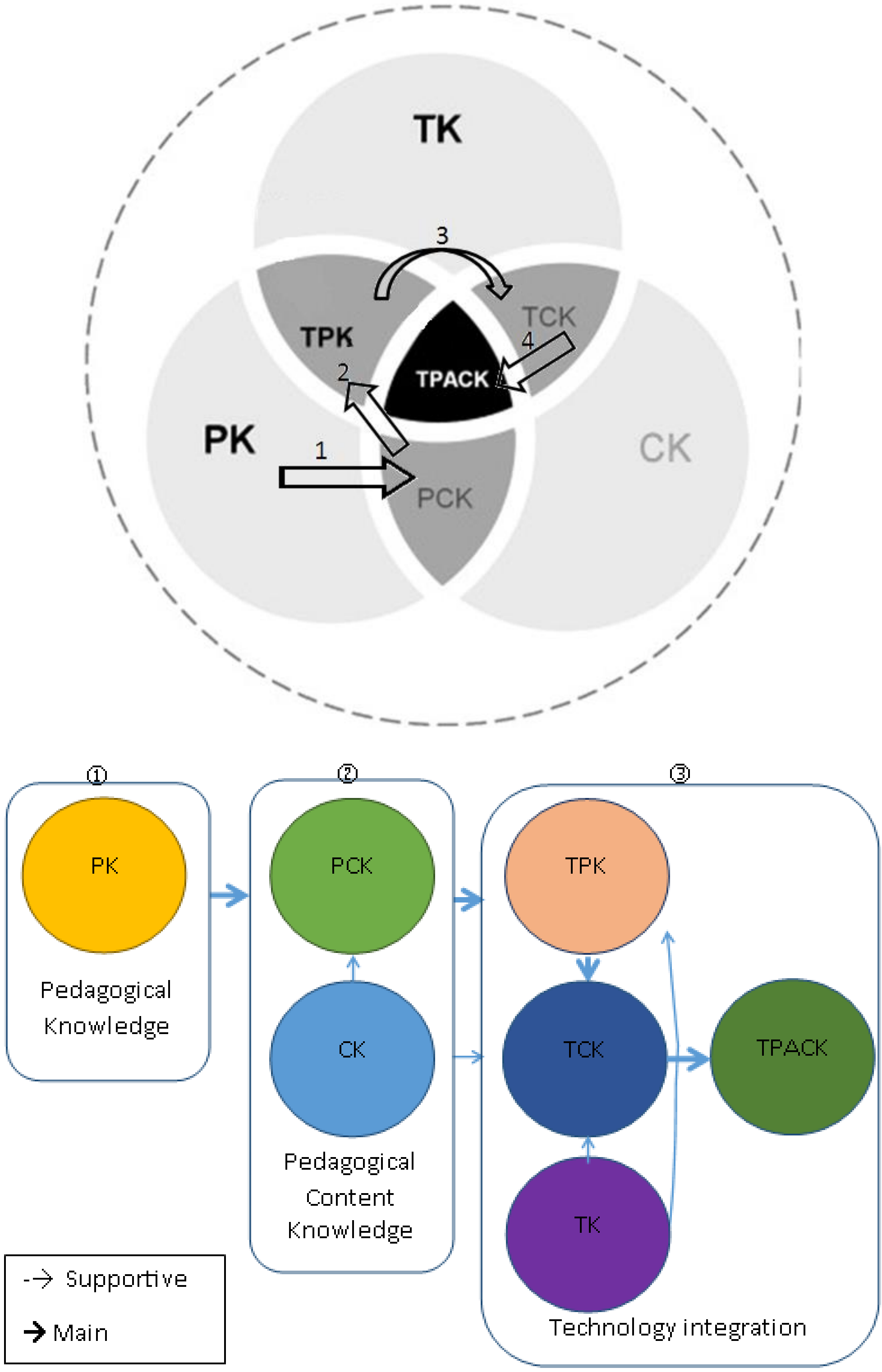


Figure 4.4 The structure of a training course model.

4.7 Validate the Arabic version of the TPACK HE instrument

This section comprises of applying the Arabic version of the TPACK HE instrument to Misurata HEIs.

Investigation of the TPACK framework in developing countries is one of the research aims, and the selected case study was Libya. So, the instrument questions were translated to the Arabic language. The translation was reviewed by two bilingual participants both of whom have experience in computer and engineering teaching in HE.

4.7.1 Construct validity

Construct validity for the Arabic version was established through the use of pedagogy experts reviewing the instrument. Two experts in teaching in Libyan HE reviewed and approved the questions of the instrument (see sub-section 3.7.4).

The translation was reviewed and verified by two bilingual participants both of whom have experience in computer and engineering teaching in HE.

The questions have been reviewed by an expert in the Arabic language who has 30-years of experience in education. He verified the questions structure and meaning from both sides linguistically and pedagogically, and he agreed them.

After that, back translation took place from two independent professional bilingual experts who were not involved in the earlier translation into Arabic. The results of back translation was good, as both back translations gave same meaning, as shown in Appendix A, p.216.

4.7.2 Sample size of the academic tutors from SST, Misurata HEIs, Libya

The participants were mostly male, with 41 responses (75.9%) against 13 (24.1%) female. The age was ranged in four blocks, three blocks from 22 to 43 and a block of 43+. The biggest age sample in a block was 15% for ages between 33-37. The responses were from every department in the SST at Misurata HEIs, including the highest number of participants from the Engineering team (45 tutors, which contributed 83.3% of the responses) most of engineering team teach in Electronic, Computing and Technology subject area, see Figure 4.5. 33.3% of staff have stated they have attended teaching and pedagogy training courses.

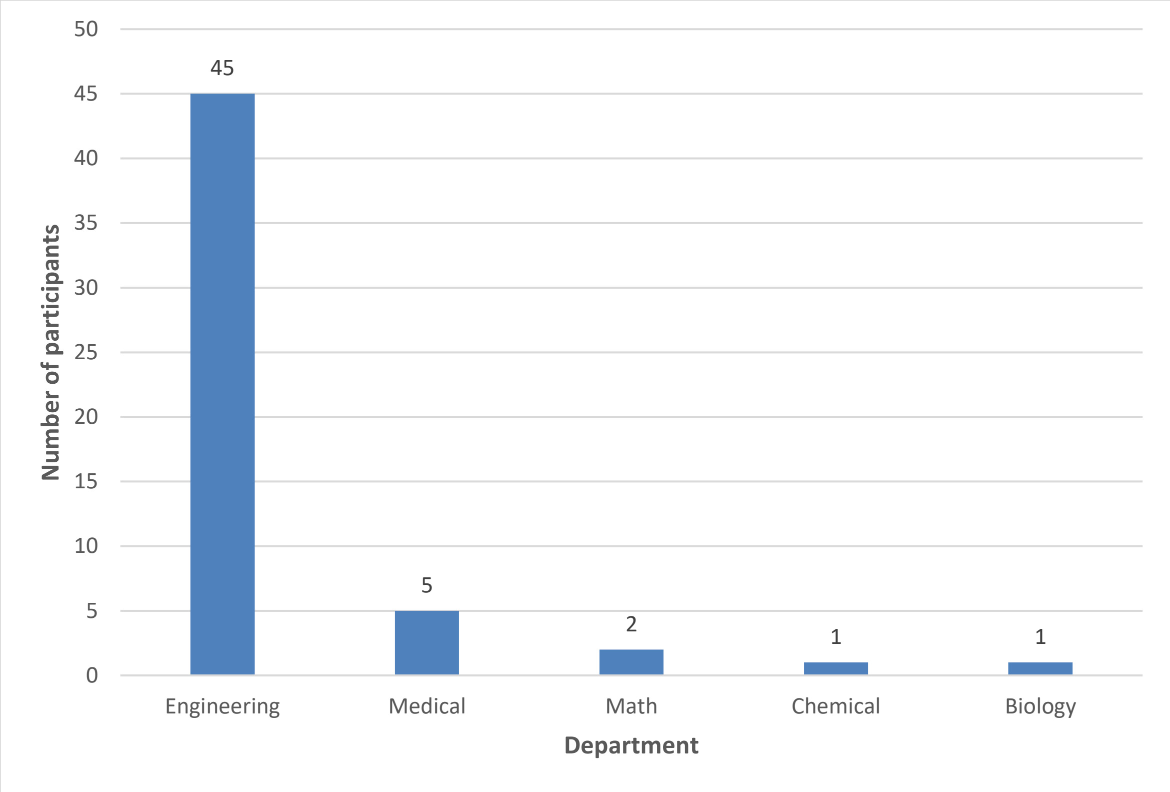


Figure 4.5 Participant numbers from each department (MU and HEIs)

4.8 Test reliability of the Arabic version of TPACK HE and AJ instrument

Cronbach's alpha coefficient was calculated for each of the 61 items of AJ instrument based on the sample of 54 tutors for the pilot study.

For the survey item's reliability determination, values of internal consistency (Cronbach's alpha) were computed for each subscale. The values in Table 4.4 are shown against descriptive statistics, with alpha values from 0.93 to 0.65, demonstrating high internal consistency reliability, all values accepted (see section 4.4).

Table 4.8 Cronbach alpha values for each domain (Arabic Version)

Domain	Number of survey items	Cronbach's alpha
Content	4	0.65
Pedagogy	15	0.93
Technology	6	0.77
Pedagogical content	6	0.89

Domain	Number of survey items	Cronbach's alpha
Technological content	4	0.72
Technological pedagogy	10	0.92
Technological pedagogical content	8	0.89
AJ	8	0.92

4.9 Development of a novel pedagogical framework (the AJ Framework)

This section presents the design and evaluation of the AJ Framework in teaching undergraduate and postgraduate modules.

As described in Chapter 2, there are good reasons to select TPACK as a framework. However, TPACK for HE needs to be linked to industrial needs. So after developing that framework, the improved framework is called the AJ Framework.

The schematic shown in Figure 4.5, and 4.6 was designed to build the perspective for the sustainable teaching of embedded and control engineering with linkage to industrial needs.

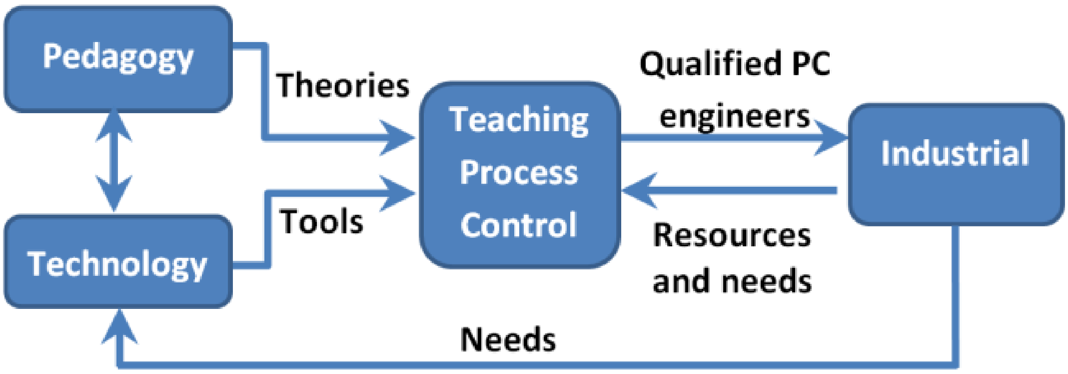


Figure 4.6 Schematic of using TPACK to teach Control Engineering

This schematic is named using the letters A and J, which are the first letters in the author's name, the first name and surname (Ali Jwaid) as presented in Figure 4.6.

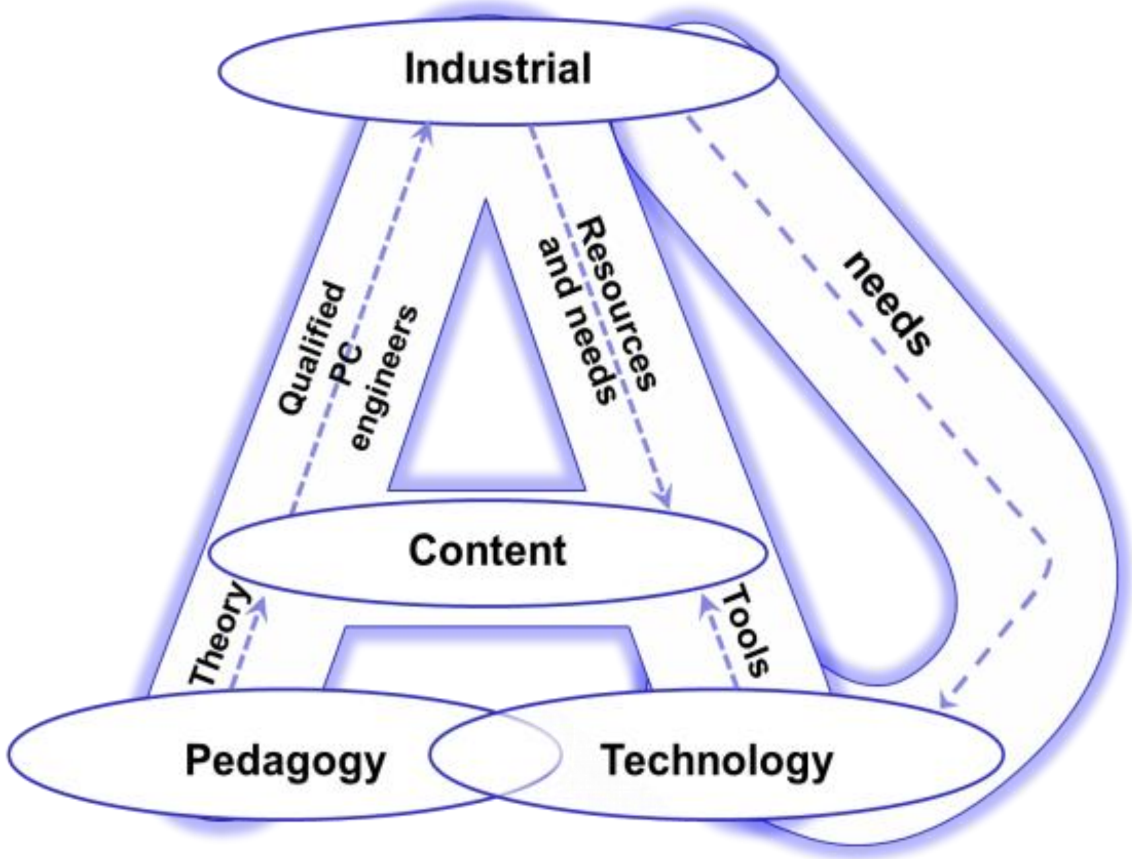


Figure 4.7 the AJ Framework to Teach Control Engineering

The teaching of control engineering designed in this research study is presented schematically as shown in Figure 4.6 and Figure 4.7. Teaching control engineering is affected by three main factors; industry, technology and pedagogy, all of which are interlinked. Industries influence much of the resources needed for teaching control engineering. In turn, the teaching of control engineering provides the industry with necessary skills. Pedagogy provides the essential theoretical knowledge for the best methodology for teaching these skills. This includes different teaching methods, the design of different assessment methods and the theories behind different learning skills. Technology provides some essential tools required for teaching control engineering, such as computer hardware and, various useful forms of software, packages, and programs. The combination of these three factors makes the teaching of control engineering much more efficient to execute (Jwaid A.E et al., 2014).

This research is the first work implementing the TPACK framework in HE control engineering and related STEM and the first use of TPACK in HE linked to industrial needs (see more details in sub-section 2.5.3, p.23).

4.10 Theoretical evaluation of the AJ Framework

From the main domains of the TPACK framework (content, pedagogy and technology), we will start to simplify the practices needed to reach the best understanding of using the framework. In addition, we highlight the borders between these domains and conjoint areas.

Firstly, the content (CK); the content should be compatible with the industrial needs, to provide qualified engineers for the labour market. (Åström, 2012) discussed in his presentation on the perspective for Process Control Engineering, illustrated in Figure 4.8 below, there are borders between these subjects: between control and mathematics, computer science, physics, etc. For example; we need the control student to understand the physical meaning of control components and how they can be mathematically modelled before they are converted to a control program, compiled and subsequently implemented in control hardware. The barrier between control engineering and computer science can cause problems when they need to work together on an industrial control application. If the control engineer does not know enough about the related computer science, or the computer scientist does not know enough about the related control engineering.

As shown in Figure 4.8, there is a common area between process control/embedded systems and computer science, all of which are fairly young and rapidly developing subject areas. The next paragraph discusses content issues and how they affect Pedagogical Knowledge (PK) to meet these challenges.

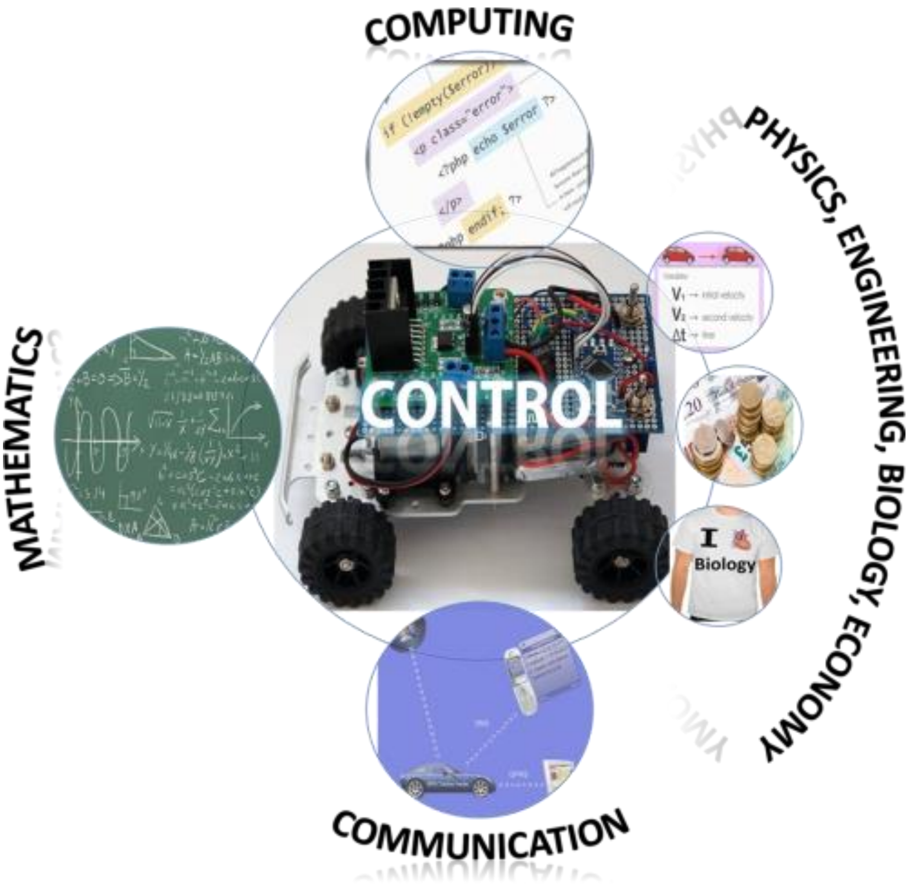


Figure 4.8 The Perspective of Control Engineering

Secondly, we will consider pedagogy (PK): successful teaching and training of control engineering programming and hardware interfacing is challenging for several reasons. For example, the new versions of microcontrollers have complex systems, with handbooks of more than a thousand pages. It takes a long time to become familiar with a microcontroller family in the detail necessary for course integration; a time-consuming task for a teacher or trainer (Bencomo, 2004; Ebert & Jones, 2009). Here we see the conjoint area between content and pedagogy so we obtain the fourth domain Pedagogical and Content Knowledge (PCK). This domain defines combining of knowledge (content and pedagogy) to show how we can improve subject understandability. As discussed above, the subject of control engineering is new, rapidly changing and expanding; therefore, there is a need to continuously change the curriculum to meet the current industrial requirements. The result of this educational challenge manifests itself with the question, “How to teach the future engineers?” Discussing this challenge and to help modify the contents of the curriculum, by receiving feedback from the industrial sector also costs time and effort. Furthermore, many of these updates could easily be obtained from the research department in the universities, which are considered as a ‘theatre’ to develop practical industrial research, as we built our approach shown in Figure 4.6, and Figure 4.7.

Thirdly, we consider technology (TK): computer technologies offer the ability to visualize and manipulate control objects in an interactive way; this is really useful in education, to simplify conception of the ideas delivered to the students and to separate these from the complexity of the control mathematics (Bencomo, 2004). E-Learning has become an increasingly important approach for all subjects. In its comprehensive definition, E-Learning includes transmitted lessons via all electronic media. For example, CD-ROMs, internal or external memory, servers on Internet or intranets, interactive TV, satellite broadcasts, and media elements, as words/pictures/audio/video, to deliver the content (R. C. Clark & Mayer, 2011; Govindasamy, 2001). Here we will highlight the fifth domain where content is shared with technology in the area of Technological and Content Knowledge (TCK). This domain describes the ways of using technology for better teaching, such as animation, or video to make it easier to imagine the theoretical or physical phenomena under examination (Niess, 2005). Although it is very useful to use technology to explain and simplify the content, sometimes it is better to avoid the use of technology. This depends on which skill we want the students to learn, for example, using Bloom's Taxonomy (Churches, 2008), (see Appendix C), to decide the best teaching approach (Krathwohl, 2002). If we are expecting the students to reach the level of ‘apply’ not only just ‘know’, we need to support them by doing exercises.

The sixth domain is the common area between Pedagogy and Technology, (TPK), this is if we need to conduct assessments using technology (for example an online ‘test’).

The seventh domain is TPACK which describes the relationship amongst the main domains Content Knowledge, Pedagogical Knowledge and Technological Knowledge while technology is applied in progressing teaching or learning. In addition, it covers the difficulty in the relationship between the student and tutor.

Project Based Learning (PBL) is one of the key teaching and learning methods in a practical subject (Prince & Felder, 2006) like control engineering. more details about PBL and its importance as a pedagogical approach particularly in engineering subjects like Embedded Systems and Digital Control are detailed in sub-Section 5.3.1, p.101. To apply TPACK framework, we need to understand the seventh domain for a successful application. After explaining the definition, the border areas and the challenges, the implementation will be presented in Chapter 5 with two modules. For more details about PBL and its importance as a pedagogical approach particularly in engineering subjects like Embedded Systems and Digital Control (see sub-Section 5.3.1, p.101).

In this research, we recommended formalised pedagogical blended learning strategies within the TPACK framework and take advantage of technological advances to shape online learning support for traditional (face-to-face) learning which increases the opportunity of optimising the advantages of both face-to-face and online learning environments.

4.11 Practical evaluation of the AJ Framework

The new framework needs to be evaluated to verify the theoretical concepts through practical application. This research used three data driven approaches as detailed below:

4.11.1 Quantitative evaluation

As AJ questionnaire instrument included extra six items in CK, PK, TK, TCK, TPK, and TPACK. The correlation was calculated between the average of the TPACK HE instrument items of each sub-scale (domain) and the AJ added item. The purpose of calculating the correlation was to study the relationship between tutor ability and confidence within each TPACK domains and linked to real life needs (including industrial needs), as these are all important factors (especially in STEM HE as mentioned in the literature review). The questionnaire was distributed to SST tutors at NTU and SST tutors in MU:

i. SST tutors at NTU

So, starting with the first TPACK domain (sub-scale), CK. The item “I am confident to update the content linking it to real life needs” correlating calculation was made with the previous three CK items and the results are shown below in Table 4.9.

Table 4.9 Correlation between the average of the CK items and the AJ added

Correlations

			sumCK	CK15
Spearman's rho	sumCK	Correlation Coefficient	1.000	.233
		Sig. (2-tailed)		.206
		N	31	31

The correlation coefficient is not significant so this indicates there is a training need to ensure tutors have improved confidence to update course material for incorporating industrial needs. This is part of the basis for the training advice covered in section 4.6.

On the next TPACK domain (sub-scale), PK. The item "I am confident in adapting the teaching approaches based on real life needs" correlating calculation was made with the previous fourteen PK items and the results are shown below in Table 4.10.

Table 4.10 Correlation between the average of the PK items and the AJ added

Correlations

			sumPK	PK30
Spearman's rho	sumPK	Correlation Coefficient	1.000	.257
		Sig. (2-tailed)		.163
		N	31	31

The correlation coefficient is also not significant so this indicates there is a training need to ensure tutors have improved confidence to update course material for incorporating pedagogical development in the context of real life needs. This is also part of the basis for the training advice covered in section 4.6.

On the next TPACK domain (sub-scale), TK, the item "I am confident to use appropriate technology linking it to real life needs" correlating calculation was made with the previous six TK items and the results are shown below in Table 4.11.

Table 4.11 Correlation between the average of the TK items and the AJ added

Correlations

			sumTK	TK37
Spearman's rho	sumTK	Correlation Coefficient	1.000	.722**
		Sig. (2-tailed)		.000
		N	31	31

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation coefficient is significant so this indicates there is no urgent training need in this area. Since we are dealing with SST tutors this is perhaps unsurprising.

On the next TPACK domain (sub-scale), TCK, the item “I can choose appropriate technologies (hardware, software, simulation) to be useful in real life needs” correlating calculation was made with the previous three TCK items and the results are shown below in Table 4.12.

Table 4.12 Correlation between the average of the TCK items and the AJ added

Correlations

			sumTCK	TCK47
Spearman's rho	sumTCK	Correlation Coefficient	1.000	.199
		Sig. (2-tailed)		.284
		N	31	31

The correlation coefficient is also not significant so this indicates there is a training need to ensure tutors have improved confidence to update course material for incorporating the development of the linkage of using the right technology to enhance the content in the context of real life needs. This is also part of the basis for the training advice covered in section 4.6.

On the next TPACK domain (sub-scale), TPK, the item “I am able to use technology to introduce my students to real world scenarios” correlating calculation was made with the previous ten TPK items and the results are shown below in Table 4.13.

Table 4.13 Correlation between the average of the TPK items and the AJ added

Correlations

			sumTPK	TPK58
Spearman's rho	sumTPK	Correlation Coefficient	1.000	.604**
		Sig. (2-tailed)		.000
		N	31	31

The correlation coefficient is significant. SST tutors are clearly more confident in the use of technology in pedagogy than pedagogy based enhancement in general. This may need further investigation to ensure this confidence is appropriate in comparison with the lesser confidence in the PK area. There may be training needs identified in this. This potential need was backed up by the views of experienced tutors in the work described in chapter 5 and by the input of the school Teaching and Learning Coordinator.

On the next TPACK domain (sub-scale), TPACK, the item “I am able to combine content, pedagogy and technology to introduce my students to real world scenarios” correlating calculation was made with the previous seven TPK items and the results are shown below in Table 4.14.

Table 4.14 Correlation between the average of the TPACK items and the AJ added

Correlations

			sumTPACK	TPACK66
Spearman's rho	sumTPACK	Correlation Coefficient	1.000	.784**
		Sig. (2-tailed)		.000
		N	31	31

The correlation coefficient is significant, so, SST tutors are clearly more confident in the use of content pedagogy and technology. Yet given the non-significance in

CK, PK and TCK it is felt this requires further investigation and almost certainly additional training needs. This potential need was backed up by the views of experienced tutors in the work described in chapter 5 and by the input of the school Teaching and Learning Coordinator.

Finally the correlation was made between each TPACK domain with the combination of all the other TPACK domains. The results were shown in Table 4.15.

Table 4.15 Correlation between the average of the TPACK sub-scale items

Correlations

			sumCK	sumPK	sumTK	sumTCK	sumTPK	sumTPACK
Spearman's rho	sumCK	Correlation Coefficient	1.000					
		Sig. (2-tailed)						
		N	31					
	sumPK	Correlation Coefficient	.057	1.000				
		Sig. (2-tailed)	.762					
		N	31	31				
	sumTK	Correlation Coefficient	.583**	.257	1.000			
		Sig. (2-tailed)	.001	.164				
		N	31	31	31			
	sumTCK	Correlation Coefficient	-.021	.009	.231	1.000		
		Sig. (2-tailed)	.910	.964	.212			
		N	31	31	31	31		
	sumTPK	Correlation Coefficient	.124	.579**	.303	.168	1.000	
		Sig. (2-tailed)	.505	.001	.098	.367		
		N	31	31	31	31	31	
	sumTPACK	Correlation Coefficient	.006	.661**	.179	.051	.874**	1.000
		Sig. (2-tailed)	.973	.000	.335	.785	.000	
		N	31	31	31	31	31	31

**. Correlation is significant at the 0.01 level (2-tailed).

There are significant correlations between CK and TK; PK and TPK; PK and TPACK; TPK and TPACK.

The highest correlation (0.874) was obtained between TPK and TPACK This result supported the PCA results in section 4.5. This result is in line with Schmidt (2009)

The correlation (0.661) between PK and TPACK was also high and the correlation (0.579) between PK and TPK. The last correlation was between CK (0.583) and TK. As the SST tutors are confident in the use of technology in pedagogy, and the reason might relate to the participants' subject areas within SST.

The correlation between CK and TK was significant, and the reason might be related to the participants, as all of them are from SST, and the higher ratio from computing and technology department (56.1%) as the content is including technology. The high correlations between CK and TK was similar in pre-university teachers in Schmidt (2009) with science and maths subject area, and also in (Koh, Chai, & Tsai, 2013).

4.11.2 Qualitative evaluation

Data was collected to evaluate the concept of The AJ Framework from experts in HE (UK case study), and from HE experts in industrial training (Libya case study).

Note: In the UK case study the input of experts from the industrial sector are discussed in Chapter 5 with the implementation of the AJ framework.

i. Developed country (UK)

Semi-structured interviews were undertaken with five expert tutors in SST at NTU. The time of interviews was about 15-20 minutes in average and the questions included the use of technology in HE (these apply to evaluate all TPACK domains), the current state of university-industry linkage and the impact of it in terms of enhancing STEM education. Also, if there is still a need for improved industrial links (these apply to extended framework 'The AJ Framework').

a. What do you think about integrating technology (TK) with the pedagogical (PK) practice and the content (CK)?

The first point was about using technology in HE and what they think about it in terms of enhancing teaching and learning. One of them expressed concerns about a potential NTU over-reliance on technology to present the content of the module and recommended that not all teaching material be totally presented online. Full online content in some areas had led to students not attending lectures (as "everything is online") and other students attended but did not engage fully with the lectures (for similar reasons). Four other tutors had a common concern: they believe that technology should be used carefully by thinking about how it specifically improved achievement of the learning outcomes of the module. One of these four mentioned that " technology cant enhance learning unless it is built into a suitable learning activity designed from sound pedagogical principles. For example, does it help "construct" learning or does it risk becoming just "entertainment"". This is a clearly a TPACK issue. Another mentioned that some aspects of technology could fall into an area of low quality input and/or cause information overload; care is required especially with use of social media types of technology use. In other words does the technology help the student formulate and enhance the way they construct a sound framework of principles/concepts/content knowledge.

The second point was about the link to industrial needs to improve the content of the modules (CK). One tutor said "Industry often states that students lack the skills they need but don't often engage with HE to support development of these. There is work around "SIPs" which goes part way to address these". SIPs are an NTU School Industrial Partnership initiative.

Another tutor mentioned the type of collaboration is limited because we can't teach the specific knowledge which might be required by some industry in the future; we can teach fundamental knowledge and transferable skills but the industrial sector still needs to have ongoing training with graduates. Another tutor said that the content should include more links to the industry, and university and industry should arrange more field studies and strengthen the placement programmes to allowed students to gain knowledge and skills which introduce them to the real life challenges, to increase their future success. These tutors answered the quantitative AJ Framework items in a summarise manner with their qualitative comments; this can be used to explain differences in the quantitative output and validate the quantitative output.

b. What do you think about the cooperation, at the present time, between education and industry sector in the UK.

The tutors agreed that is cooperation between education and industry and some opinions as the follows:

- "It exists but the best work seems not to be properly utilised in University HE. There is still sadly a stigma attached to industrial linkage with

Universities from too many academics, even some in STEM areas. Arguments against industrial partnerships often insult the intelligence of academics to develop independent critical thinking in the students involved in such partnership arrangements; partnerships, that can work well at FE and college level HE. The new graduate apprenticeship arrangements might be a positive development in this area."

- "Britain is behind most of the EU in terms of the public regard of the importance of engineering education for the future of the economy. The professional bodies, like the IET, alongside the best University engineering departments, have made some positive contributions to reversing this, with government policy often lagging well behind. The funding mechanism for degree courses arguably underfunds most equipment intensive STEM subjects and alongside the lack of protection of courses (except medicine) in the STEM area has led to way too many course closures based on market economics".
- "At school education levels, things are working better within the subjects linked to STEM showing better government support and with much innovative teaching, use of technology, and positive curriculum changes, (that would, meet TPACK/AJ domains). A good example being computing where proper skills are now being utilised with devices like the Raspberry Pi (compared to too much previous emphasis on soft skills like learning Microsoft Office packages)".

c. What do you think about the outputs of the educational process, does it suit the needs of the labour market in my country?

In this question one tutor thinks the outputs of the educational process is suited the needs of the labour market. But the other four tutors think it is not suited; as one of them stated:

"Most certainly not in the case of HE STEM: without skilled labour movement from elsewhere, especially the EU, a poorly supported manufacturing sector would really suffer. With the recent Brexit vote potentially affecting skilled migration this is an existential threat to the economy".

d. Do you think that industrial development has a direct impact on the educational content?

Two tutors disagreed and two tutors agreed with this statement; one said:

"I agree with this but not to the extent I would like to see".

e. Do you think that industrial development has a direct impact on the technology used in the educational process in my country?

All tutors think this is true; as one of them stated:

"This is more true (than d) but in the context of the general disappointing government support for HE STEM education in the UK and the less than ideal industrial linkage at University levels. We are developing new engineering courses at NTU specifically to try and counter this trend, with a much stronger emphasis on industrially led PBL than most UK courses".

f. Do you think that industrial development has a direct impact on the educational teaching methods used in the educational process in my country?

Four tutors do not think that there is a direct impact on educational teaching methods from industrial development. As one tutor mentioned:

"I think there is a huge disjoint in this area in HE. The IET and some researchers in engineering and in education have done admirable work in this area but too often it's like pedagogy and industry are speaking foreign languages. Things are better in vocational STEM teaching in FE but the FE sector in the UK is undervalued and underfunded and too disconnected from the University part of the HE sector".

g. Do you think that the outputs of the educational process would be more appropriate for the needs of the labour market, if technology employed to teach the content is used in pedagogical ways in my country?

All tutors agreed and supported more linkage with industry.

h. Do you think that the industry sector ought to offer needs and resources that are needed by the educational process in my country?

Similarly, all tutors agreed and supporting more linkage with industry. One tutor gave more details:

"This would benefit the country but needs to be set in the legal context (must not break EU rules on state support) and there need to be financial benefits for the companies to engage. The recent return of apprenticeship levy (removed in the UK in the 1980s) are to be welcomed in this respect".

i. Do you think that the industry sector ought to offer technologies that are needed by the educational process in my country?

All tutors agreed and one tutor mentioned:

"Yes this would be and is in some cases a benefit. There are already internal incentives for companies to be more involved in this respect, so less need for state encouragement".

We can conclude from the consistency of interview evidence from expert tutors there is need for more linkage between university and industry. Some gave interesting qualitative suggestions for what might help best.

ii. Developing country (Libya)

Focus group/ workshop

In April 2014, the researcher presented the AJ framework in the 7^{th} workshop on "Higher Education Institutions and the Requirements of the Labour Market" (which aims to link the learning outcomes of HEIs with industrial needs), held in Misurata, Libya, with representatives of 96 HEIs from all around Libya participating. The committee of the workshop concluded some further actions (7^{th} workshop communications: http://alshamela.com.ly/pwt.php) :

- The first was they strongly recommended implementation of an AJ style framework in HEIs in Libya, with the top priority of the work considered at the workshop (other proposed HE pedagogy projects from other researchers were prioritised at a lower level).

- Within this plan was an aim to implement The AJ framework through stages. As Libyan HE is spread across a wide area in a large country the implementation should take place in four test venues with the first step in each venue to establish a CPD training course to enable wider uptake of the AJ framework elsewhere. Then to monitor tutor progress in real teaching modules in Libyan HE.
- It was recommended to look at other subject areas in STEM especially medical related subjects including Biomedical Science and Nursing Education.

However, because of the unsuitable political situation and the war in Libya, the development had to be postponed. So the proposed work is now discussed in future work (see Sub-section 6.3.4).

4.11.3 Experimental Evaluation

In the next phase, there was a shift from studying tutor knowledge, ability, and intention to use technology, as most of the previous TPACK research, to the actual practical design and implementation of TPACK knowledge and usage of TEL in academic module practice (taking into account the industrial needs, as for the AJ Framework aims).

The AJ Framework was implemented three times in an MSc Digital Control module, and once in a BSc Embedded Systems module. This study contributed formalisation of the previous evaluation methods. The evaluation methods of the AJ Framework were designed based on common evaluation approaches. This study formalised the available evaluation approaches and synthesised them between the university and industry. This stage is described in the next chapter, Chapter 5.

4.12 Summary

This chapter examined the validity and reliability of HE TPACK instrument for both version; English and Arabic, and discussed a suggested HE training model. It also presented the development of a novel framework (the AJ Framework) and presented the theoretical and data-driven evaluations. It also described the very positive outcomes of the 7th Libyan workshop on “Higher Education Institutions and the Requirements of the Labour Market”.

5. Chapter Five: Testing the AJ Framework, implementation and evaluation for BSc and MSc modules

5.1 Introduction

This section presents the evaluation of the AJ Framework through empirical evidence. The data and information were obtained by experimentation, engagement and performance data, observations and semi-structured interviews. As the selected case study of this research was the control engineering subject area, two modules in this area were chosen to test the AJ Framework. The effectiveness of the AJ Framework to enhance student performance in these modules is examined. The implementation and evaluation of the AJ Framework was in teaching Embedded Systems as an undergraduate model and Digital Control as a postgraduate module.

Both modules, Digital Control and Embedded Systems, already followed good teaching practice with use of appropriate technology, pedagogy and some industrial input before the implementation of the AJ Framework. However, the study gave them a formalized approach, following the TPACK framework and the AJ framework.

Development of the AJ Framework involved refining and rendering existing learning and teaching material on the Digital Control and Embedded Systems Modules following each identified domain in the frameworks. This included considerable consultation and cooperation from the module tutors of both modules and review of the previous and adapted learning material under TPACK.

The Digital Control module is taught to Electronic Engineering MSc students. The aim of teaching this module is to develop the understanding of the key principles, underlying technologies and practical application of digital control; including digital filters, control system design and process control. The module is delivered through mixed lectures, seminars and labs to achieve the aims. To assess student learning outcome achievement, laboratory assessed assignments and written assignments, both based on project based learning are used.

The Embedded Systems module is taught to BSc first year students, as a part of the curriculum of the Computer Systems course. The aim of teaching this module is to develop the understanding of the key principles, underlying technologies and practical application of embedded systems; their operation and the hardware components. The module includes lectures and laboratories to cover the aims. To assess student learning outcome achievement, there is a laboratory assignment, a written assignment, and a written exam.

The following research questions will be addressed in this chapter:

RQ1: How can we improve the accommodation of industrial needs?

RQ2: What are the best strategies that can be used to optimise tutor and student performance in HE?

RQ3: Does using the AJ Framework increase student engagement and performance?

5.2 The AJ Framework Evaluation Methods

This research formalised the available evaluation approaches and the synthesis between the university and industry. Figure 5.1 shows the schematic of the evaluation methods which are used to evaluate the AJ Framework. This section will cover content development, selecting learning outcomes, and development and implementation of the lesson plan process; in addition to tutor observation and student observation (see Subsection 3.7.9 iii and 5.2.2). Each stage evaluates some or all domains of the AJ Framework.

The AJ Framework was developed to enhance teaching and learning in HE with the respect (consideration) of industrial needs. Thus, the main parts in evaluation methods are HE institutions and industry.

5.2.1 Initial content evaluation

The original module material was evaluated using the AJ framework. This included lecture material, lesson and course delivery plans, laboratory exercises, assignment definitions, supporting information (including past formative and summative feedback) and descriptions of technology (utilised hardware and/or software). This covers the one (or a combination of several) of the following domains: CK, TK, TCK, PCK, TPACK and AJ.

5.2.2 Observation design

Observation was used for collecting some data. Tutor performance and student engagement and performance were observed. The researcher attended all lecture and lab sessions, also, audio records were taken.

Observation research methods were used to evaluate and assess the effects of the AJ Framework on tutor performance and student engagement and performance alongside industrial needs (through formal meetings, and through filling in feedback forms). This stage sustains and support engagement and performance improvements for HE.

i. Tutor observations

To evaluate and validate the AJ framework, it is important to observe tutor performance in the context of utilisation of module content and technology, in order to adapt delivery to follow the AJ framework; including any changes needed for the next session or the delivery next year. This process started with updating the content based on TPACK and industry needs as clarified in AJ framework. Also as the tutor takes the role of delivering the content, so pedagogical skills are also monitored: which strategies the tutor used, with which content, and which technology is used to represent the content; all of these fall within one (or a combination of) PK, PCK, TPK and TPACK and AJ domains.

After implementing the first stages of the framework (which were updating the content, and delivery plans), the module had started delivery according to the AJ framework in order to improve the outcome of the educational process. The researcher observed all lectures and labs. The researcher attended the lectures and wrote down notes in lectures and recorded the lectures. For the labs, the researcher was walking around and wrote notes. The researcher checked during the lectures of how the tutor followed the lesson plan and adapt to the delivery circumstances.

The observation procedure followed a structure in some respects similar to the teaching observation scheme of Nottingham Trent University (www.ntu.ac.uk) which consists broadly of four stages as shown in Figure 5.2:

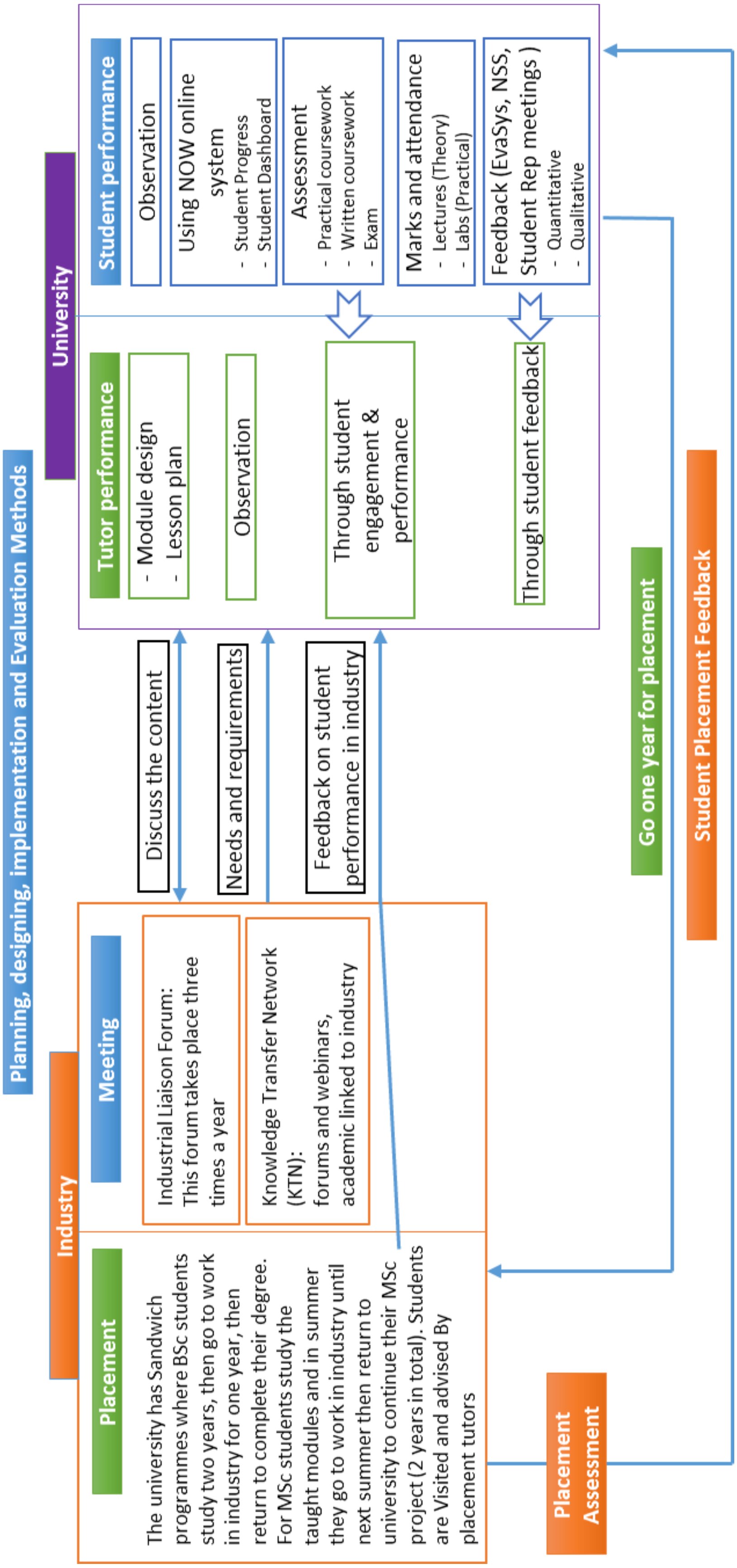


Figure 5.1 Evaluation methods of AJ framework

1	2	3	4
Pre-observation preparation	Observation	Preparation for the post-observation meeting	Post-observation meeting

Figure 5.2 Stages of teaching observation scheme

ii. Student observations

To evaluate and validate the AJ Framework the researcher observed student engagement and performance and assessed work in all lectures and labs.

The researcher observed student performance on assignments and formative exercises, how they engaged with the teaching strategies, how they communicate with the tutor, how they used the resources, how they were asking and answering class questions and how they received verbal and written feedback. During the lectures and labs, the researcher was monitoring student performance and taking narrative notes about student activities and how they interact with theoretical and practical information. This includes pedagogical aspects in terms of student learning and which student learning style attracted them and with which they engaged more. This included evaluation for PK, PCK, TPK, TCK, and TPACK domains.

Student progress was also observed through their access to online materials on university system. The student dashboard is a tool that was used as TPK. The student dashboard is a system used to monitor student engagement. It measures student attendance, using the NOW online system, access to the online module material, use and access to university buildings, including library services and directed study laboratory services.

5.2.3 Student assessment

Assessment forms were used to evaluate student understanding of learning outcomes, as well to assess teaching strategies of the AJ Framework through student performance.

Practical coursework: includes PK, PCK, and TCK domains; while the module content included technology (software and hardware), and linking to industry in the AJ Framework (the technology was selected to fit the skills required from industry).

Written coursework: includes PK, PCK and TPK domains; also this assessment form included linkage to industrial needs through learning outcomes and problem scenarios, which simulate real life problems, as consistent with the AJ framework.

Exam: includes PK, PCK, TPK, and TPACK domains; with some requirement to write about issues relating to real life problems, as consistent with the AJ framework.

TPK in assessment covers: submitting the coursework online, checking for plagiarism (using TURNITIN), and giving formative and summative feedback to students about their work and results.

5.2.4 Design of lesson plan processes

There are different varieties of activities involved in the lesson plan process including 5 steps to lesson planning using the AJ Framework covering choice of learning goals, making pedagogical decisions, selecting activity types to combine, selecting assessment strategies and choice of tools/resources. (J. Harris & Hofer, 2009; Janssen & Lazonder, 2016; Keengwe, 2014). For the tutor, there is a complexity in selecting a lesson plan process, as argued by (Danielson, 2013; Romiszowski, 2016). As (Romiszowski, 2016, p.395) stated "instructional design is a complex systematic process. One decision often involves or influences another". Therefore, simplifying the lesson plan development involved using the lesson planning process of (Neilson, 2009) shown in Figure 5.3 by following the three main domains; objectives, methods and evaluation.

In this research, Neilson's lesson plan integrated with the above 5 steps of lesson planning and this was used in the AJ Framework. The scientific steps were followed after choosing the lesson topic, and in each step we investigated the steps below.

- What we want the student to learn from this lesson.
    - Select the learning outcomes.
    - Select and organise content.
- How we are going to access that learning.
    - Select appropriate teaching and learning strategies.
    - Select and develop teaching and learning resources.
- List out our assessment objectives for the assignment (connect it to real industrial applications).

- Incorporate appropriate assessment procedures.
- Implement learning evaluation and respond to the subsequent feedback.

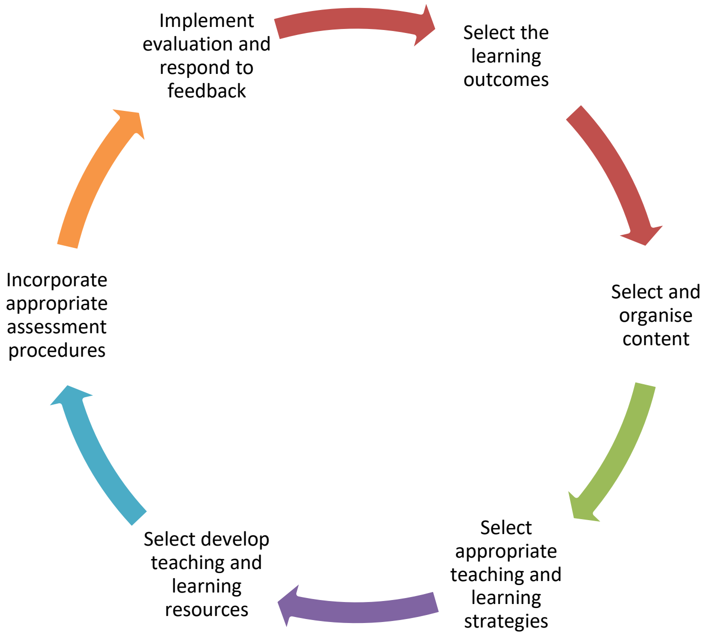


Figure 5.3 Lesson plan process for the first lesson (Neilson, 2009)

After the first lecture, the researcher added another step, which is collecting feedback to assess if there is a need to adjust the content, teaching strategies or assessment methods see Figure 5.4.

After applying the TPACK framework it was necessary to add to and modify the earlier lesson plan by highlighting each step with matching knowledge (content, pedagogy and technology) as shown below in Table 5.1.

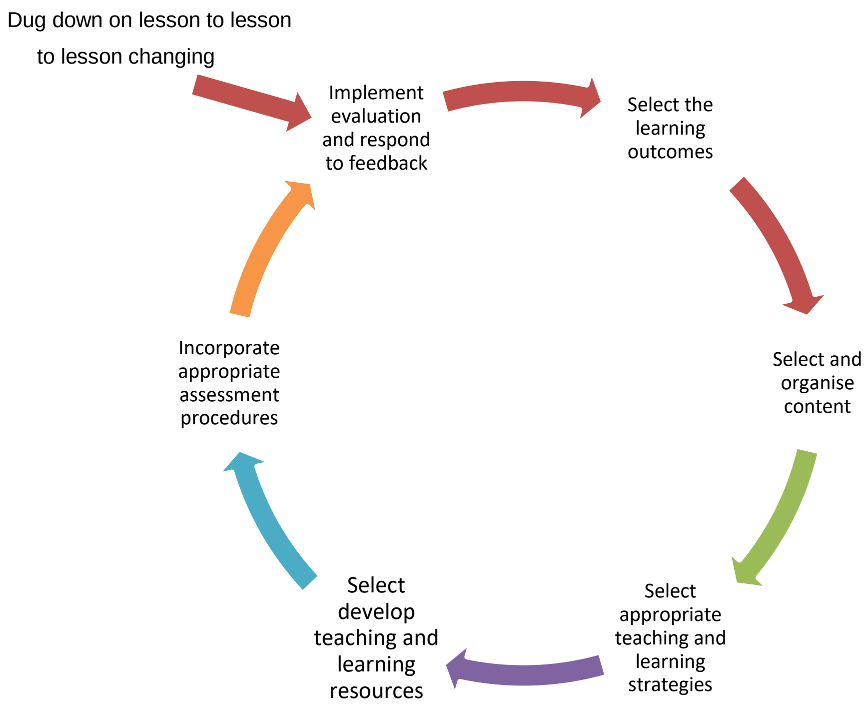


Figure 5.4 Lesson plan process after the first lesson

Here we need to study the common areas in TPACK and the borderlines between each element. For example, is there any use of technology in the assessment steps considered to be one of the pedagogy steps? This intersection area is called Technological Pedagogical Knowledge (TPK). TPK is knowledge of the general pedagogical activities that a teacher can engage in when using emerging technologies. Thus, TPK might include knowledge of how to motivate students using technology or how to engage students in cooperative learning using technology (S. Cox & Graham, 2009) .

The researcher redesigned the lesson plan process and linked it to the AJ Framework domains to illustrate related domains to each step in lesson plan process as shown in Figure 5.5. Each step of the lesson plan process needs to deal with some or all domains of the AJ Framework.

This classification helps a tutor to design and implement a higher efficiency teaching process because it will be followed and it will examine all demands for planning the lesson, to provide a clear path for the tutor to follow.

Table 5.1 TPACK earlier lesson plan

Content	• Objectives/Indicators • Prior Knowledge/Prerequisites
Pedagogy	• Identify and discuss Pedagogical Decisions • Assessment • Pre-Assessment • Formative and Summative Assessments • Models of Instruction/Instructional Strategies o Prior Knowledge Activation • Direct Instruction • Student Inquiry • Cooperative Learning • Procedures/Activities:
Technology	• Identify and Discuss Technological Decisions • Resources o What resources do you need to support the activities? Books or another • How do the resources help students achieve the objectives? • Technology Resources • List technology resources and describe specifically why they were chosen, how the resources help students achieve the objectives and how the use will be evaluated.

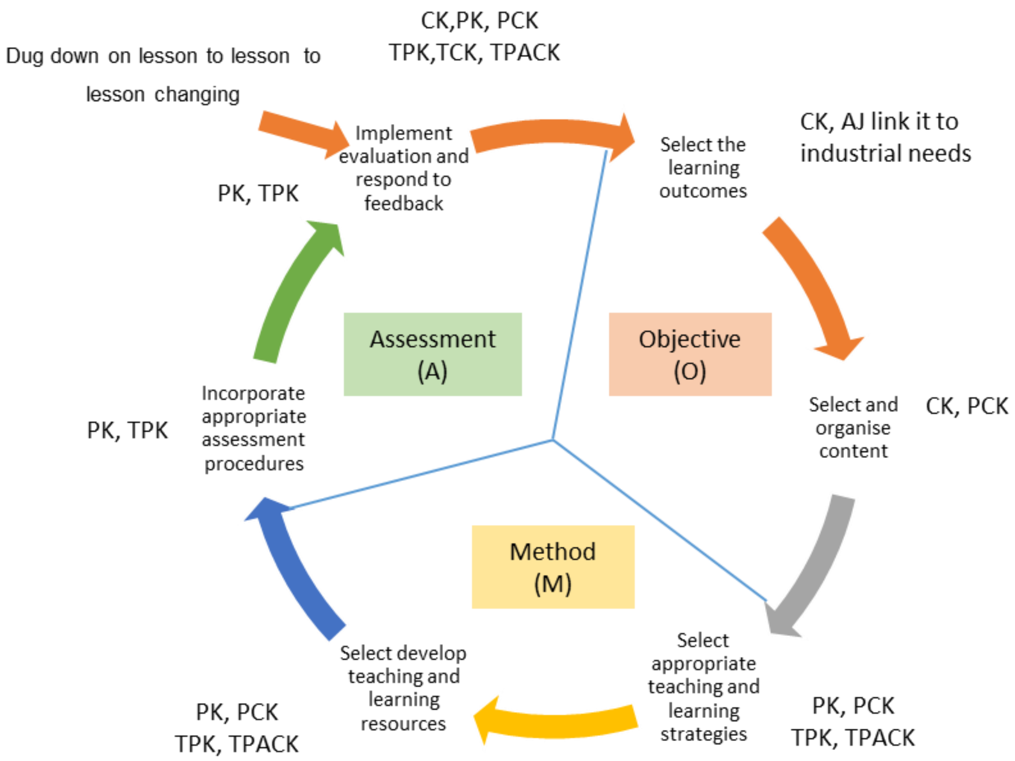


Figure 5.5 Lesson plan process stages linked to AJ framework domains

5.2.5 University-Industry linkage

Evaluation of the linkage of the university with the industrial sector in the AJ Framework, includes assessment forms and getting direct contact with industrial companies and factories through interviewing staff such as Industrial Liaison Forums or Knowledge Transfer Networks (KTN) as illustrated in Figure 5.1. Also industry provides the university information on the needs and requirements of graduates; for instance if there is specific software, hardware or any supporting material requirement. These steps integrate with module design and lesson plans. More details are given in the following sub-sections 5.3.1 - 5.3.3.

One of the main goals of the AJ Framework is to accommodate industrial needs. The feedback from the industry sector was obtained through the following:

- An industrial Liaison Forum: meeting with the industrial sector and getting their feedback on the course, three times a year (for more details visit the Employability module in now.ntu.ac.uk).

- Using current research on the need for industrial input to update the content of the module.
- Reports on student performance from their ‘careers in placement’ stage (for more details visit Employability module in now.ntu.ac.uk).
- Student feedback from those on placement: getting feedback from those students about how beneficial they found their learned knowledge and skills from their placement and if there is any more required knowledge or skills to be added in the degree course content. This was achieved using questionnaires.
- Feedback from placement industrial supervisors.
- Feedback from academic placement tutors when visiting the students and viewing placement outputs such as the placement report.
- Attending KTN, which is an independent organisation working to support content improvement by gathering industrial ideas and requirements, and discussing them with university tutors, (for more details visit their website: http://www.ktn-uk.co.uk/).
- Furthermore, the university has links with some organisations, like Loughborough Advanced Technology innovation (LATi), which work together with academics and industry (for more details visit their website: http://lati.org.uk/).

All of these steps gave industrial perspectives on how graduates/courses could be improved. This aids industry to inform the university with their needs, and opportunities by offering placements to our students to train in real life work.

The Industrial Liaison Forum, and KTN, and tutors are kept updated through other forums and ‘webinars’. Industry demands well-skilled university graduates in both subject areas; computer scientists and electrical engineers. In this research, we evaluated the impact of using the AJ Framework in this area which was built based on a TPACK model.

To answer the three research questions of this chapter, the AJ framework was implemented on two modules, Digital Control and Embedded Systems. Sections 5.3

and 5.4 cover all experiments and case studies, which have taken place; three years with the Digital Control module, and one year with the Embedded Systems module.

5.3 Implementation of the AJ Framework in the Embedded Systems module

The AJ Framework was implemented with a tutor and 50 students in an Embedded Systems module. The content was updated based on industrial needs and evaluated by a subject committee in the department. All lectures and labs were observed, to evaluate the tutor, and student engagement and performance. In addition, student feedback was collected and analysed using the EvaSys system questionnaire. The items of this questionnaire were already designed and verified by professional experts in HE, and it has been in use for several years. The EvaSys questionnaire was designed in the university, using a scale of 5 points on a Likert scale by giving 1 point for ‘definitely disagree’ to 5 points for ‘definitely agree’. The analysis was focused on five main aspects (see Sub-section 3.7.3 i, p. 42).

5.3.1 Developing the Embedded Systems module content

The embedded systems subjects are commonly referenced when computer engineering curricula are designed in different university curriculums, concerning different countries, as drawn from a number of papers (Chin & Callaghan, 2013; Freudenberg & Krogh, 2005; Jamieson, 2010; Kortuem, Bandara, Smith, Richards, & Petre, 2013; Ma et al., 2015; Ricks et al., 2008); and these included various educational models.

The module investigated here is an introductory Embedded Systems taught for Computer System students, in the second term in the first year. The aim of teaching this module is to develop the understanding of the key principles, underlying technologies and practical application of Embedded Systems: operation and hardware components. Thus, it is clear that the module includes lectures and labs to achieve its aims.

In previous years, the module lacked a formal approach to design of practical work. One of the main goals of the AJ Framework is to accommodate industrial needs. The feedback from the industry sector was obtained by following the steps in Section 5.2.5.

The module has been updated based on the demand of real life and industrial requirements. The previous version includes lectures and labs as well, however, the new update used improved theoretical information and practical work on the AJ Framework methodology. The main concentration in terms of the AJ Framework is updating the content to increase industrially related practical work to get students in line with industry feedback and impact. Previously, teaching this module included 6 lab sessions, but this was increased to 10 laboratory sessions. This alignment with AJ Framework goals, gives students deeper understanding as Mohtadi, Kim, & Schlosser (2013, p.1) said: "the students acquire a deeper understanding of programming and systems engineering with hands-on project-based learning linked with real hardware. Students also learn to think independently, investigate and explore environments, and apply tools used by practicing engineers." Therefore, laboratory coursework was added. Direct in-class practical skill assessment was included in the module for the first time (weighted at 20%). The laboratory work was also adapted, with new material to meet the new summative assessment (alongside the continuing formative assessment). This was used to better judge the student achievement of learning outcomes, and aligned to the TPACK/AJ framework. The new total assessment weighting was divided as: 20% laboratory coursework, 30% written coursework and 50% exam. This replaced the previous weighting of 50% written coursework and 50% exam.

In the BSc courses, because of British Computer Society (BCS) (British Computer Society, 2016) professional body accreditation, changing the proportion of material examined in a module requires care to adjust so generally changes in modules are only easily possible in the coursework elements (unless the balance of assessment in other parts of the course are readjusted to account for this). This is a constraint on how much learning outcomes can be assessed by PBL (Appiah, 2015).

Several research centres and universities have worked to design cheap microcontrollers, for educational use, to simulate professional industrial equipment. However, their solutions often could not be generalised and popularised outside their institutions. One of the most recent and positive developments was the Arduino family of devices. The Arduino was designed in an Italian institution called IVREA, by Massimo Benzi as a student project in 2005 (Severance, 2014). Massimo applied the concepts of free software and hardware, which was implemented in a way which was considered as a major improvement. Arduino is now used by a wide range of educational institutes, as it has proven to be an outstanding educational tool and excellent value for money. The Arduino platform for microcontrollers has seen a huge growth and it is commonly used in HE to teach aspects of electrical and computer engineering, particularly in embedded systems modules (Jamieson & Herdtner, 2015), because Arduino is a low cost, popular, versatile, open hardware platform, and software is free. All Arduino boards use the same Integrated Development Environment (IDE) which, is available for different OS (Candelas et al., 2015). Furthermore, Arduino is useful for many real life applications (Candelas et al., 2015).

In this module, Arduino was used in part to bridge the gap between the software engineers and hardware engineers (see Figure 5.6), by taking the foundation software concepts and implementing them in a platform microcontroller for making real industrial applications easy to understand. In addition: Arduino is also easy to use in terms of both software and hardware (plug and play); it can be programmed in C/C++, and JAVA programming languages; there are many available examples and open source projects; it can be prototyped quickly by students (Jamieson & Herdtner, 2015). Several researchers described their experience of using Arduino as a teaching platform successfully helping students to learn and enjoy the subject (Balogh, 2010; Buechley, Eisenberg, Catchen, & Crockett, 2008; Jamieson & Herdtner, 2015; Kuan et al., 2016). Jamieson (2010, p.1) stated “In our experience, using Arduino exposed students to sufficient complexity and challenges for an embedded system course”.

Figure 5.6 Arduino as bridge between software and hardware engineering

To achieve industrial needs (as part of the AJ framework alignment), PBL is a norm in many practical fields such as engineering, medicine, etc. PBL is centred on student learning activities (Jamieson & Herdtner, 2015). Designing assessment for the laboratory coursework was built based on PBL. Also, the written coursework was designed by asking students to investigate real life problems related to Embedded Systems. PBL engages the learning process by asking questions, researching, making a prediction, using technology, designing, and investigating (Frank, Lavy, & Elata, 2003). PBL as an active learning method helps students to build their own knowledge (Thomas, 2000). Using the project as means of learning is likely to increase student motivation and give them a sense of satisfaction (Green, 1998). The students with PBL approach engage in different types of tasks, have a better understanding of how to integrate the content and process and promote independent learning and responsibility. Another feature PBL offers is that it helps in improving long-term learning skills. All of these features and benefits of PBL supports its use as an appropriate pedagogical approach to teaching Embedded Systems and Process Control Engineering in addition to achieving industrial demands (Frank et al., 2003). So, there is PK, PCK and TPACK domain alignment (within TPACK) as well as the AJ industrial linkage alignment.

The learning outcomes and assessment criteria were designed to introduce students to the professional field by combining the Arduino platform with real machines or robots. The scenario was linked to design of a computer embedded system for an ‘everyday life’ system to link understanding with industrial needs. As Severance (2014) stated “how to design and build things, you can affect the world that surrounds you”. The AJ Framework considered assessment in practical knowledge and skills and to mitigate (closing) the gap (see sub-section 2.8.3 and section 2.10) by using TPACK/AJ framework. This is also aligned with PK, PCK, TPACK and AJ industrial linkage.

5.3.2 Selecting learning outcomes for the Embedded Systems module

As the syllabus was constructed in a computing and technology department, the learning outcomes and the module requirements were identified and specified. This stage includes selecting the content which comes in the CK domain in the AJ Framework. It also includes PK and PCK domains to cover teaching and learning strategies. In addition, it includes TCK as the content include technology (software and hardware), and going back to the content as illustrated in the AJ Framework diagram in Figure 5.4, and Figure 5.5 the selection should be based on industrial needs. The learning outcomes of the module includes knowledge and skills as the following:

i. **Knowledge and understanding.**

After studying this module, you should be able to:

K3. Demonstrate a conceptual understanding of the architecture and operation of an Embedded System in terms of its main functional units and operational characteristics.

K4. Demonstrate an understanding of the properties, functions and operations of a simple microprocessor and its related digital logic sub-systems.

ii. **Skills, qualities and attributes.**

After studying this module, you should be able to:

S2. Design simple logic circuits for interfacing.

S3. Use programming skills in an Embedded System environment.

This module covers the topics as described in Figure 5.7. It comprises two parts: Part 1 presented the introduction to the Embedded Systems, operating systems and instruction set (5 lectures). Part 2 concerned hardware concepts, Arduino, ADC/DAC, sensors, actuators and communications, (5 weeks):

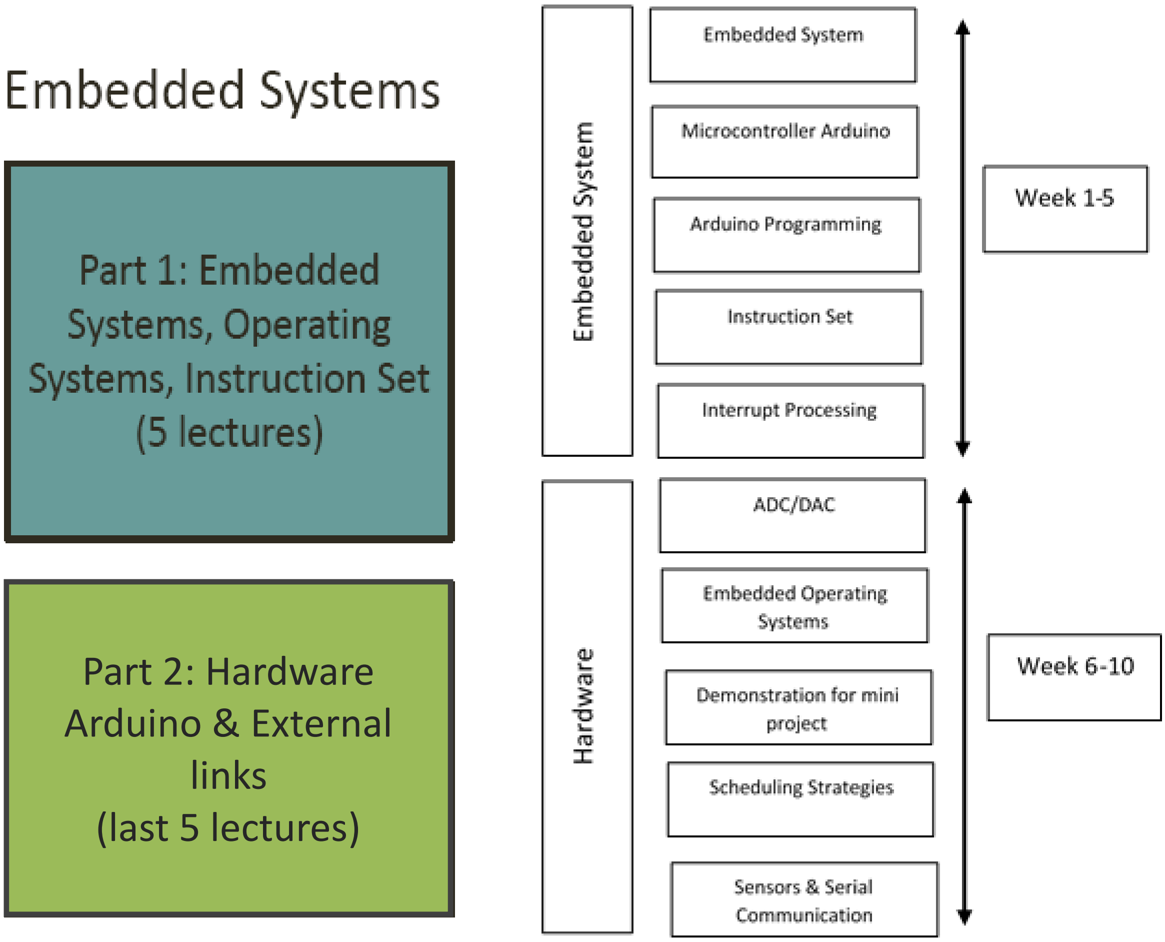


Figure 5.7 Embedded Systems Module content and planning, (Module structure)

5.3.3 Implementing teaching strategy (lesson plan process)

The lesson planning process, as a pedagogical stage in the AJ Framework, was implemented to outline the three main areas defined above, for tutors to structure lessons for the module. The starting point, after identifying module aims, is selecting learning outcomes and organising them. As illustrated above, the developed lesson plan process includes three lesson plan stages, each stage including two steps. As an example, the first lecture and laboratory will be presented to demonstrate the followed teaching strategies in this module.

i. Lecture teaching strategies

From the previous experience of the tutor, he was following the lesson process plan in Figure 5.7. As mentioned above it includes three main lesson plan stages as follows:

a. Selecting learning outcomes and organising them:

This step covers the CK domain and the AJ domain, as mentioned above, for linking the content with industrial needs; organising the selected learning outcomes includes the CK domain as well as PCK domain. The PCK domain involves the blended area between the content and pedagogy on how to organise presenting the subject matter.

The first lecture was an introduction. Thus, the lesson plan for this lecture selected the relevant learning outcomes and organising them. As the first lecture for first-year students, it is useful to cover the basics of this subject area. The following outline was covered:

- Module aims.
- Overview and structure of the course.
- What are Embedded Systems?
- Sensors and Actuators.
- Making an Embedded System.
- Inputs and Outputs.
- Real-time Operating Systems.
- Designing and programming the Embedded Systems.

b. Teaching and learning strategies and developing the content.

This stage, with two steps, obviously includes PK and PCK domains. Also, it includes the TPK domain where a particular technology is used in teaching and learning settings. In addition, it includes the TPACK domain which involves good teaching by using technology to represent the content in constructive ways, to make it easier to learn (which requires understating pedagogical techniques that use this particular technology).

All teaching and learning strategies designed were based on PBL to achieve the long-term target of teaching this module which produces graduates who are able to work in an industrial sector with efficient skills in the embedded systems subject area, as consistent with the AJ framework design.

Teaching and learning strategies were selected to encourage the students to participate positively in learning in the module by engaging them with their classmates and the module tutors (Chalmers & Fuller, 2012). In addition, teaching students how to use (and the importance of) available resources in the NOW system, university library, and other online resources to get more knowledge about the subject areas in general like research skills and report writing skills, also it is about specific areas such as getting greater depth of information about specific industrially related hardware or programming skills. In addition, to maximise the benefits of using online materials provided in online learning room through the NOW system; especially in their own directed study time. The teaching is mainly based on student centred learning strategies. So providing students with the tools for learning is really important to help them to achieve higher understanding. The teaching strategies are consistent with the PK TPK, TPACK and AJ domains.

For the first lecture, after providing the definitions of embedded systems, the students were asked to provide examples of 'things in our life' that use embedded systems. This made the lecture interactive by getting the students involved to share their knowledge. After that, further common examples of embedded systems were presented to them. Again questions were asked to encourage the students to participate in the discussion, such as: "how different is each Embedded System from the other?", then, "what do these devices have in common?". The tutor provides system images and diagrams to enhance understanding, and integrated into a varied overall delivery in order to maintain student interest and focus.

c. Assessment and evaluation procedures

Assessment procedures evaluate and grades students by measuring their academic quality or potential (Palomba & Banta, 1999; Race, Brown, & Smith, 2005). Race *et al.* (2005) list seventeen reasons why we should assess (more details in the Appendix A, p. 235). Assessment is an essential requirement of HE courses and of professionally accreditation of these courses. In assessment, aspects of PK and TPK are used to test student performance and their level of achievement in terms of the knowledge and skills of the learning outcomes.

This stage in the lesson plan (see Figure 5.5) included two steps: incorporate appropriate assessment procedures and implement learning evaluation and respond to the subsequent feedback. In terms of the TPACK/AJ Frameworks this involves both PK and TPK. The formative assessment is designed to be for each lecture by monitoring student learning to provide ongoing feedback during the lecture. A review point was set up in the middle of the lecture. At this point, questions about the first part of the lecture were asked. The benefits from this are: the students were engaged and were more active; also the tutor can assess and adjust to student understanding at that point. The questions were simplified sometimes to make it easier for responses, and occasionally the students needed to do some problem solving. These actions gave an improved chance to students to organise the given information. The tutor can also assess if there are students who did not understand key points but felt too shy to ask. At the end of the lecture, the students were asked review questions and if they had any questions or comments of their own. The process of planning for the next lecture starts from the observed points, for instance, if there is anything additional that needs to be covered or considered differently from previous plans.

ii. Laboratory teaching strategies

The same stages were taken for laboratory lesson planning, starting with selecting learning outcomes including the same AJ domains followed in lecture teaching strategies. In the laboratory due to the practical nature there is more use of technology (software and hardware), also more practical skill linkage to industrial needs. In the first lab, the hardware equipment was introduced to the students. Practical work, was designed based on PBL. This aligned with TCK, TPACK and AJ domains.

a. Selected learning outcomes and organising them

The learning outcomes in lab sessions is mainly to require higher order thinking skills, as presented in Bloom’s taxonomy: apply, analyse, evaluate and create (Leonard, Noh, & Orey, 2007). This also would strengthen understanding of theoretical aspects taught in lecture sessions. This makes it more beneficial for students during their study; also when they start their jobs, as the AJ Framework aims.

In practical work, the students need to apply the experiments by themselves, give the structure and provide an example; after that, they need to implement what they learnt. It was following teaching strategies called ‘*learn by doing’* as used in

(Jazayeri, 2004). The labs were designed to cover learning outcomes gradually. First, introduce the hardware equipment and software. Then initially building small experiments moving to more complicated ones.

b. Selected teaching and learning strategies

Pedagogical knowledge with the other domains with an intersection; PCK, TPK, and TPACK, takes the main role in selecting teaching and learning strategies. The hardware equipment, hand-in requirements and lab sheets were published online on the learning room in NOW. While students start work in the experiments by following the tasks in lab sheets, the tutor walks around and answers student questions and gives them formative feedback.

c. Assessment

The tutor conducted a formative assessment during the learning process in labs to improve student accomplishment. In addition, they adapted teaching and learning activities and created effective assessment and feedback in order to increase student engagement and attainment. For overall student learning assessment in lab sessions, the laboratory coursework was designed based on PBL to assess understanding learning outcomes in programming and hardware aspects. Also, the written coursework was designed to cover real life problems; similar to the real type of work and problems in industry. These assessment forms make students more independent and have more responsibility, engage more in learning and learn about knowledge needed later in industry. This step aligned with PK, PCK, TPK,TCK, TPACK and AJ domains.

5.4 Evaluation and Results of implementing the AJ Framework in Embedded Systems module

The evaluation stage was designed in this research to assess the effects of the AJ Framework on students and tutor performance alongside industrial needs. This stage sustains and supports engagement and performance improvements for the course in HE (see section 5.2).

This section presents results after implementation of the framework, which covered; observing the tutor and student engagement and performance, student attendance and student feedback.

5.4.1 Tutor observation in the Embedded Systems module

The teaching observation scheme in Figure 5.2 was followed. As mentioned above this scheme has four stages as follows:

i. First stage: pre-observation preparation

This stage was conducted between the researcher and the module tutor, mainly via a face-to-face and rarely via email or telephone. The tutor provided the researcher some background information about: the coming session; the intended coverage of learning outcomes; the pedagogical strategies (PK, PCK); the technology (TK) used; and if there is any concern (PK, PCK and TPACK), for example, challenging topics that students may struggle with.

In terms of the content (CK) and supporting material (PCK and TCK) for the researcher to review them, the tutor added the researcher as a contributor to the module learning room in NOW to review the lectures/lab content and supporting material (TPK and TPACK).This also gave an option to negotiate with the tutor to add further supporting materials and to consider the efficiency of the presentation (PK, PCK, TCK,TPK and TPACK).

ii. The second stage: observation

The researcher was observing teaching and learning in the module lectures and labs with focus on implementing the AJ Framework. In addition, the impact of it on student performance, which will be covered in the next section. During the lectures and labs, the researcher was writing narrative notes of what took place. The researcher described what the tutor and students were doing. This stage includes PK, TPACK and AJ domains.

iii. The third stage: preparation for the post-observation meeting

The tutor prepared for the post-observation meeting by considering questions to discuss with the observer (researcher), such as: What other teaching approaches the researcher might suggest to addressing the focus subject area, and how the tutor might develop this aspect of his teaching.

The tutor also needed to reflect about student understanding; to what extent they learnt and how the learning resources supported student understanding.

The researcher discussed the narrative notes in more details and both discussed the focus area and reflection of teaching strategies, technology use, student learning, engagement and performance. This stage includes PK, PCK, TPK and TPACK domains.

iv. The fourth stage: post-observation meeting

The researcher summarised the meeting, the agreed area of focus, and resource design, student engagement, communication, summary of strengths and areas of development. This stage included all domains of TPACK/AJ framework, especially, PK, PCK, and TPK.

As a result of this observation, we can conclude that in general, the tutor was doing well in following the lesson plan, starting the lecture by presenting lecture aims and learning outcomes, and used various ways of presenting information, using PowerPoint, whiteboard, video, demonstrating equipment and asking students questions to make the lecture more interactive. Also solving problems on the whiteboard and involving students, by making everyone think (sometimes pointing to the student, to make them more active). In labs, the tutor explained what the tasks are and then walks around to answer student questions. Tutors summarised the lecture at the end of each lecture and introduced the coming lab and gave guidelines. They used appropriate and good quality resources. They used various teaching and learning methods which suit different student learning styles. The tutor gave attention to individual needs in lectures and labs by verifying understanding; sometimes by asking if they have any questions, and sometimes by asking them a question about the topic. They were sensitive to student needs and led their learning and encouraged them to increase their confidence and make them more independent. They were enthusiastic about what was taught and a good communicator: simplified the difficult and complex concepts for students and made the subject more interesting. In terms of managing the learning process, they implemented sound pedagogical strategies to achieve the learning outcomes.

The key strengths were about making students feel free to ask questions, especially for first-year students, it is a new environment for them and some of them feel shy to ask questions. Asking students if they have any questions at break points in the lecture, then asking them questions at the end to recap the earlier path of the lecture, also reviewing the previous lecture by asking questions in the beginning of the lectures.

Regarding areas of development, the students engagement overall was fine, as student feedback showed (more details in section 5.4.4). However, there was one student who had a lack of attendance in the first weeks, and he seemed unconcerned and less engaged in lectures and labs. Thus, the researcher and the tutor noted that he needed some support. Subsequently additional support was retained until he became engaged and perhaps as a result of this, the student passed the module. The researcher suggested some area of development based on student needs and prerequisites, and of this feedback, some was actioned straight away with the solutions implemented in the next lecture, while some suggestions will be implemented next year, such as downloading the software on local PCs instead of using the software hub (so the operation and response is acceptable in-class).

The observation meeting concluded with what should be done for the next session. Some requirements could not be dealt with by the tutor (e.g. NTU Information Services related software problems) and as such there was an arrangement with the department to subsequently develop an action plan and follow it up for next year. Also, the tutor reported the strengths and challenges of the module to the department in module leader's reports and elsewhere.

Overall the tutor implemented good teaching skills based on sound pedagogical principles, as shown by the student feedback results (mentioned later in student feedback section 5.4.4).

The tutor performance shows implementation of TPK, TCK and TPACK domains. This demonstrates good teaching practice as following:

- The CK domain was exemplified in the tutor updating the content, which keeps pace with industrial needs, and current research (including ACM/IEEE updated curriculum). This demonstrates the utility of the AJ Framework.
- The TPK domain embodied in tutor performance within the use of existing technology like the NOW system (for monitoring student progress) in

addition to using The Student Dashboard (to monitor student engagement), and uploading module material. The use of this domain will be discussed later in more detail. By using this technology, the tutor can monitor the changing data and results.

- In the TCK domain, the tutor included technology with content as both related reciprocally. The content included practical work using Arduino software and hardware.

In the TPACK domain, the tutor used technologies by following pedagogical techniques for appropriate teaching for the Embedded System content. The teaching and learning styles that he used covered various dimensions to meet student needs for understanding the subject.

5.4.2 Student observation in the Embedded Systems module

This section presents the researcher's findings from student engagement and performance. In the beginning of the term, and as first-year students, too few students were asking questions or participating in discussion. After a few weeks, due to the tutor approach to making them feel more confident, the number of active students increased. As in any class, diversity in response was there: in labs some students were independent and more confident (they were following the experimental structure and implemented the tasks smoothly), while others work slower. In general, students were asking more questions in labs than lectures.

In lectures, the researcher noted that the majority of students pay more attention when the tutor used various techniques to attract student attention. In terms of students, attendance in lectures (60.49%) was lower than attendance in labs (80.28%) as shown in Figure 5.4, even though this was lower, it is not statistically significant. In discussions with staff and some engaged students this was probably because the lecture was at 09:00am. As well as being an unpopular time there are significant transport problems to the Clifton campus due to jams on the main road and overcrowded busses. According to tutor feedback attendance and lateness in some modules had been significantly negatively affected when classes were moved to 9:00am. This affected student attendance in lectures and makes a few arrive much later than they would want. This was also commented on in the qualitative student feedback data.

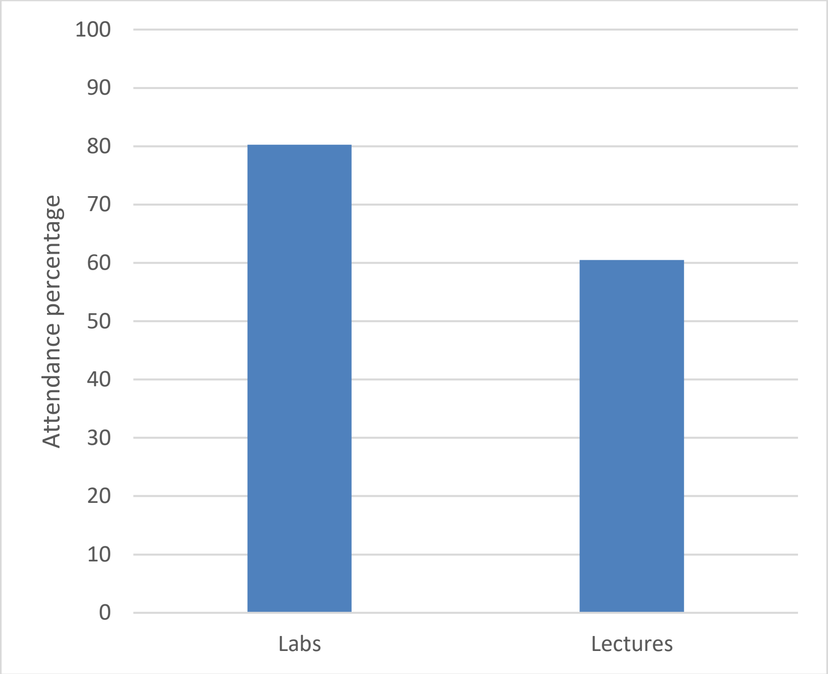


Figure 5.8 Students attendance ratio; lectures and labs

The researcher noted some special cases for the student performance: two examples are student # 5 and student # 50. Student # 5 performance in the third lab session, which was the first time he attended, was really good, and it was soon clear that he had previous experience. Student # 50 was performing reasonably well but with a little confusion because he did not attend some lectures and labs in the beginning of the term. However, when the tutor provided him with specific motivation the student performance notably improved. From tutor discussions, these are typical of the range of issues that a tutor faces and that the module design and operation required the flexibility to adapt to.

The impact of implementing the AJ Framework in student performance is represented in each domain:

- PK and PCK: teaching and learning styles and lesson plans, and how the tutor observes students interacting with these strategies.
- TK: students used university email to contact the tutor if they have any question or request accessing the lab at a different time. Also, technology used in the attendance register in the NOW system.

- TPK: the NOW system allowed the tutor and researcher to monitor student progress, and the Students Dashboard to monitor student engagement.
- TCK: using Arduino hardware and software technology as part of the content, which is reflected in student feedback, and the AJ Framework in terms of linking to industrial needs.
- TPACK: Students accessing the module content on the NOW system and the tutor can monitor this access in the NOW system.

5.4.3 Student marks and attendance

There is a need to examine students, as part of the module assessment regime, to verify their state of learning. In this research, assessment is used to collect more evidence for validation of the AJ Framework. This section presents the study of the effects of implementing the AJ Framework on student performance.

Hypothesis 1 (H_1): implementing the AJ Framework has added a positive impact on student engagement and performance.

So, the Null Hypothesis (H_0): implementing the AJ Framework has not added a positive impact on student engagement and performance.

After that, tutor performance was observed by following the AJ Framework steps and the student engagement and performance. Thus, to evaluate the AJ Framework there are various steps to examine the hypothesis:

- Check student marks which will reflect student and tutor performance
- Study student feedback
- Record tutor observations
- Record student observations
- Obtain industrial feedback
- Consider tutor feedback and adaption to circumstances
- Take into account external factors, such as different class abilities from year to year and class time
- Consider tutor and other experienced inputs (e.g. course manager etc.) on the overall module outcomes

These steps need to be critically checked, and to do that there is a need to compare between teaching this module before and after implementation of the AJ Framework.

In terms of students' marks, 82% of students passed the module in 2014/2015; this gives a good initial indication of the effectiveness of implementing the AJ Framework in teaching the Embedded Systems module. However, there is need to compare it with student marks pre-implementation of the AJ Framework alongside other factors.

In academic year 2013/2014, the AJ Framework was not implemented. The researcher compared the marks of 2013/2014 and 2014/2015 academic year . The total number of students who joined the module was 51 students in 2013/2014 and 50 students in 2014/2015. The total number of students who passed the module in 2013/2014 was 33 students, which represent about 65%. The total number of the students who passed the module are 41 students in 2014/2015, which represents 82% as shown in Table 5.2. The increasing ratio of students passing the module is noteworthy (according to tutors and those involved in course management and quality). This may show the positive impact of using the framework on student performance.

Table 5.2 Comparison between students marks of 2013/2014 and 2014/2015.

Year	2013/2014	2014/2015
Pass	65% (33)	82% (41)
Fail	25% (18)	18% (9)

More detailed statistical results in both academic years, before and after implanting the AJ Framework, are shown in Table 5.3 and Table 5.4 respectively.

Table 5.3 Statistical results before implementing the AJ Framework

2013/2014	Coursework marks (50%)	ES Exam marks (50%)	Total Mark (%)	Lecture attendance (%)	Lab attendance (%)	Total attendance (%)
Mean	25.81	22.08	47.89	61.55	76.64	69.10
Median	27.00	23.00	48.00	60.00	90.00	75.00
St.	12.17	12.13	21.07	33.38	29.09	29.75
Max	43.00	48.50	86.00	100.00	100.00	100.00
Min	0.00	0.00	0.00	0.00	0.00	0.00

Table 5.4 Statistical results after implementing the AJ Framework

2014/2015	Coursework marks (50%)	ES Exam marks (50%)	Total Mark (%)	Lecture attendance (%)	Lab attendance (%)	Total attendance (%)
Mean	28.64	25.81	54.45	60.49	80.28	70.38
Median	31.15	29.50	59.43	63.64	88.89	72.73
St.	9.19	11.49	19.28	30.97	24.13	25.47
Max	40.70	48.00	83.80	100.00	100.00	100.00
Min	0.00	0.00	0.00	0.00	11.11	6.25

In general, after implementation the score is higher in means and medians, and standard deviations are reduced. In terms of attendance comparisons, the lecture attendance reduced by 1%, (arguably less than may have been expected given the issues reported about the 9:00am time). However, in the laboratory the attendance ratio increased by about 4%. The reasons may be partly because in this year the laboratory coursework became part of assessment and partly due to implementing the AJ Framework (albeit these overlap as the change was due to the AJ implementation); this was evidenced from tutor, quality and course manager views. We will see in the student feedback section how adding laboratory work helped motivate students and how, from the input from industry, it also increases the industrial relevance of the course.

To test the hypothesis statistically, the Z score test was conducted to compare two population proportions, by using the rejection region approach and calculate p-value approach.

The Z score test, as shown in Equation 5.1 is used to know whether two groups (populations) differ significantly on some characteristic.

$$z = \frac{\hat{p}_1 - \hat{p}_2}{\sqrt{p^*(1-p^*)\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}} \quad \textit{Equation 5.1}$$

$$\hat{p}_1 = \frac{X_1}{n_1} \quad \textit{Equation 5.2}$$

$$\hat{p}_2 = \frac{X_2}{n_2} \quad \textit{Equation 5.3}$$

$$p^* = \frac{X_1+X_2}{n_1+n_2} \quad \textit{Equation 5.4}$$

Where X_1: is Number of individuals in Sample 1 with the characteristic of interest: X_1

X_2: is Number of individuals in Sample 1 with the characteristic of interest: X_2

n_1: Sample size from Group 1 (Population 1)

n_2: Sample size from Group 2 (Population 2)

The value for each parameter shown in Table 5.5

Table 5.5 The value of the both years parameters

population proportions (Group)	Group 1 2013/2014	Group 2 2014/2015
Total (n)	51 (n_1)	50 (n_2)
Pass (X)	33 (X_1)	41 (X_2)

X_1=33, n_1= 51, X_2=41, n_2=50

So, if we apply the equations 5.1-5.4 we will get:

$$Z = -1.9635$$

As we got Z value > -1.96 that indicates we should reject H_0 and accept H_1

To find p value:

$$\textit{p-value} = \mathrm{P}(Z>1.96)$$

$$=1\text{-}\mathrm{P}(Z<1.96)$$

$$=1\text{-}0.9750$$

$$p\text{-}value = 0.025$$

The results are significant at $p < 0.05$. Thus, this is good statistical evidence supporting H_1.

We want to assess the relationship between the attendance and marks after implementing the AJ Framework is significantly different than the relationship before implementing the AJ Framework.

Figure 5.13 and Figure 5.14 show the regression plots of both years. The regression models for both show that there is no significant difference between the slopes. But, in terms of the regression model the constant was higher after implanting the AJ Framework. and from the scatter plots, after implementation It is clear more students are above the line than students before the implementation of the AJ Framework. The improvement in student marks may be considered as one possible outcome of implementing the new framework; we will investigate this below.

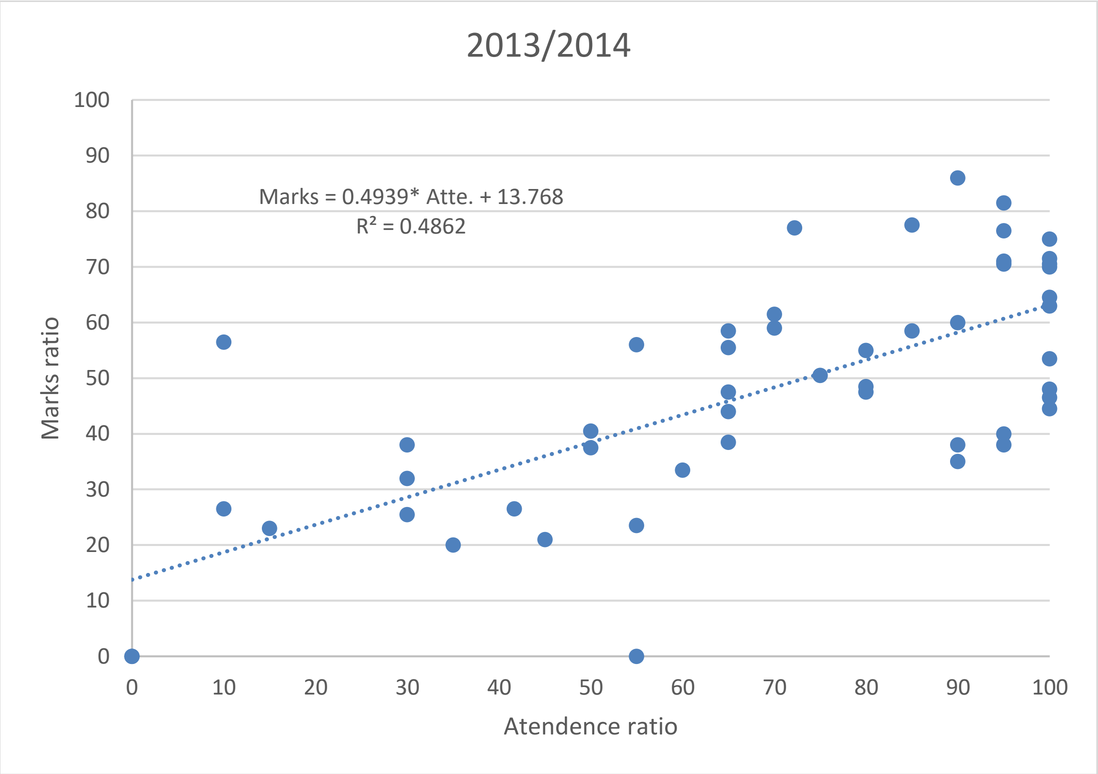


Figure 5.9 Regression model between the attendance ratio and marks before implementing the AJ Framework 2013/2014

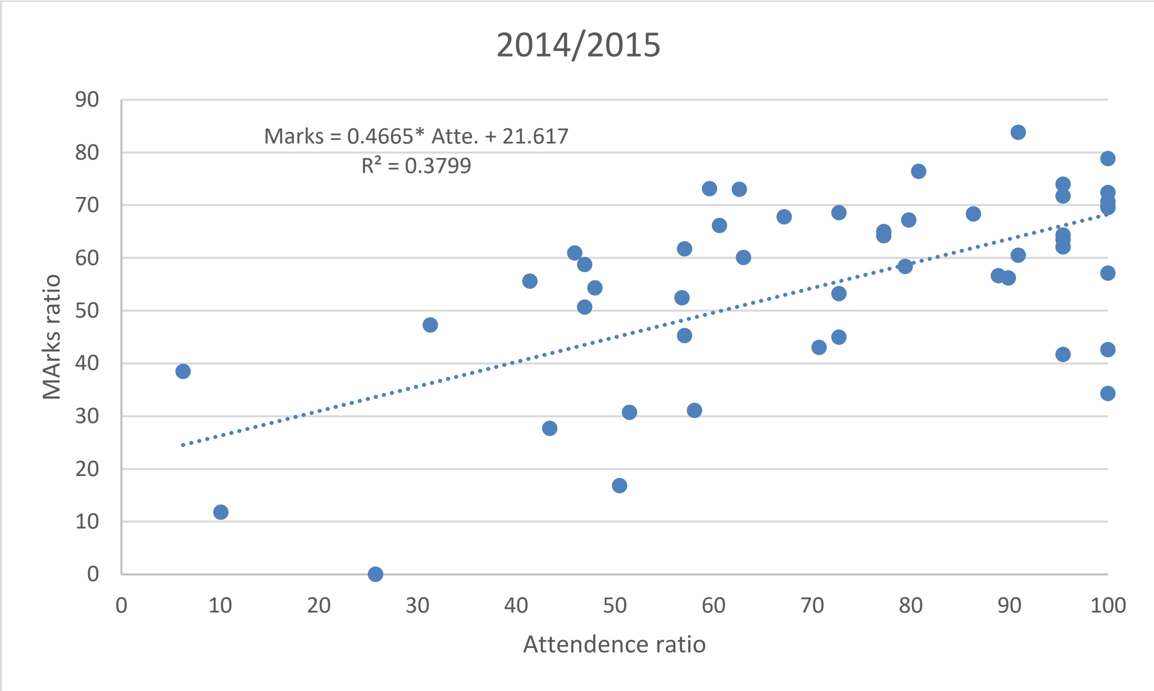


Figure 5.10 Regression model between the attendance ratio and marks after implementing the AJ Framework 2014/2015

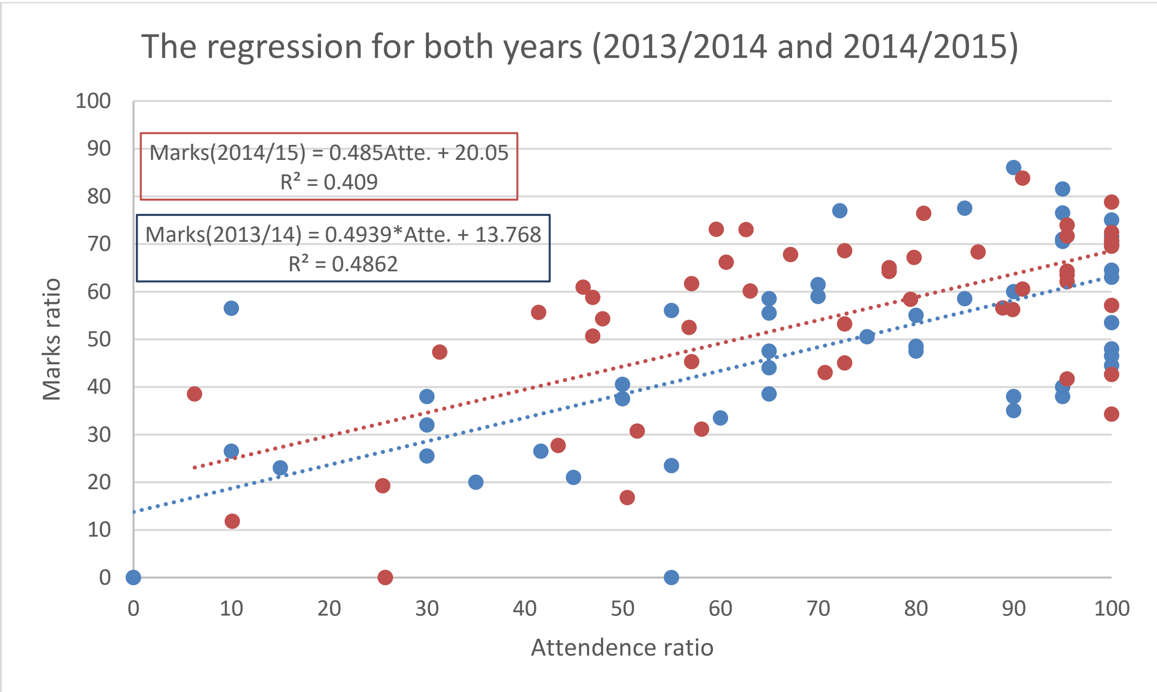


Figure 5.11 Regression model between the attendance ratio and marks before and after implementing the AJ Framework2013/2014

In terms of correlation of attendance and marks, we can calculate the correlation coefficient (r)

Whereas:

$$r = \sqrt{R^2}$$

2013/2014: $R^2 = 0.486,\ so,\ r = \ 0.697$

2014/2015: $R^2 = 0.485,\ so,\ r = \ 0.616$

Both correlations are 'strong positive', as r-values. The rule of thumb, for absolute value of r are as follows:

0.00 - 0.19: very weak positive correlation.

0.20 - 0.39: weak positive correlation.

0.40 - 0.59: moderate positive correlation.

0.60 - 0.79: strong positive correlation.

0.80 - 1.00: very strong positive correlation (M. J. Campbell & Swinscow, 2011).

The correlation before implementation was slightly bigger

To investigate if there is a significant difference between before or after implementing the AJ Framework, we will use Fisher test (Wuensch, Jenkins, & Poteat, 2002). Firstly, we need to transform each correlation by using the Equation 5.5.

$$r' = (0.5)log_e\left[\frac{1+r}{1-r}\right] \text{ Equation 5.5}$$

And then calculate the Z by using Equation 5.6

$$Z = \frac{r_1' - r_2'}{\sqrt{\frac{1}{n_1-3}+\frac{1}{n_2-3}}} \text{ Equation 5.6}$$

$$r_1' = (0.5)log_e\left[\frac{1+0.697}{1-0.697}\right]$$

$$r_1' = 0.861$$

$$r_2' = (0.5)log_e\left[\frac{1+0.616}{1-0.616}\right]$$

$$r_2' = 0.719$$

Now, Z can be calculate it from equation 5.10 as:

$$Z = \frac{0.861 - 0.719}{\sqrt{\frac{1}{51-3} + \frac{1}{50-3}}}$$

$$Z = 0.696$$

Now we can use the Table C.1 in Appendix C to find the probability value ($p - value$) to check is there a statistical difference or not between the correlation in both academic years, before and after implementation of the AJ Framework.

$$p - value = P(\mathrm{Z} > 0.696)$$

$$p - value = 1 - P(\mathrm{Z} < 0.69)$$

$$p - value = 1 - 0.7549$$

$$p - value = 1 - 0.7549$$

$$p - value = 0.2451$$

As $p - value$ is greater than 0.05 then the difference between the correlations is not statistically significant.

Even though there is a strong correlation in both years with attendance having a positive effectiveness in general, as consistent with other researchers (Rodgers, 2001; Stanca, 2006). In fact, it is regarded as normal to get positive correlation between the ratio of attendees and passing the module as (Credé, Roch, & Kieszczynka, 2010) concluded in their research.

There is no direct evidence from the p-value that there is a causal difference with implementing the AJ Framework. However, from the scatter plot there is distinction between the linear regression plots for the two sets of students, as shown in Figure 5.11. After implementing the AJ Framework: the average mark for a fixed attendance value is higher by about 6% for the students who were taught on the course after the AJ framework had been applied.

Further investigation will be presented for studying student performance as case studies by using information that was collected by the technology (NOW system in this case) for the students progressing, which come with TPK domain in the AJ Framework. The online learning room in the NOW system is using technology to try and enhance learning partly by making the material accessible at any time. Yet, as some tutors pointed out: because students have access to the lecture material online in NOW system, that might have encouraged absenteeism from course lectures in general, hence students lose the benefits of the pedagogic planned delivery and improved contextualisation in the classroom.

From the scatter plot there is distinction between the students as shown in Figure 5.11 after implementing the AJ Framework. Thus, investigation was done to verify the effects of attendance on student performance (face-to-face teaching strategy by following the AJ Framework steps), the students were divided into two groups based on attendance ratio; the first group got 50% or more and the second group who got less than 50% attendance rate overall in lectures and labs. A T-test was conducted to find out if there are any differences in the performance of two groups by comparing their marks, see Table 5.6 and Table 5.7.

Table 5.6 One-Sample Statistics of both groups

	N	Mean	Std. Deviation	Std. Error Mean
First group >=50%	39	59.4128	14.87285	2.38156
Second Group < 50%	11	36.8636	23.33133	7.03466

Table 5.7 One-Sample Test of T-test of both groups

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
First group >=50%	24.947	38	.000	59.41282	54.5916	64.2340
Second Group < 50%	5.240	10	.000	36.86364	21.1894	52.5378

The $p - value$ is less than 0.001 (p <0.001) so the result shows a statistical significance at $p < 0.01$. This supports the result of correlation that the attendance positively affects the student performance, demonstrating higher attendance granted students more in-depth knowledge of the content of this module, especially if the tutor following good teaching and learning strategies, which was achieved in this case study (as presented in the tutor observation section).

After comparing pre-implementation and post-implementation of the framework, now we want to dig deeper and evaluate the AJ Framework in terms of student learning and at the same time reflect tutor performance.

One of the main points of the AJ Framework is to link teaching in HE with the industry needs, thus, students are required to do industrial related practical work and be assessed on it. So we want to investigate in addition to used technology. Did students obtain the industrially related learning outcomes. This investigation implicitly will reflect tutor performance and using technology to provide supporting material in the NOW system which come under TPK and TPACK domain in the AJ Framework.

Student performance was measured on the three types of assessment. Each assessment form assesses a different set of learning outcomes in a different way. The average marks and standard deviations are shown in Table 5.8 and student numbers for those who passed and failed in these three assessment forms are shown in Table 5.9. The average result of these assessment forms presents student understanding of the content and their level of competency in applying what they learned, which are represented by the learning outcomes.

Table 5.8 Average marks in each assessment form and average total marks

	Written assignment LO(K3, S2, S3) 30% weight	Laboratory assignment LO(K3, S2, S3) 20% weight	Exam LO (K3, K4, S2) 50% weight	Total mark 100%
Mean	50.40	60.48	51.62	54.45
Std. Deviation	21.61	21.89	22.97	19.28

Table 5.9 The numbers of passed and failed students in each assessment.

	Written assignment LO(K3, S2, S3) 30% weight	Laboratory assignment LO(K3, S2, S3) 20% weight	Exam LO (K3, K4, S2) 50% weight	Total mark 100%
Passed	43 (86%)	39 (78%)	37 (74%)	41 (82%)
Failed	7 (14%)	11 (22%)	13 (26%)	9 (18%)

The results show 82% of students passed the module. Regarding student attendance: many students with high attendance rates clearly gained more in-depth knowledge of the topics such that their performance improved.

The average marks in each assessment form is shown in Table 5.8. The average of the written assignment got a higher average. There may be many reasons for this for instance it might be because of the exam stress, examination preparation, memory, as the exam is subjective questions (Roney & Woods, 2003; Sieber, O'Neil Jr, & Tobias, 2013). Atherton (2013) stated that "Examinations typically generate high degrees of anxiety, amounting to cognitive paralysis on the part of some candidates. They call for very specific skills, which may well be irrelevant to the subject being examined, and are therefore often low on validity, but high on discrimination potential."

In terms of lower average in the laboratory assignment, this might be the limited exposure time to the laboratory equipment (from student feedback) and partly as the assignment is new this year and not as well aligned, as an improved version will be for the next academic year (from tutor feedback).

The tutor provided prompt feedback about the first coursework, to highlight good work and to avoid repeating previous mistakes, by using NOW to feedback and comment on student work. A high ratio of students mentioned in their EvaSys questionnaire that the tutor feedback was helpful. This will be covered in more detail in the Student feedback section. This promotes learning by assessment activity and feedback.

In regards to validating student marks, as (Newstead & Dennis, 1990) argue that bias might operate in marking. The marking of all forms of assessment requires moderating to improve validity of students marks (Falchikov & Goldfinch, 2000). NTU operates a moderation policy for all assessments which is supported, as in all NTU courses, by the viewing of all marked work (contributing to degree classifications) by the external examiners.

In terms of checking the consistency of student performance in the different summative assessment forms, the correlation was calculated as shown in Table 5.10. As presented the correlation is positive between all of the three assessment forms. The correlation between written coursework and exam was a strong positive correlation with r- value 0.666.

Table 5.10 Correlation between assessment forms

		Written coursework	Laboratory coursework	Exam
Written coursework	Pearson Correlation	1		
	Sig. (2-tailed)			
	N	50		
Laboratory coursework	Pearson Correlation	.452**	1	
	Sig. (2-tailed)	.001		
	N	50	50	
Exam	Pearson Correlation	.666**	.546**	1
	Sig. (2-tailed)	.000	.000	
	N	50	50	50

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation of assessment forms (written coursework, laboratory coursework and exam) might be considered as a reflection of the tutor progress to consistently deliver the learning outcomes.

The positive correlation between student marks in all assessment forms reflect that the teaching and learning strategies was balanced. The positive correlation indicated that tutor performance was good.

We next want to further study the extent attendance affects student marks, especially with accessibility of the content through the NOW online system. And try to reflect the student observation and use the TPK domain to investigate other unobserved factors.

To test this Pearson's product-moment correlation, as inferential statistics, was used to determine the relationship between students attendance and their marks (See Appendix E for full data). Table 5.11 shows the module overall mean marks and standard deviations. The correlation result is presented Table 5.12. The results show significant positive correlation between the attendance and performance (r=0.616).

Table 5.11 Descriptive Statistics

	Mean	Std. Deviation	N
Total Mark	54.45	19.279	50
Lecture Attendance	60.49	30.967	50

Table 5.12 Correlations between total attendance and total marks

		Total	Total Attendance
Total Mark	Pearson Correlation	1	
	Sig. (1-tailed)		
	N	50	
Total Attendance	Pearson Correlation	.616**	1
	Sig. (1-tailed)	.000	
	N	50	50

**. Correlation is significant at the 0.01 level (1-tailed).

This result shows that the performance rate was associated with a positive attendance rate.

And for more investigation to verify the impact of using the AJ Framework in teaching and learning strategies by studying students learning through each assessment forms which cover the learning outcomes; the correlation was calculated to study the relationship, especially with laboratory coursework as a new assessment form which was added for the first time. Table 5.13 shows the correlation between the lab attendance and Lab coursework marks. Also, for lectures and theoretical assessment (written coursework and exam) as shown in Table 5.14.

Table 5.13 Correlations between lab attendance and lab coursework marks

		Attend LAB	LAB CW
Attend LAB	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	50	
LAB CW	Pearson Correlation	.555**	1
	Sig. (2-tailed)	.000	
	N	50	50

**. Correlation is significant at the 0.01 level (2-tailed).

The results also indicate that there is a significant positive correlation between lab attendance and practical coursework (r=0.555).

The correlation between lecture attendance and theoretical coursework as well as final exam is significant as well (0.526). All correlations results were positive.

Table 5.14 Correlations between lecture attendance and theory coursework and exam marks

		Exam and written CW	Attend Lectures
Exam and written CW	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	50	
Attend Lectures	Pearson Correlation	.526**	1
	Sig. (2-tailed)	.000	
	N	50	50

All the previous results demonstrate the effectiveness of using the AJ Framework in terms of triangulation of tutor observation, tutor comment, student engagement and performance, and their marks. However, as the AJ Framework uses technology to associate pedagogy in two domains TPK and TPACK, therefore that gives more ability to investigate student performance. The NOW system records student progress, including any viewing of available material. This is in the TPK domain of the AJ Framework. The researcher noted that five students' performances were pass standard while their attendance ratio was about 48%, which is classified group B (Attendance lower than 50%). Thus, deeper investigation took place to investigate the reasons behind this.

Student #1 and student # 7 have 100% engagement with material available in NOW system as shown in Figure 5.12 and Figure 5.13. They have visited the main and supported material. That indicated that using online technology with face-to-face would help some students to a certain extent even in the case of missing some face-to-face teaching.

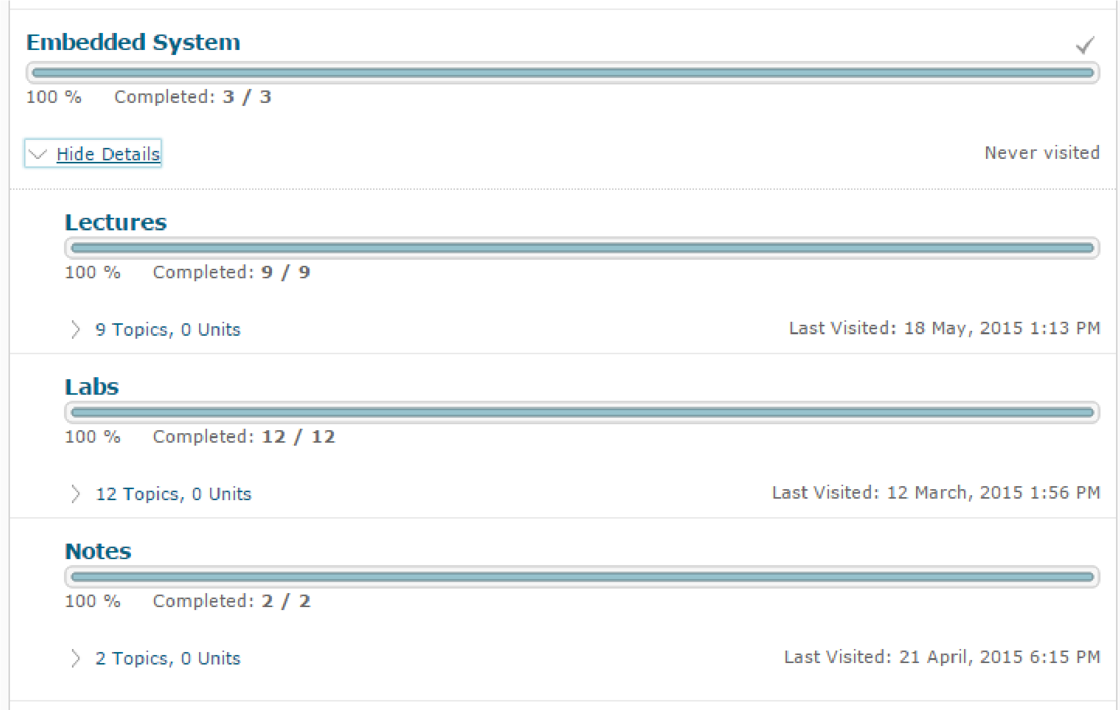


Figure 5.12 Student #1 progress with the online system.

However, there were a few exceptions: Five students with low attendance but high or moderate online material access were able to pass the module, albeit not with high marks. However, it still implies that attendance of the student does positively affect the student performance in the exam. For example, student # 50 has only 47% attendance could only achieve 50% marks. He viewed 52% (33% lectures, and 75% labs) of online material available on the NOW system as shown in Figure 5.14. This particular student, student # 50, got more observation because the researcher noted his good performance once he started to attend, but he needed some motivation to make him finish his experiments. The tutor provided this advice and motivation. These cases show the importance of the tutor understanding of student weaknesses and how and when to go about solving them.

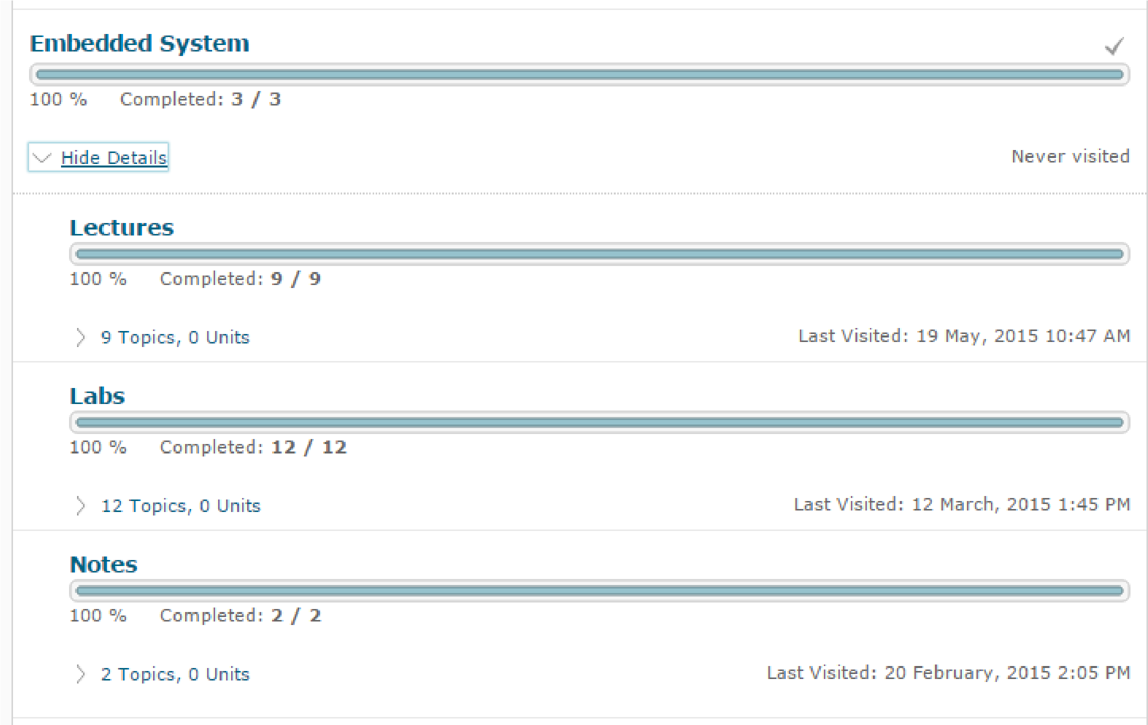


Figure 5.13 Student #7 progress with the online system.

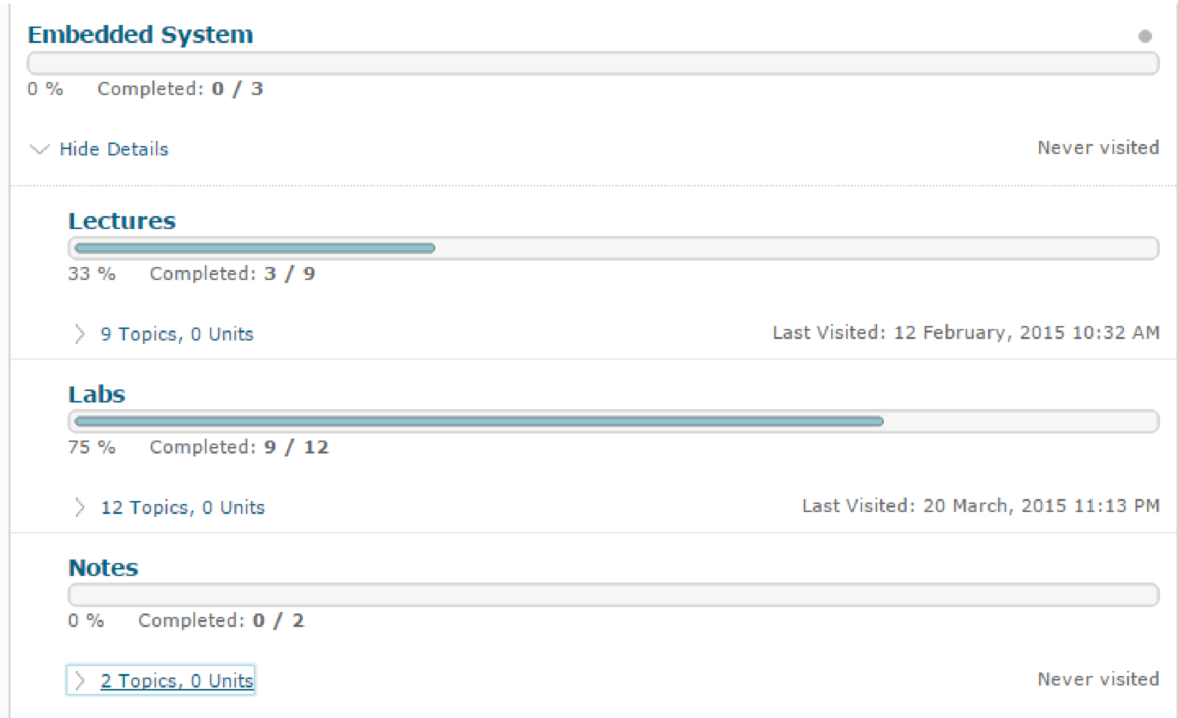


Figure 5.14 Student #50 progress with the online system.

5.4.4 Student feedback

The evaluation of the AJ Framework implementation was also based on student feedback. A mixed method research approach was used to study the level of satisfaction of students on various aspects of this module. The EvaSys questionnaire was completed by students to report their degree of agreement with a set of items for each aspect. (see sub-Section 3.7.3, p.42 for more information on EvaSys). The response rate was 40% (22 students responded) when collected in the second half of the term.

The following paragraphs summarise the results of EvaSys questionnaire:

i. Evaluation of teaching on the Embedded Systems module

Several items of teaching strategies on the Embedded Systems Module were analysed. Skills in item 1, 2, 4 and 5 were all about the tutor's personal actions in the class and lab: organised, supportive, enthusiastic about what they are teaching and make students feel free to ask questions; all averages were between 4 or 4.1 (an average greater than agree) as shown in *Table 5.15*. Items 1, 2 and 4 evaluate the PK domain and item 5 evaluates PCK in the TPACK and the AJ Framework. and item 5 evaluates PCK as these results showed 80% or more of the students agreed that tutor achieved these skills. The teaching and learning strategies: explaining things, in well-structured sessions, made the subject interesting, and used suitable teaching methods to help student learning. Skills in items 3,6,7 and 8 presented averages around 3.7, which showed ratio between 60%-70% of students' agreed that tutor achieved these skills. The skills from items 3, 6 and 7 also evaluates the PK domain, while item 8 evaluates tutor skills in PK and PCK, also TPK domains where the tutor used technology to help. Skills in items 9 presented a 3.6 average and evaluate the structure of the sessions which cover PK and PCK domains. The ratio of students agreeing with this item is 61.9%. Finally, in item 10, the 'overall teaching quality on this module' aspect, the overall satisfaction presented a 3.8 average that came with 75% of students satisfied with the teaching; this overall quality is mainly covering the PK domain and partly PCK and TPK domains.

The overall average of teaching on this module was good 3.7 with standard deviation 1.1.

Table 5.15 Responses to the EvaSys questionnaire: Teaching on this module.

Definitely Agree = DA	Agree = A	Neither Agree/Disagree = N	Disagree = D	Definitely Disagree = DD

	Statement	DA	A	N	D	DD	Total number of responses	means	Standard deviation	Agreement ratio
1	My tutor is well organised	6	11	2	0	1	20	4.1	0.9	85%
2	My tutor is supportive	8	8	2	0	2	20	4	1.2	80%
3	My tutor is good at explaining things	7	8	3	1	2	21	3.8	1.2	71.4%
4	I feel able to ask questions	12	5	1	1	2	21	4.1	1.3	81%
5	Module teaching staff are enthusiastic about what they are teaching	9	7	2	1	1	20	4.1	1.1	80%
6	Module teaching staff are good at explaining things	1	12	4	2	1	20	3.5	0.9	65%
7	Module teaching staff have made the subject interesting	6	8	6	0	1	21	3.9	1.0	66.7%
8	The range of teaching methods used on this module have helped my learning	5	7	4	4	0	20	3.7	1.1	60%
9	The teaching sessions are well structured	5	8	4	3	1	21	3.6	1.2	61.9%
10	Overall, I am satisfied with the teaching quality on this module	4	11	3	1	1	20	3.8	1.0	75%

ii. Evaluation of assessment and tutor feedback

The second aspect that we collected is the student opinion about assessment methods and getting feedback about their progress. *Table 5.16* summarized this aspect. This aspect depends on the clarity of assessment criteria, the time it takes to get feedback, getting detailed comments and identification of areas which can help improve for future work. For the item 11, the first question in this aspect, about the clarity of assessment criteria which come under PK, PCK, and TPK (as technology was used to provide the criteria in the NOW system). The student opinion presented an average of 3.9 (66.7% agree or definitely agree) which is a positive indicator. However, this ratio will be discussed in more details in critical analysis Section 5.7. In terms of getting prompt feedback, the average opinion of the students was high 4.2 and 90.5% of students agreed or definitely agree; the evidence on the high agreement ratio shows how the tutor was keen to give feedback for first coursework before the second coursework deadline which helped students to improve the future work for coming coursework and exam. The details of the tutor feedback also presented a high average 4.2 with a high ratio of 85% agreement.

Table 5.16 Responses to the EvaSys questionnaire: Assessment and Feedback (Formal and Informal).

Definitely Agree = DA	Agree = A	Neither Agree/Disagree = N	Disagree = D	Definitely Disagree = DD

	Statement	DA	A	N	D	DD	Total number of responses	means	Standard deviation	Agreement ratio
11	The assessment criteria have been clearly communicated	7	7	4	3	0	21	3.9	1.1	66.7%
12	Feedback on my work has been prompt	8	11	1	0	1	21	4.2	0.9	90.5%
13	I have received detailed comments on my work	9	8	1	1	1	20	4.2	1.1	85%
14	Feedback has identified areas that I can improve on in the future	7	8	5	0	1	21	4	1	71.4%

iii. Evaluation of module organisation and resources

The third aspect includes organisation and resources in the module shown in *Table 5.17*. The mean of student opinion was 3.8 in understanding the aims and learning outcomes of the module with a 68.2% agreement percentage; this item comes under PK, and PCK. The same mean attached to their opinion on if the now online resource for this module have helped support their learning, this yielded a percentage of 68.4% (this item comes under PK, PCK, TPK and TPACK). This is a positive indicator for mixed teaching strategies. In terms of well organised and running smoothly, this got 3.7 and the percentage in this aspect was only 57.1%. This, as we mentioned, was influenced by lab problems which some students face in interfacing the hardware and software due to problems relating to use of the software hub. In terms of their opinion of understanding how this module links with the rest of their course, this was rated 3.6 but with a better percentage of agreement at 63.2%; this item comes under PK, and PCK. The lower mean was affected by 33.3% of them who answered neither agree nor disagree. This point needs more investigation. The percentage answering “I find the module to be a valuable learning experience” was good 72.2% of the students answered agreed (50% definitely agree, and 22.2% agree) with a high mean of 4. This is a good indicator of module organisation and resources, which shows that students enjoyed this module and had good teaching and learning experience from it. This item is supported with the following item, which is 68.4 percentage of student opinion found the module intellectually stimulating with a 3.8 mean.

The total mean of this aspect was 3.8 with 1.2 standard division, which shows students overall agreed with the organisation and resource in this module.

Table 5.17 Responses to the EvaSys questionnaire: Module Organisation and Resources.

Definitely Agree = DA	Agree = A	Neither Agree/Disagree = N	Disagree = D	Definitely Disagree = DD

	Statement	DA	A	N	D	DD	Total number of responses	means	Standard deviation	Agreement ratio
15	I understand the aims and learning outcomes of the module	7	8	4	2	1	22	3.8	1.1	68.2%
16	The NOW online resources for this module have helped support my learning	6	7	4	1	1	19	3.8	1.1	68.4%
17	The module is well organised and running smoothly	5	7	7	1	1	21	3.7	1.1	57.1%
18	I understand how this module links in with the rest of my course	4	8	3	3	1	19	3.6	1.2	63.2%
19	I find the module to be a valuable learning experience	9	4	2	2	1	18	4.0	1.3	72.2%
20	I find the module intellectually stimulating	7	6	3	2	1	19	3.8	1.2	68.4%

iv. Evaluation of facilities (school specific questions)

The school specific questions aspect was focused on evaluating university facilities. This aspect includes two items which are summarized in *Table 5.18*. The first item is about the ability to access the equipment and facilities when they need to. This item had a low average of only 3.1 with poor ratio of 35% of student opinion agreed, 35% neither agreed nor disagreed, and 30% disagreed. The second item is the satisfaction regarding learning resources. The average was also low at only 3.0; the student agreement ratio was a little bit higher at around 43%. The low score in this aspect related to problems with accessing the hardware equipment. Those two questions evaluated PK, TPK, and TPACK domains.

Table 5.18 Responses to the EvaSys questionnaire: School Specific Questions

Definitely Agree = DA	Agree = A	Neither Agree/Disagree = N	Disagree = D	Definitely Disagree = DD

	Statement	DA	A	N	D	DD	Total number of responses	means	Standard deviation	Agreement ratio
21	I've been able to access specialist equipment/ facilities when I needed to	3	4	7	4	2	20	3.1	1.2	35.0%
22	The rooms and learning resources for this module have been Satisfactory learning	2	7	5	3	4	21	3	1.3	42.9%

v. Evaluation of Overall Satisfaction

The final aspect is getting student opinion regarding their overall satisfaction. The average was 3.7 with a good ratio of student agreement more than 68%. The rest of students around 16% neither agreed nor disagreed and 16% disagreed, see *Table 5.19*.

Table 5.19 Responses to the EvaSys questionnaire: Overall Satisfaction

Definitely Agree = DA	Agree = A	Neither Agree/Disagree = N	Disagree = D	Definitely Disagree = DD

	Statement	DA	A	N	D	DD	Total number of responses	means	Standard deviation	Agreement ratio
23	Overall, I am satisfied with this module	4	9	3	2	1	19	3.7	1.1	68.4%

vi. Qualitative feedback

Mixed methods were used as a triangulation approach, as mentioned in the methodology chapter, as a powerful technique to facilitate data validity through two or more sources for verification purpose (Punch, 2009). Therefore, the students were asked to participate to give qualitative feedback in the EvaSys as open ended questions. And this covered all the 5 questionnaire aspects. The university ‘police’ the privacy of the EvaSys questionnaire as it is designed to provide fully anonymous information. Therefore, it is not possible to evaluate who said what in all questions. As a result of our research, this point will be discussed later and suggestions will be given.

Firstly, in regards of teaching on this module the question is:

“ What aspects of the teaching do you particularly value and why? (Please give specific examples)”

In this section, 16 students gave feedback. All their responds were positive and the responses can be categorized as following:

- **Value all used teaching strategies in the module:**

One student said “All of it”. That means all aspects of used teaching strategies were valued. Another two students said briefly “All”.

Another student said “the enthusiasm brought by the staff towards the subject makes learning content more interesting. The range of methods used to teach is also good i.e. Questions, Seminars, lectures”

This reflects and supports all the other results and observations mentioned above and gives clear evidence of effectiveness of implementation of the AJ Framework. As the pedagogical domain (PK) in the AJ Framework includes engagement of a tutor to show enthusiasm of what they teach that increases the chance of student engagement and learning, which evaluate PCK domain, whereas this item come cross the used pedagogy to deliver the content. This response was supported by 80% agreement of students who participated in EvaSys questionnaire in aspect: i. teaching on this module.

- **Value hands on experience, practical work**

One student said: “working in labs gives hands on experience” and this support the aims of using the AJ Framework which plans in the pedagogical approaches to ensure students get the knowledge and skills by ‘doing’ alongside study, rather than just by reading about it or just seeing it being done.

Two other students mentioned the value of the practical work and how they enjoyed it and earned detailed understanding and practical skills.

“value labs which allow practical work in order to understand the topic in more detail”

“I value the practical lessons (labs) as I enjoy the hands on work”.

“Technical Arduino work is good”

“The lab sessions use the more interesting aspects of this module”.

All of these responses reflect the impact of the AJ Framework in terms of linking the module to practical work as students are looking for it to increase their chance in future to get a job after they built their experience in their early stages at the university. Using PBL as recommended in the AJ Framework helped students to obtain the industrial sense by thinking and solving real life problems by doing. As John Gay said “ Tell me and I forget, show me and I remember, involve me and I understand” (Franks, 2016). Also Richard Branson said "You don't learn to walk by following rules. You learn by doing, and by falling over" (Stephenson, 2013).

Another student valued: “lab sessions, technical side. Having support labs when needed”. This goes against low rate agreement of students, as shown in Table 5.14, regarding ability to access specialist equipment/ facilities when they needed (only

35%) and 42.9% satisfaction about the rooms and learning resources for this module. This point will be discussed in more detail later in aspects of teaching students think need to be improved. This comment illustrates that extra labs were offered but not enough students attended them.

- **Value the tutor interaction, helpful and supportive**

In terms of implementing the pedagogical knowledge in teaching methods and make the tutor more interactive with students helping and supporting them.

"Lab sessions are interactive and I learnt a lot through doing them".

"The interaction with the teaching stuff, running the lab straight after the lecture, means that knowledge still fresh".

This student also valued the time of the lab, which was allocated straight after the lecture that made it more beneficial for understanding the subject by getting theory and to implement it respectively.

This opinion was similar from another student who said: "I like that we do over the theory and then practical, so we understand it better".

"I value the labs because the tutors were very helpful if I don't understand something". Here, this student mentioned the value of labs, which emphasizes the effectiveness of the AJ Framework.

Another student said: "Everything was very hands on and the tutor was always there when we needed them". This as shown in Table 5.1 that one pedagogical aspect is student inquiry, which is mainly classified as part of student centred learning.

These students also valued the labs and how the tutor was supportive and this triangulates and boosts the quantitative results of the EvaSys questionnaire with 80% of agreement for the item of "My tutor is supportive". In terms of ability of asking questions "I feel able to ask questions" which got 81% agreement in quantitative data as shown in Table 5.12.

These comments evaluate the PCK domain as the subject matter represented instruction in the module, also the TPACK domain where the technology (including the hardware and software) and content introduced the concept of Embedded Systems.

- **Value the tutor feedback**

Another student stated tutors were “Supportive and responsive to feedback”. This statement triangulates and support the quantitative results as presented in section ii., evaluation of assessment and tutor feedback. As presented in Table 5.12, 85% of students agreed that they received detailed comments on their work, also, 90% of student agreed that the feedback on their work have been prompt. This reflects the PK domain in the AJ Framework which covers the teaching methods and clearly reflect the lesson plan process as shown in Figure 5.7 and Figure 5.8.

- **Value tutor understanding/good at explaining**

One student said: “They mostly know what they are teaching”. And “The labs are interesting and I learnt lots”. This triangulates with 71.4% agreement of ‘My tutor is good at explaining things’, which demonstrates the PCK domain.

A student mentioned “I think everything about teaching was fine it is not that bad”, which indicates a lower level of satisfaction. However, they still considered teaching was “fine” and they did not support or explain their opinion with more clarification.

Secondly, the students were asked about the aspects of ‘what teaching do you think could be improved and why? (Please give specific examples)’

In this question, 10 students participated.

- **Suggested increase in lab session time**

Some students asked to increase lab session times.

“Make the labs longer because it is short amount of time”.

“Longer labs- by the time Arduinos are set up. The lesson is half way through. Labs at least 2 hours”.

“For the lab sessions, we were often not given enough time, with half of the lab spent setting up the device – In addition, for the report project, not enough time was given with the devices (hardware), needed to buy one myself”.

As discuss earlier in section 5.4.1 tutor observations and detailing student feedback in EvaSys, some students had clearly faced some problems with interfacing the hardware with the Integrated Development Environment (IDE) because of compatibility issues with the Software hub.

Other student opinion was about taking hardware equipment out of the class: “in Arduino labs having longer with actual Arduino such as being able to take them out of labs would really help”. Another student mentioned the same point. However, with regards to this issue the module was designed to offer access to the hardware equipment in lab sessions and in surgery session as needed. But still as mentioned above too few students attended these extra sessions so, it is not sensible to use the lab problems as much of an excuse (they negatively influenced access but did not prevent enough access).

- **Having lectures in the first morning session**

One student stated “No 9:00 am lectures”. This was discussed in sub- section 5.4.2 student observations. Clifton campus being off a very busy main road with ongoing transport problems causing regular disruption leads to 9:00am lectures being unpopular even with conscientious students.

- **Explaining issues**

One student said: “sometimes a demonstration could be useful especially for the more complicated parts”. In this regard, the demonstrations were used as a part of teaching strategies to help student understanding. However, some challenging aspects were made to motivate higher level directed study and build on self-study skills for the better students. In student centred learning they were able to do their own research first and then ask the tutor if they need help and they got that as the students feedback and researcher observation for both tutor and students performance. Another student mentioned that he did not understand the programming parts by saying: “Lost with programming, not a very good teacher”. In any class some students struggle but from class observations it was very obvious that those students who were struggling who engaged with the module seemed to overcome their difficulties so maybe this student was blaming the tutor for their own lack of engagement. The majority of the students were satisfied with most of searching strategies, as found from all previous resource of collecting data to evaluate this module performance, also, most students mentioned and rated the good support and interactive with the tutor.

When students needed to implement an LED ‘blinking’ code, because they were more familiar with Python than the C language, the tutor uploaded additional information how this type of code works in Python and how it can be converted to C used for Arduino. This was part of the weekly feedback loop of the lesson plan process as shown in Figure 5.8.

Thirdly, the students were asked to add any additional comments about three aspects:

- Assessment and Feedback (Formal and informal).
- Module organisation and resources
- School specific questions

Five students commented on the same issue discussed above which is getting more lab time, or have the hardware equipment ‘kit‘ with them, would improve teaching this module,. Students statements were as follows:

“Need more than 1 hour an Arduino”.

“More time in the labs for the Arduino could be handy”.

“Arduino kits need to be made more accessible”.

One student commented in this section that using “bigger Arduino boards are needed”. As a first year module, the Arduino kits which are used covered all aspect and learning outcomes in this stage, but for the next year they used more complicated Embedded Systems to fit the learning outcomes of each stage.

Finally, the students were asked to comment about overall satisfaction:

Part 1: things they liked about this module and why.

In this part, 17 students participated. All but one expressed their enjoyment learning this module, also, the tutor’s ability to simplify the subject, such as: “I enjoy the subject to study as it is intellectually stimulating – the staff know what they teach and can easily answer questions”.

Other students liked the interactivity of the tutor which helped them to understand the module learning outcomes. “Tutor is interactive and explaining in depth and doing this module has helped me understand a whole world of system”.

Another student mentioned that the thing he likes in this module is “It required a lot of different skills and has been a very hands on module”. Again here we can see how the hands on and practical work was preferable from most of the students, based on the changes built from implementation of the AJ Framework. The following comments from other students supporting that:

“I liked doing the practical work on the Arduino”.

“The hands on work – Creating interesting systems”

Some students express their interesting with the topic and

“the topic is a relevant and interesting on – the hardware/software interaction is one topic need to cover, so good to go over it”

“The Arduino stuff is interesting”

“The labs are interesting and I learnt lots”

“Technical/Arduino very good and interesting”

Part 2: things they feel could be improved this module and why

In this part, 17 students participated also. The main points were similar as those mentioned above which can be summarised as:

- Getting more labs
- increasing labs sessions’ time.
- A wish to use hardware kit outside of the lab.

As discussed before, some students faced delays because the software interface for the Arduino IDE software hosted in software hub had a fault that caused operation problems at times. To resolve the issue with the fault extra time was given to access the lab (where a few students attended), also the Arduino simulator was explained to the students to enable them to try their design work in their own time. The fault was resolved for next year by download the Arduino software locally in the lab PCs.

All these issues evaluated PK in terms of teaching strategies, PCK using pedagogical knowledge to deliver the content, TCK the technology as content, which is here Arduino software and hardware. TPACK covered teaching techniques by using technology to deliver the content. The AJ domain was from using real-life scenarios in the practical project and in the written project a link to students thinking about real industrial design.

All of these domains had mostly good student satisfaction ratings in EvaSys (as quantitative data and students feedback as qualitative data) which triangulated them and further triangulated with other evidence sources. The items that got less satisfactory rates had identified reasons and actions either in same year or for the next year.

5.5 Implementation of the AJ Framework in the Digital Control module

The case study of the MSc level Module was originally called Applied Industrial Process Control (AIPC), then after the first year of research the name and content changed to a new module called Digital Control. The module was originally part of the MSc in Electronic Engineering and also the MSc in Cybernetics and Communications; it is now part of the MSc in Electronic Engineering (only) (S. Clark, 2016).

The module includes:

- Motivations for digital control, including computer-based control; theory and practice.
- Discrete representation of continuous systems: theory and practice
- Use of MATLAB in digital control simulation and design
- Digital system design examples: digital filters and PID controllers.
- Process control theory and practice
- Use of Agilent Vee Pro in real time control simulation and design using real industrial examples from Gyrometric Systems (Orton, 2011).

The module is an introductory Digital Control course; the aim of teaching is to develop the understanding of the key principles, underlying technologies and practical application of digital control: including digital filters, control system design, process control design, software simulations and real world implementation strategies. The module includes lectures and laboratory exercises and assignment work to achieve its aims. The module is assessed by two assignments forming a 100% coursework element.

The module used the following software: MATLAB with control toolkits, and Agilent VEE Pro real-time process control software (the company providing this software has changed its name to Keysight Ltd and the software name is VEE Pro (http://www.keysight.com).

This module covered the topics as described in Table 5.20. It comprises two parts. Part 1 presents the introduction to the Digital Control, with digital control, digital filters and PID controllers using MATLAB, including assignment 1, which is all covered in six weeks. Part 2: concerned process control theory and practice, using of Agilent Vee Pro in real time also covered assignment 2 in four weeks.

The first assignment area before implementing the AJ framework was: digital filter design work for a simulated real world application (using MATLAB). The second topic area before implementing the AJ framework was: industrial process control application for the simulation of monitoring bearing noise (using VEE Pro). In addition laboratory work, before implementing the AJ framework, was used to provide formative feedback; to enable the assignment work various other real world examples were covered including a PID controller demonstration.

The Digital Control module was delivered in the first term of the MSc electronics programme, and students came from different backgrounds. Thus, the module was considered as an introductory module, so the students should have the basic knowledge of electronics, computing and mathematics subject areas.

Although strongly based on industrial approaches the module was traditional in some respects with lectures, laboratories and seminars determined by a learning outcome approach. However, the delivery was mixed with all three teaching methodologies mixed within the 3 hour sessions. In some respects the module already included a lot of the areas expected from a TPACK approach without being formal in this requirement. Assessment was by coursework (2 assignments) with practical industrially linked examples on computer packages with required written sections to link the practical results to theory and industrial context (for more details visit Digital Control module in now.ntu.ac.uk).

Table 5.20 Digital Control Module Topics and planning, (Module structure)

Topics (Lectures/Labs)	**weeks**
Introduction to digital control and MATLAB (mixed)	Week 1-6
Digital control lectures and laboratory examples (mixed)	
Digital filter lectures and use of MATLAB digital filter tool (mixed)	
PID controllers MATLAB control tools and intro to Assignment 1*	
Formative lab exercises and Assignment 1 *	
Assignment 1 *	
Introduction to process control with practice in Agilent Vee and introduction to Assignment 2 *	Week 7-10
Process control lectures with Assignment 2 *	
Assignment 2 *	
Assignment 2 completion and in-class assessment	

* Significant direct study, students need to work in their own time.

5.5.1 Developing the Digital Control module content based on the AJ Framework

The module has been updated based on the demand of real world industrial requirements. The previous version included 10 weeks of 3 hour sessions with mixed content delivery of lectures, laboratory exercises and assignment work (explicitly linked to industrial projects). There was also a significant amount of directed self-study, assignment work. The module was assessed by two assignments based on PBL. The first assignment was partly assessed 'in-lab' and partly based on a written assignment report. The second was partly based in-lab and partly on an Agilent VEE code solution to the industrially related set problem. However, despite this module previously involving many aspects that are related to the TPACK/ AJ domains the formal application of this research led to important improvements of the presentation of some theoretical information and, the practical work in various laboratories and in both assignments. Therefore, after implementation the main concentration in updating the content was to increase the relevance of the industrially related practical work.

In the first implementation of the AJ framework the taught materials on PID Controller were significantly modified by using MATLAB script and tools and the assessment was changed to include a small PID project. A Simulink application was also written and demonstrated in class. The emphasis on the linkage of the assignments to real-world applications was improved.

In the second implementation (year), new taught materials were produced on Simulink and the first assignment assessment was changed to include a small Simulink project assessment.

In the third implementation, the taught materials were adapted to produce more practical MATLAB coding example of some theories, more Simulink, LabVIEW, and how to compile code from MATLAB to hardware, using an Arduino system as an example. More background was provided on more complex industrial solutions such as FPGAs (Field-Programmable Gate Array).

The impact of implementing the AJ Framework in student performance in the Digital Control module is almost similar to Embedded Systems module impact, which is represented in each domain below:

- PK and PCK: teaching and learning styles and how students interacted with these strategies.
- TK: students used university email to contact the tutor if they have any questions or request accessing the lab at a different time. Also, technology used in the attendance register in the NOW system.
- TPK: the NOW system allowed the tutor and researcher to monitor student progress, and the Students Dashboard to monitor student engagement.
- TCK: using technology as part of the content MATLAB and Agilent VEE Pro, which is reflected passivity as we will see in student feedback, and this reflects the AJ Framework in terms of linking to industrial needs
- TPACK: Students access of the content on NOW can be monitored by the tutor NOW system.

i. **First implementation of the AJ framework (2013/14)**

a. Implementing teaching strategy (lesson plan process)

The lesson plan process for lecture and laboratory followed Figure 5.5, on the appropriateness of the three main steps of: objectives, methods and evaluation. Aspects of pedagogical (PK) and technological (TK) and content knowledge (CK) were all assessed; similarly to the process in the Embedded Systems module the same steps have been taken.

5.6 Evaluation and Results of implementing the AJ Framework in Digital Control module

5.6.1 Tutor observation in the Digital Control module

The teaching observation scheme in Figure 5.2 was followed, the same four stages were followed.

We can summarise the observation results as in general; the tutor was doing well in following the lesson plan, starting the lecture by presenting lecture aims and learning outcomes, and used various ways of presenting information, using PowerPoint, whiteboard, video, demonstrating equipment and asking students questions to make the lecture more interactive. Also solving problems on the whiteboard and involving students, by making everyone think (sometimes pointing to the student, to make them more active and that was obvious from students engagement as the researcher observed also from their feedback.

5.6.2 Student observation in the Digital Control module

This section presents the researcher’s findings from student engagement and performance. As in any class, diversity in response was there: in labs some students were independent and more confident.

The Digital Control module has been designed for 3 hours a week. This 3 hours including the lectures/seminars and laboratory work. The researcher noted that the majority of students pay more attention when the tutor used various techniques to attract student attention.

The impact of implementing the AJ Framework in student performance is almost similar to that presented in the Embedded Systems module (see sub-section 5.4.2), but TCK is different.

TCK: using MATLAB, Simulink and Agilent Vee pro software technology as part of the content, which is reflected in student feedback, and the AJ Framework in terms of linking to specific industrial needs.

5.6.3 Student marks 2013/14

The research conducted in this study, makes use of the TPACK/AJ framework to teach Digital Control at NTU as a case study to develop better practices in using suitable pedagogy and technology for engineering control education. Our target group was seven students, the content was divided into two parts, and we taught the first part by a conventional teaching strategy and the second part by applying the TPACK/AJ framework and gave them an assignment for each part.

One approach to measure the effectiveness of using the AJ framework to assess student performance, so the assessment of the two strategies were compared, as shown in Figure 3.6. We found the average marks of the assignment 2, which is taught by using the TPACK framework was higher as illustrated in Figure 5.15 below. Five students got higher marks, one got the same mark, and one got less.

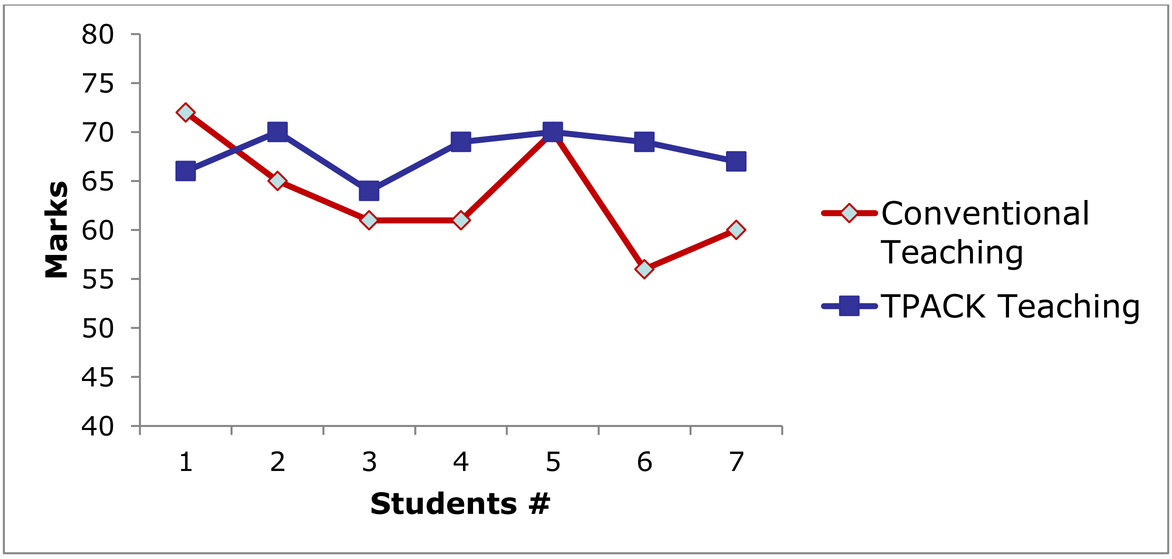


Figure 5.15 compare two teaching strategies

In this case study, we concentrated on qualitative methods because our target group is too small for quantitative significance. These mark comparisons was just to check in general the performance of using TPACK/AJ framework and its impact on performance.

5.6.4 Student marks 2014/15

The TPACK developed in the present study was applied to the classroom in order to find its impact on the student learning in the class. The grades obtained by these students in the module was used as the measure of student learning i.e. higher grades indicate likely better learning and vice versa (confirmed by triangulating with other evidence from observations, engagement data and interviews). The TPACK was delivered through lectures as well as made available online through the online student learning rooms. The online learning resource made available to the students was divided into 38 files (see Figure 5.16). The number of files visited by the student was recorded and percentage determined. Similarly the lecture/lab attendance was also recorded as shown in Table 5.21.

Table 5.21 number of viewing the online material and Lecture/lab attendance ration

Student	**visits to the online learning rooms**	**Lecture/lab attendance**
A	33/38	100%
B	33/38	90%
C	24/38	100%
D	31/38	100%
E	25/38	100%
F	38/38	70%

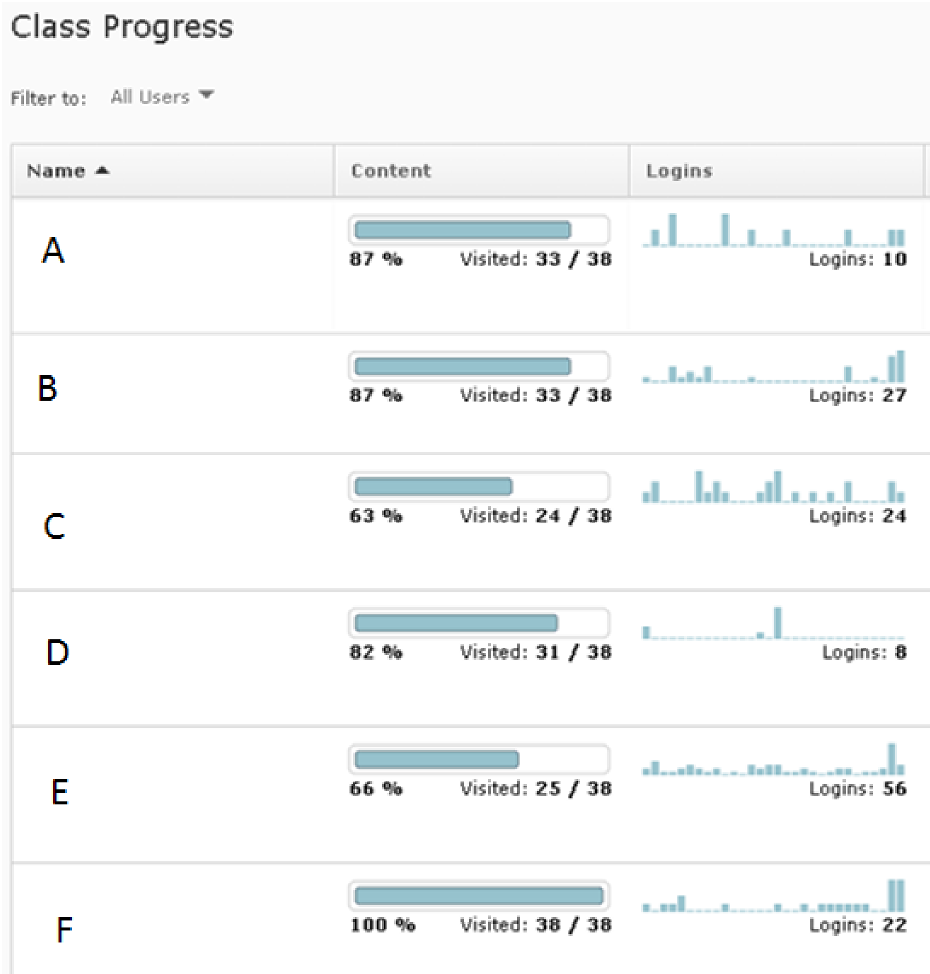


Figure 5.16 Student progress in Digital Control module 2014/2015

The impact of TPACK/AJ on the overall learning capability was assessed by comparing the grades obtained by each student against the number of visits to the online learning rooms and attendance in the lectures. The results indicated that higher the number of visits to the learning rooms, the better the grades obtained by the student and vice versa. Similarly the higher the lecture attendance the better the grades obtained by the student as shown in Figure 5.17. Hence the two factors student visit to the online learning resource as well their attendance in the lecture were the key for their performance in the module taught using TPACK. An exceptional case was the student #E who visited the 100% of the online resource had lowest grades. However a number of other factors could affect the results produced by this student. It must be considered that the student # E had poor lecture attendance. Another factor could be that student only accessed the online resource files but did not read them properly as the login record was also poor.

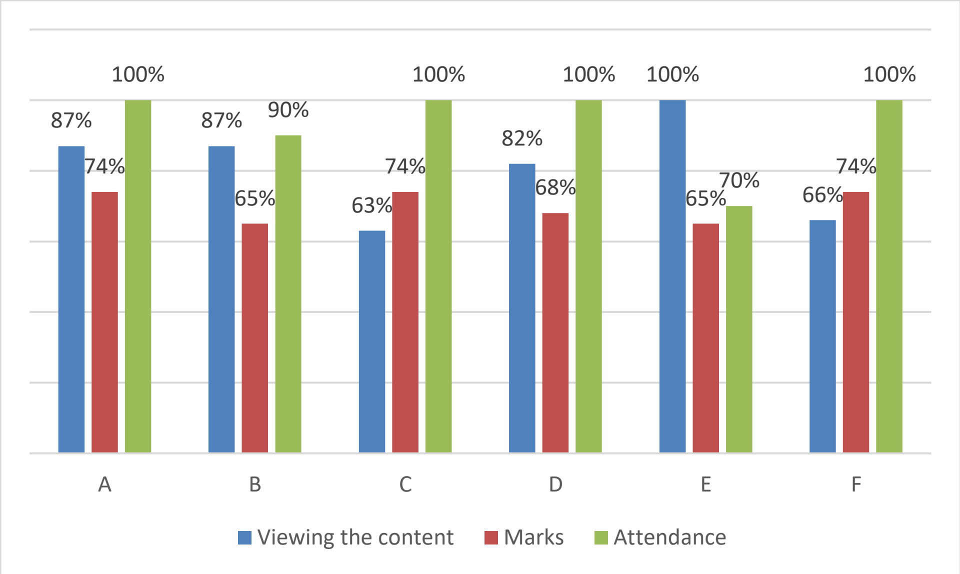


Figure 5.17 Students progress (Marks, attendance and viewing the online content)

5.6.5 Student feedback 2013/14

To evaluate our approach, we used interview research to obtain evidence. (This year EvaSys was not used, it started in the following year).

The students expressed that in the main areas of objectives methods and evaluation, the framework was successful, enjoyable and useful and the practical approach was supportive by refreshing the previous theoretical knowledge needed to build new knowledge. Regarding the theoretical and practical, we tried to support this by the real life examples. However one student feedback was, to improve clarity, it might be better to provide more explanation of all the systems used as examples rather than just the one that was used in the laboratory learning exercise; this could be easily be included in the module in future as additional information (not directly related to the practical work). They liked the mixed presentation of lectures/seminars/labs including PowerPoint, video clips and written illustrations on a whiteboard and practical examples on the IT tools. One of student said if we utilized more interaction in the lecture delivery within the practical examples on Agilent Vee Process Control software, by using video clips for example, this will hopefully reduce reliance on less than ideal program help files. Regarding the use of suitable technologies in Process Control engineering teaching, we are using MATLAB, Simulink and Agilent VEE as very powerful software tools in Process Control to simulate theory and design, to assist the development of practical control solutions. We incorporated some video material to improve the explanation of PID controllers by using Simulink and the PID tuning tool. A key benefit of using video as a saved resource provide students an opportunity to review and re-watch at any time, and they found as part of the total learning process this was useful and convenient to apply to the exercises. They also found the video material clear and interesting.

As an example of the approach we used, in one MATLAB laboratory exercise we first aimed to learn how MATLAB script can be produced to calculate some parameters. By this exercise we allowed them to practice reaching the skill of applying knowledge, as in Bloom's taxonomy categories (Krathwohl, 2002). In the second stage, they utilized an existing section of script which they needed to understand and adapt. From the first stage, the students were able to understand the difficulties in producing code for themselves (especially learning from mistakes) before they utilized code from others in the second stage. As a result, from the analysis of the interview feedback, most of the students considered that applying this type of approach is helpful and effective. There are some areas of feedback where we can improve.

One of the students said if we utilised more interaction in the lecture delivery within the practical examples on Agilent Vee Process Control software, by using video clips, for example, this will hopefully reduce reliance on less than ideal program help files.

5.6.6 Student feedback 2014/15

In this year, only 6 students studied Digital Control module. The feedback was collected by using EvaSys, including quantitative questions and open-ended questions, which we considered as qualitative data. In terms of student opinion about the teaching on this module, students expressed their satisfactions for example:

“ My professors are very good and supportive in teaching”

“ the teachers were very helpful”

In terms of the content and the examples: one student said that he liked the practical and real-time examples which helped him in understanding.

There were two practical suggestions for changes:

- “ the subject was interesting but it would become more interesting if some more practical example would be given instead of only software”. He asked to include hardware work in this module.
- “ practical work on some real physical system would help more to understand the subject and its importance”

Although mainly positive and high scoring the EvaSys evidence was not especially useful (aside from the last two points) so the main evidence for assessment of the utility of the AJ framework this year and the sub-domains was from interview, engagement data and observations.

5.6.7 Student feedback 2015/16

In this year 6 students attended this module as well.

The students liked the teaching strategies which were used in this module, and the value:

“ Explanation and precise” as one student said. Another student valued:

“ showing each step on computer, and the examples is very good for understanding” another said: “ the practical real time applications that are taught in this class”.

“ Presentations and real life examples given value a lot”.

In term of aspects could be improved: one student mentioned to the complicity of Simulink and he suggested to give more time for explaining.

Another said “More hours in lab helps us, I think”.

And another has got different opinion by saying “ nothing much”.

In addition, a comment by two students mentioned to the speed of MATLAB:

“MATLAB is working slowly” and “MATLAB was running very slow”

In terms of overall satisfaction: “Good explaining everything and understanding”

“ The software is useful for my career”

“ Good”, “ very interesting”

“ The things I like about this module is the software used to explain the module; MATLAB and Simulink”.

“the module is perfect for me no need to improve”

The new use of the software hub had led to some issues with slow operation of MATLAB but the tutor adapted delivery where possible to reduce the effects of this problem. Feedback was provide to the course team to consider placing MATLAB on individual PC’s.

Again although mainly positive and high scoring the Evasys evidence was not especially useful so the main evidence for assessment of the utility of the AJ framework this year and the sub-domains was also from interview, engagement data and observations.

Third implementation of the AJ framework (2015/16)

This 2015/16 academic year we had major problems at the start of the module due to students arriving three weeks late on a ten week delivery (due to visa issues) but these were surprisingly easily dealt with due to the teaching and learning strategies making the initial work so easy to pick up in some parallel-scheduled catch-up sessions. The results of the second assignment were slightly disappointing indicating some of the late arrival students had rather 'run out of steam', maybe partly due to the intense workload of catching up, but most achieved merit status in the module all the same and all indicated they thoroughly enjoyed the module in all aspects of the EvaSys feedback areas.

As previously, although very positive and high scoring the EvaSys evidence was not especially useful, so the main evidence for assessment of the utility of the AJ framework this year and the sub-domains was also from interview, engagement data and observations (for more details see extracts of Digital Control module leader semi-structured interview post AJ framework implementation, Appendix B, p. 231).

5.7 Critical analysis

5.7.1 Embedded Systems module

The AJ Framework covered teaching strategies, which in general improved the education process. As a good impact of lesson plan processing, 85% of students agreed that the tutor was well organised. However, the percentage of agreement in regards to sessions being well-structured was 62% of students. The reason for this as observed, is that there were some technical problems of interfacing the hardware with the compiler; this affected some students and caused a delay for them. In addition, the researcher did more investigations by observing student performance in the labs and they were not happy about the delay caused by this problem, which made them feel the lab session was not well-organised. However, the tutor responded quickly to resolve the issue by providing extra time and support and used a different software hosting the following year.

In terms of clarification of assessment criteria, the student agreement was positive. However, 19% of students' response were neither agree or disagree and around 14% of them disagreed. From the researcher's observation of student performance, it was noted that around 30% of students asked questions about assessment criteria; this was clarified in the class and it was detailed, and uploaded in learning room in the NOW system. It was clear that those students did not follow the tutor while he was explaining it and also did not read the assessment on NOW system nor did they spend enough time to read it. The researcher decided to investigate further. The system used in NTU is powerful in terms of using technology to monitor student engagement and using the material available on-line in module learning room (which is classified on AJ and TPACK frameworks as the TPK domain). The researcher checked individual student progress on the NOW system and found their progress was explained. Figure 5.16 and Figure 5.17 reflected this inference, for student # 45 and student # 20 respectively. The ratio of visiting the assessment criteria was 0% for Student # 45 and 33% for student # 20. As shown in Figure F.1 in Appendix D, which presents the relation between total mark and the average of attendance (Labs, lectures) in Appendix D, both of these students had lack of attendance which was around 26%, so they lost the face-to-face learning, and had weak usage of online materials on NOW learning room of this module. As a result of this low engagement, their mark was affected negatively. Also, the system showed some students accessed but did not read all resources. For example, from student observation the researcher noted student 40 # asked questions about the assessment criteria, and he mentioned some points were not clear. So the researcher checked his progress on the system and found that the student visited only 67% of coursework specification even after he submitted his coursework, as shown in Figure 5.18. We conclude from this that as student's learning styles are different, and some students are verbal learners, that made some students prefer to listen to the specification verbally from the tutor. Although, this student's engagement of using online materials was not high, however, he passed the module because he focused on face-to-face learning with around 90% attendance as Figure F.1 in Appendix D showed. This student was an example of other similar students who engaged well with the different approaches in the module to help students with different learning styles.

In general, there is a limitation in this approach to track student performance, especially where a student did not spend enough time on the system because they could download it once and work on their own computer/laptop without accessing the module learning room in university or at home.

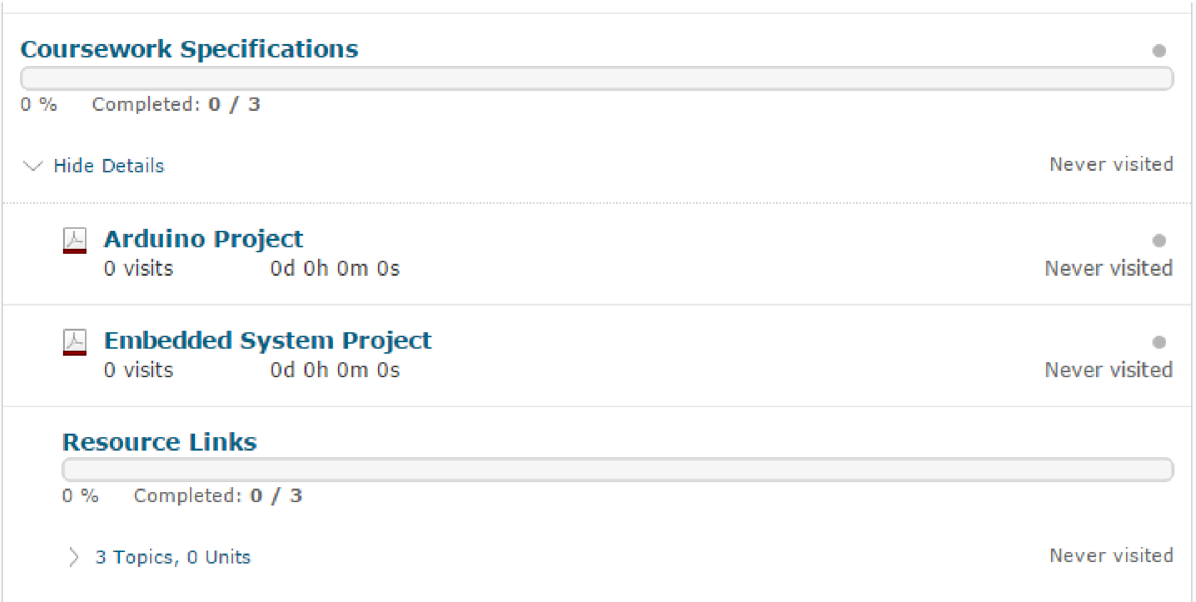


Figure 5.18 Visiting coursework specification of Student # 45

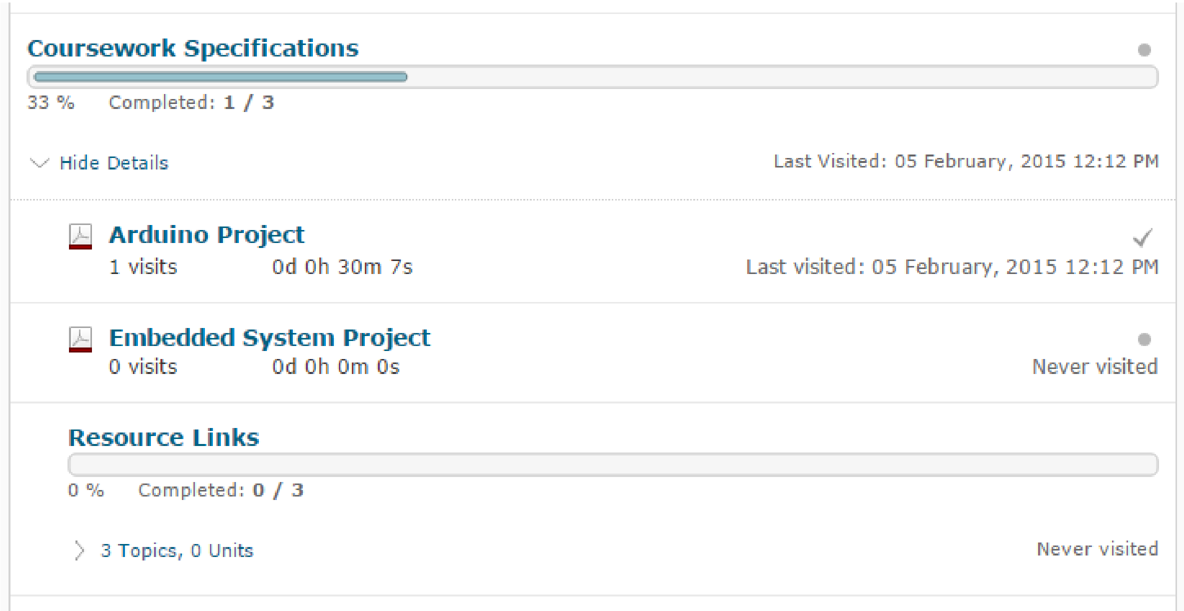


Figure 5.19 Visiting coursework specification of Student # 20.

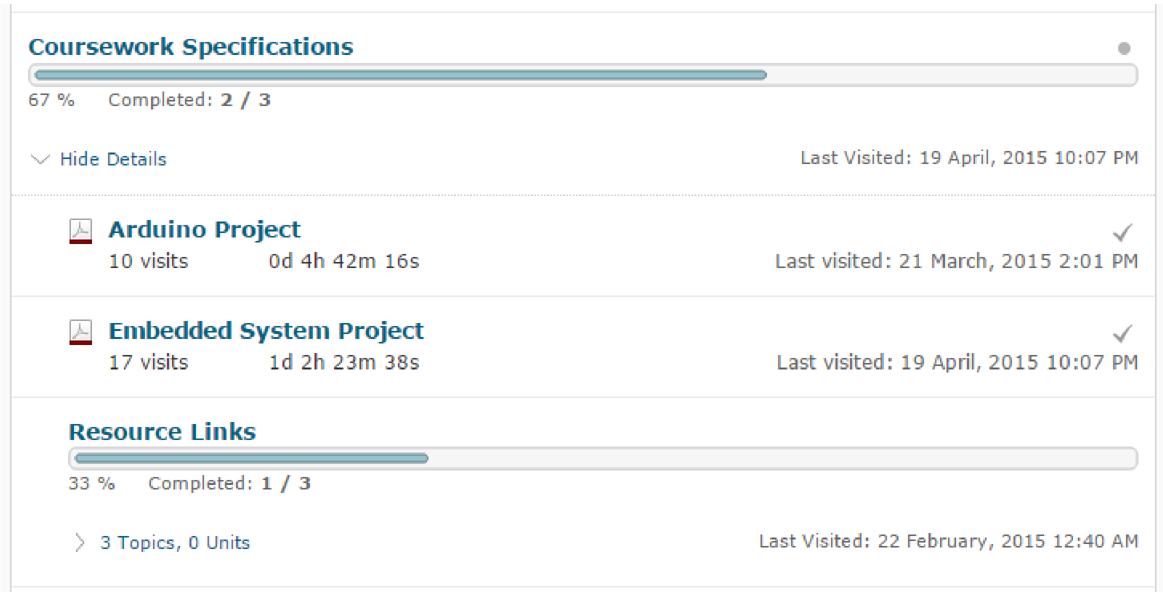


Figure 5.20 Visiting coursework specification of Student # 40

The lowest ratio of student agreement was about the school specific questions. Students can access the facilities and equipment when they need. From open ended questions some students mentioned that they were not happy that they did not get access to the equipment all the time. However, they got full access to the time of the labs and also there were surgery sessions; the strange point is few students turned up for these. This question is, if around 30% of the students disagreed, why did they not attend these extra sessions to get more time to use the equipment?

In terms of overall satisfaction, the ratio was 68.4% agreed. If we compare student overall results, we found 70% of students got 50% or more in their marks and 30% less than 50%. This gives an indication that the students may give feedback based on their marks and not based on the real teaching performance. Such student survey evidence always needs additional evidence to triangulate on the real success and real issues of a module. The module tutor confirmed this point in the semi-structured interview: that we need several sources of evidence to triangulate the valid data from student surveys (a common view of all tutors interviewed, in all roles of the course delivery and management).

The third aspect in student feedback was the module organisation and resources, it was all rated good. This is perhaps surprising at first sight considering the variable views on the module learning experience. However, this reflects the skills and efforts of the tutor within the AJ framework: how the module and practices were organised with technology and industrial needs. In addition, this reflects the quality followed in teaching and learning strategies, despite some students facing problems in labs in terms of interfacing hardware and software which caused delays at times. This incident affected negatively the percentage of students' agreement if the module was organised and ran smoothly, this got only 57.1%. In terms of online resources helping them and support their learning, the percentage was 68.2%, This can be compared with the student progress which was recorded on the NOW system, and the marks of those engaged using these resources. The student level of engagement was almost the same as the level of students satisfied and from observations and tutor interview evidence this was likely no coincidence: students who engaged with this well designed module appeared to be satisfied.

Finally, the marks of last year and this year were compared as shown in Table 5.2. It shows the comparison between the results of this year and previous year. The increasing ratio of students passing the module is significant, in a change from 65% to 82%. That shows the good impact on student performance of using the new module with clear evidence this was significantly influenced by use of the AJ framework. This improved performance occurred despite the problems of interfacing the software and hardware which some students faced and which affected the student feedback in EvaSys, as mentioned in sub-section 5.4.4.

5.7.2 Digital Control module

As presented in implementing the AJ Framework section, the positive student feedback about used teaching strategies and how they preferred the increased use of technology to illustrate real life scenarios and the improvement in terms of the content based on industrial needs and student feedback took place.

It presented the negative points of using technology, such as using software hub and how that affected the performance of the simulation was clear from the student feedback.

In the second implementation, the benefit was clear of using the online system to provide students back-up content if they missed the lecture/lab as in student #F, however, self-reading was not probably enough to replace the face-to-face teaching as this student got the lowest mark.

Some students suggested to have more hardware work in the Digital Control module which is really important, but the time is a big challenge, as the module is designed within the course to be an introductory module covered in 10 weeks, so it is not easy. Also, other modules cover some hardware and students learn in the next term more about building hardware projects.

5.7.3 Other aspects and general comments

The AJ Framework as a new framework covered teaching strategies which in general improve the education process and the industrial links to this. The AJ Framework formalised current practice and emphasised industrial links and careful use of technology. Given the complexity of teaching changes in a module from year to year, with a different group of students, to evaluate effectiveness requires triangulation of many forms of evidence: tutor observations, student observations, student feedback, student engagement and performance, the input of the module leader, course leader, quality manager and teaching and learning coordinator all in the context of the module circumstances, course material and the lesson planning. Evidence forms include, class observation notes, student quantitative and qualitative feedback, NOW and Dashboard evidence of performance and engagement, semi-structured interviews with academic staff, before and after module delivery. Gathering and critically analysing this evidence should provide an adequate measurement for the effectiveness of the framework. Also, subsequent iterations of the TPACK/AJ framework undertaken in the Digital Control module were made, consolidating evidence and analysis over several years.

The two modules already involved much good practice in linked pedagogy, technology and content with explicit industrial linkage. Despite this, improvements were demonstrated. In more traditionally designed STEM modules the AJ framework is likely to show much more significant benefits.

As module leader of the Digital Control commented when he asked about his view on the evidence sources for measuring the effectiveness of the implementation of the AJ framework in your module?

"The combination ('triangulation') of the evidence from interviews, observations, student feedback and engagement and performance data should give a more than adequate evidence base to measure the success (or otherwise) of the implementation. EvaSys is not always the best research evidence source to measure subtle responses to complex learning strategies but it has to be done as part of NTU module evaluation requirement and gives anonymised output which helps validate other forms of student feedback. Student evaluation questionnaires like EvaSys and the NSS has been critiqued by various researchers, including the Royal Statistical Society, for not showing any clear correlation with teaching quality, but in this research we use many sources of evidence".

The AJ Framework provided positive results when tested at NTU, therefore, it is worth wider investigation in the HE STEM field and to proceed to case studies in developing countries in order to study the implications there. Despite this, there are useful areas of further research identified into how we can apply this framework for improved teaching of control engineering and related subjects in developing countries (including Libya if the political situation improves).

There are more difficulties faced by the education systems in STEM subjects in some developing countries and often expensive overseas consultants are used to bridge this education gap. Dealing with this problem and the constant changing requirements of the professional workforce pose a huge challenge but hopefully work; like the AJ framework can help these countries develop in an improved direction: of building more local skilled STEM graduates and professionals through improved local HE and industrial training.

5.8 Summary

In this chapter, the implementation of the AJ Framework experiment with the BSc Embedded System module and the MSc Digital Control module were covered: beginning with a background of the module subject area, then the methodology used to implement the framework, after that, updating the content and developing teaching strategies and presenting the results of each evaluation approach and finally discussions were presented. In this chapter, we see the impact of implementing TPACK and the AJ Framework in these HE modules.

6. Chapter Six: Conclusion

6.1 Introduction

This chapter provides the conclusion based on the research findings, the main research contributions and the limitations leading to suggested areas of future work.

6.2 Main Research Contributions

This research is the first reported investigation into the use of TPACK for improving control engineering related subjects in HE. The main contributions listed as below, referring back to the five research questions numbers on page 4:

- Development of a tutor assessment instrument in TPACK for HE level and producing a validated and reliable English version, which answered research questions 1 and 2.
- Producing a validated and reliable Arabic version of a tutor assessment instrument in TPACK for the HE level, which answered research questions 1 and 2.
- Development of a CPD training model for HE, based on TPACK instrument results, which answered research questions 3.
- Development of a new teaching framework (The AJ Framework) and implementation in two modules, at BSc and MSc level, which answered research questions 4 and 5.

Hence, each of the questions have been answered.

The next subsections provide a summary of each contribution.

6.2.1 Development of a tutor assessment instrument in TPACK for HE level

The literature on TPACK is dominated by a focus on pre-university teachers (Chai et al., 2013; M. C. Herring et al., 2016). The review here led to the reasoning why TPACK could be useful in HE. This research inspects the validity and reliability of the TPACK framework using NTU as a case study of HE in the UK, through the developed instrument of self-assessment which measures tutors TPACK knowledge.

This research is the first on examining STEM tutor perceptions of their TPACK knowledge in HE (Chai et al., 2013) which included:

- A self-assessment instrument questionnaire was designed.
- Validity of the designed instrument was achieved: as experts reviewed the instrument; CVI, pilot study and factor analysis (PCA) was undertaken.
- Reliability of the designed instrument was achieved through Cronbach alpha, and test and retest achieved repeatability.

TPACK is obviously a helpful framework from an organisational perspective. (Mishra & Koehler, 2006) state “The TPCK framework, we argue, has given us a language to talk about the connections that are present (or absent) in conceptualizations of educational technology. In addition, our framework places this component, the relationship between content and technology, within a broader context of using technology for pedagogy.” (p. 1044). Despite this, the results of the PCA showed that it is hard to separate the domains. This result matches with earlier research (L. M. Archambault & Barnett, 2010, p.1656) “measuring each domain is complicated and convoluted, potentially due to the notion that they are not separate.”.

This study presented the most important component as Technology Integration, which gathers domains that include all the technology elements; this is in line with what Graham (2011) claimed (see section 4.6, p.68).

6.2.2 Producing a validated and reliable Arabic version of a tutor assessment instrument

Research on TPACK instruments has been dominated by the application in the English language, with some other languages used to a lesser extent, such as Turkish, and Korean (Karadag, 2016).

The literature on TPACK showed that “ There are no studies to date that have examined the validity and reliability of Arabic version of the TPACK self-report measure adapted from Schmidt et al. (2009)” (Khine, Ali, & Afari, 2016). This research was the first work applying the Arabic language in a TPACK HE self-assessment instrument, including the following:

- The research has produced the first translated version in the Arabic language of TPACK HE self-assessment instrument and validated the translation.
- Applied the Arabic version of TPACK HE to Arabic speakers.

6.2.3 Development of a CPD training model for HE based on TPACK instrument results

The instrument helps to assess tutors in-service and pre-service for CPD training programmes. This research proposes a training model within TPACK for tutors in HE (see Figure 4.4), based on factor analysis (PCA) results, which clarify the most appropriate path to follow in particular training courses, based on the real needs of the participant tutors.

The research responded to a knowledge gap: a need to investiagte TPACK constructs based on data driven research as recommended by Graham (2011).

This study presented how TPACK can be understood and gives suggestions to CPD trainers to follow gradual steps: starting with pedagogical knowledge and moving to PCK and after that moving to technology integration, the biggest component. The research suggests that using the instrument and checking the means of TPK and TCK (deciding which is higher) needs attention before completing the design of this final stage. Following the results from the collected data, the model would give positive results and optimise the structure and the timing of the training course, especially for the in-service tutor (those who need optimal use of their time and effectiveness of the training course).

The findings of this research were significant and based on strong theoretical concepts. In addition, the findings gave a clearer path to follow, comparing with (Chai et al., 2010) (see Appendix B).

This study recommends that training in TPACK would provide tutors with wider understand of technology-enhanced teaching and learning.

6.2.4 Development of a new teaching framework (The AJ Framework)

A novel framework (the AJ Framework) was developed to provide tutors with the suitable pedagogical knowledge to select appropriate technology and content. The target is to enhance student performance and achieve industrial needs.

Industry demands well-skilled university graduates in both subject areas; the science of computer and electrical engineering (Freudenberg & Krogh, 2005; Wu et al., 2015). The developed AJ Framework, that was built based on TPACK model, was used to evaluate this.

The AJ Framework has been implemented in two modules:

i. The Embedded Systems module, BSc level

The result of using the AJ Framework in terms of tutor and student performance was a clear improvement. Using industrially influenced PBL helped as a pedagogical approach offering better understanding for students in real life work issues and linked them to more practical work, which increases their employability chances because of the link to skills for industry. In addition, the modification in assessment was led by the AJ framework to improve the module within the constraints of the defined learning outcomes.

An improved average mark of the module and its feedback scores on EvaSys are good indications for the effectiveness of implementing the AJ Framework. The specifics within the feedback were triangulated with tutor interviews, observations, module engagement and performance data to ensure validity of improvements under the AJ framework.

This research shows a positive effect in terms of increased student attendance and engagement after implementing the AJ Framework. In general, attendance and engagement will have a good impact on students marks either with implementing the AJ Framework or without, but when the new laboratory coursework was added, attendance in students, moved from 76.64% before implementation to 80.28% after implementation.

The impact of implementing TPACK and the AJ Framework in the module was investigated. In addition, the weaknesses were addressed and implemented for the following year.

ii. Digital Control module MSc level

The result of using the AJ Framework in terms of tutor and student performance was an initial improvement when the Digital Control module was formed from the old Applied Industrial Process Control (AIPC) module then was improved slightly in subsequent years. Improving the industrially influenced PBL newly under the AJ framework helped as a pedagogical approach. In addition, the modifications in assignments was led by the AJ framework to improve the module within the constraints of the defined learning outcomes.

The students expressed that in the main areas of objectives, methods and evaluation, the framework was successful, enjoyable and useful, and the improved practical approach was supportive by refreshing the previous theoretical knowledge needed to build new knowledge. Regarding the mix of theoretical and practical content, we tried to improve this, following TPACK/AJ, by using more real life examples. Students liked the improved mixed presentation of lectures/seminars/labs including PowerPoint, video clips and written illustrations on a whiteboard and practical examples on the IT tools, there was an average higher marks after implementing TPACK/AJ in teaching strategies.

Student performance and feedback infer the positive effectiveness of implementing the AJ Framework, especially with the laboratory work, which increased an already high attendance ratio, and their feedback that the laboratory work which helps them to understand the module theory and improve their employability. The specifics within the feedback were triangulated with tutor interviews, observations, module engagement and performance data to ensure validity of improvements under the AJ framework.

6.3 Recommendations for Future Work based on Research Limitations

Within the light of some interesting contributions and findings, there is need to recognise that there are still limitations to the importance of this research.

While the findings of this research have helped providing some clarity of using the TPACK framework in HE, there is still considerable work to fully comprehend the framework's complexity in this educational environment. The following sub-sections cover the recommended work for future research.

6.3.1 More investigation on the English version tutor assessment instrument in TPACK for HE level

This study demonstrated the reliability and validity of the developed instrument of self-assessment to measure tutor TPACK knowledge. It also verified the suitability of use of the PCA technique for the data set. Nevertheless, the study also faced some limitations. Firstly, because the population of this study is only university tutors in SST at NTU, the collected responses were 57, and to perform PCA it is preferable to have 100 responses or more (Kamel, 2010). However, all requirements to perform PCA exceeded the acceptable values as demonstrated in the results section. Additionally, although the quantitative study is rich in data, it has drawbacks, as the nature of the survey is self-reported, instead of measuring behaviour by observation, which casts possible doubt on the accuracy. Furthermore, quantitative research is often flawed in terms of explaining the reasons for the variable relationships, although it does establish the clear relationship among variables (Barker, Pistrang, & Elliott, 2005). Thus, some qualitative research is needed to improve verification of the study.

An additional limitation in this phase is that the findings are based upon self-assessment measurements of tutor opinions based on research opinion (Rienties et al., 2013; Stes, Min-Leliveld, Gijbels, & Van Petegem, 2010).

As the developed instrument of the English version was tested with limited participants: one university (NTU) and although the sample size was acceptable it was slightly small. Therefore, to generalise the results there is a need to expand the target group and try to get a bigger sample size to include more participants for more statistical validity, increase confidence levels and decrease margins of errors. Hence, it may be worth confirming the findings with other universities including some from other countries.

In terms of pre-service tutors (PhD students who plan to teach in HE) we need to investigate participation in the instrument analysis of the data, and compare it with in-service tutors results.

6.3.2 More investigation on the Arabic version tutor assessment instrument in TPACK for HE level

Similarly, to the first stage of the English version, the validity and reliability of the Arabic version faced limited sample size of participants because of the current Libyan situation. This situation also meant it was not possible to carry out most of the intended case study work in the country.

Likewise, more investigation for the Arabic version is requested: to generalise the results it would be necessary to conduct the survey instrument with a greater number of tutors. Furthermore, the range of HEIs studied was limited. Only tutors of HEIs of one Libyan city study was conducted (Misurata HEIs).

6.3.3 Implementing of CPD training model for HE based on TPACK HE instrument results

Given the limited time of this research, the researcher did not get time to implement the proposed TPACK training model (see Figure 4.4) in a real training CPD course, by investigation of using the instrument for in-service and pre-service tutors in the university.

This research proposed and recommended a CPD training model based on strong theory and data driven research. Investigation of it would be necessary for this model to give empirical results for an in-service and pre-service tutor in the university. The model may help optimise the structure and the timing of the training course, especially for the in-service tutor (those needing the optimal use of their time and effectiveness of the training course).

Other future work, would be investigation of TPACK understanding in Libyan HE CPD (or equivalent), and use of the TPACK training model to develop in-service and pre-service tutors in professional development programmes.

6.3.4 Implementing the AJ Framework in teaching engineering modules

Within the implementation of the AJ Framework in real course teaching, we faced some limitations. Firstly, getting permission to implement the new framework in real teaching courses is a long procedure through the department, even when the module leaders agreed. However, we did get the chance to test the novel framework and implement the theoretical concepts of the AJ Framework in a real course.

Secondly, the sample size is considered as a major issue in implementation as mentioned in instrument assessment (see Sub-section 3.7.7). In this case, the researcher had no control over the number of students, as he dealt with the available number. In the three cases of implementing the framework in the Digital Control module, the total number was less than 10 in each year, which is statistically insignificant; however, good qualitative data was collected.

The researcher cannot force students to participate in giving feedback and filling in the EvaSys questionnaire instrument. As happened in the Embedded Systems case, the percentage sample of the population was about 45% (as was calculated in Sub-section 3.7.7). Although only 40% off students agreed to give feedback, this ratio is not too bad comparing with other related publications (Watt et al., 2002).

The empirical implementation took place over three years with the Digital Control module but only with a limited number of students. Thus, continued testing the AJ Framework may be worth for confirming the implications.

In terms of the Embedded System Module, the empirical implementation was over one year. It would be necessary to retest the AJ Framework in this module to refine the results.

6.3.5 Implementing the AJ Framework in teaching engineering modules in developing countries

The war and unsuitable political situation in Libya (as the proposal developing country case study) prevented implementing the AJ Framework in a real course in Libya to test its effectiveness on HE in a developing country.

There are more difficulties faced by the education systems in subjects of automatic control, engineering and applied sciences in some developing countries as consulting overseas consultants can cost huge money. Dealing with this problem and the constant changing requirements of the workforce pose a huge challenge. To deal with this problem the technology, education and training centres have to react as efficiently as possible to the ever-evolving skill requirements in the industry (Jwaid A.E et al., 2014). This is especially important for developing countries in order to fill the skill gap with the industrialised world (Kheir et al., 1996).

The AJ Framework provided positive results when tested at NTU, therefore, it is worth investigation in developing countries to study the implications.

Further research is required into how we can apply this framework for improved teaching of the control engineering and related subjects in developing countries. The case study for the next stage of the research was Libya, where many factories, oil fields and other service agencies, such as airports or ports, need qualified control engineers to solve their problems. To train them, suitable equipment and facilities are needed (Jwaid A.E et al., 2014). All of these currently have high costs, because they often need a high level of expertise and expensive training of hardware and software, mainly imported from overseas (Abrahamson, 2004).

The motivated initial results of this new framework, and the urgent insisting need, in the case of a developing country to have such a useful framework to speed up the improvement which would benefit all the country, individuals, HE, industrial sector, and the economics of the whole country is a crucial factor to improve HE in these countries.

We recommend that testing and implementation take place once the situation has improved in Libya, and to try to get access to any other developing countries.

6.4 Other Recommendation for Future Work

This research opens the door for testing the TPACK framework in HE. Thus, there are other recommendations as below:

6.4.1 More investigation on student learning styles and links with the AJ Framework

As TPACK is used to integrate the appropriate technology, pedagogy and content, an investigation of student learning styles could be usefully linked to TPACK concepts.

6.4.2 The TPACK and AJ Framework in HE STEM teaching

It is possible to increase the benefit of student feedback and make it more accurate by linking it with the student performance, which is monitored at NTU through ‘The Students Dashboard’ by integrating it with EvaSys results in NOW system. As shown in this study in Chapter 5, some students give negative feedback based on their marks, and not reflecting the actual tutor performance. This is a well-known problem with using evaluation questionnaires (Stehle, Spinath, & Kadmon, 2012; Zabaleta, 2007). Moreover, this conclusion reported recently by The Royal Statistical Society (RSS) regarding the use of The National Student Survey (NSS) and Teaching Excellence Framework (TEF) (RSS, 2016).

6.5 Final conclusions

In this research, a guide for the process of formatting and adapting control related engineering teaching in HE was based on the TPACK framework. After reviewing the literature, the procedure of the study started with developing a new TPACK instrument for HE, which included an industrial ‘needs’ factor. After data collection and analysis, a novel framework (the AJ Framework) was built and was tested on two modules.

The most significant result of this research is the validity of the TPACK framework in HE for control engineering teaching. Another key development is investigating a new pedagogical framework (the AJ Framework) for teaching and learning in HE and its confirmed effectiveness at BSc and MSc levels.

Both modules, the Digital Control and Embedded Systems modules, already followed good teaching practice before implementing the framework. However, the study gave them a more formalised TPACK framework and linked them more clearly to industrial needs.

Student performance and feedback reflect the positive effectiveness of implementing the AJ Framework, especially with the laboratory work as it increased the attendance ratio. The student feedback was that the laboratory work helped them to understand the module theory and they felt would help them in their jobs in future.

The validity and reliability of self-assessment TPACK HE have been demonstrated in an English and an Arabic version.

Finally, the research proposes a training model within TPACK for tutors in HE, based on factor analysis (PCA) results, in which the researcher determine the most appropriate path to follow in particular training courses based on the real needs of the participant tutors.

There are obviously further possibilities for research in applying the TPACK HE self-assessment instrument to other groups of English and Arabic speakers. There is the need to investigate the AJ framework again with the same modules and other modules in STEM subject areas.

References

References

Abdulwahed, M., & Nagy, Z. K. (2012). A control systems engineering approach to designing an effective lecturing model: The implication of feedback and self-construction of knowledge. *Innovations,* , 29-48.

Abod-her, S. (2013). Impacts of globalisation and awareness of higher education policy in adoption and use of ICT in libyan universities.

Abrahamson, M. (2004). *Global cities* Oxford University Press New York, NY.

Akkoç, H. (2011). Investigating the development of prospective mathematics teachers' technological pedagogical content knowledge. *Research in Mathematics Education, 13*(1), 75-76.

Aljojo, N. M. (2012). Teacher assisting and subject adaptive material system: An arabic adaptive learning environment.

Almås, A. G., & Krumsvik, R. (2008). Teaching in technology-rich classrooms: Is there a gap between teachers' intentions and ICT practices? *Research in Comparative and International Education, 3*(2), 103-121.

Alzain, A. M., Clark, S., & Ireson, G. (2014). Libyan higher education system, challenges and achievements. *Engineering Education (ICEED), 2014 IEEE 6th Conference On,* 67-72.

An, H., & Shin, S. (2010). The impact of urban district field experiences on four elementary preservice teacher's learning regarding technology integration. *J.Technol.Integration in the Classroom, 2*(3), 101-107.

Andrew, F. (2013). UK skills gap in STEM subjects. Retrieved from https://yougov.co.uk/news/2013/10/11/uk-skills-gap-stem-subject/

Angeli, C., & Valanides, N. (2005). Preservice elementary teachers as information and communication technology designers: An instructional systems design model based on an expanded view of pedagogical content knowledge. *Journal of Computer Assisted Learning, 21*(4), 292-302.

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education, 52*(1), 154-168.

Antonius, R. (2003). *Interpreting quantitative data with SPSS* Sage.

Appiah, K. (2015). *Embedded systems module leader, private communications*

Archambault, L. M., & Barnett, J. H. (2010). Revisiting technological pedagogical content knowledge: Exploring the TPACK framework. *Computers & Education, 55*(4), 1656-1662.

Archambault, L., & Crippen, K. (2009). Examining TPACK among K-12 online distance educators in the united states. *Contemporary Issues in Technology and Teacher Education, 9*(1), 71-88.

Archambault, L., Wetzel, K., Foulger, T. S., & Kim Williams, M. (2010). Professional development 2.0: Transforming teacher education pedagogy with 21st century tools. *Journal of Digital Learning in Teacher Education, 27*(1), 4-11.

Ashe, D., & Bibi, S. (2011). Unpacking TPACK and students' approaches to learning: Applying knowledge in pieces to higher education teaching and learning. *Ascilite,* 128-132.

Åström, K. J. (2012). Accomplishments and prospects of control, american control conference plenary lecture. Retrieved from http://www.ieeecss-oll.org/lecture/accomplishments-and-prospects-control

Atherton J S. (2013). *Learning and teaching; Forms of assessment* [on-line: UK]

. Retrieved from http://doceo.co.uk/l&t/teaching/assessment_unseen.htm

Ay, Y., Karadağ, E., & Acat, M. B. (2015). The technological pedagogical content knowledge-practical (TPACK-practical) model: Examination of its validity in the turkish culture via structural equation modeling. *Computers & Education, 88*, 97-108.

Balogh, R. (2010). Educational robotic platform based on arduino. *Proceedings of the 1st International Conference on Robotics in Education, RiE2010. FEI STU, Slovakia,* 119-122.

Banas, J. R. (2010). Teachers' attitudes toward technology: Considerations for designing preservice and practicing teacher instruction. *Community & Junior College Libraries, 16*(2), 114-127.

Barker, C., Pistrang, N., & Elliott, R. (2005). Self-Report methods. *Research Methods in Clinical Psychology: An Introduction for Students and Practitioners, Second Edition,* , 94-118.

Bartlett, M. S. (1954). A note on the multiplying factors for various χ 2 approximations. *Journal of the Royal Statistical Society.Series B (Methodological),* , 296-298.

Bekirogullari, Z., Minas, M. Y., Montrieux, H., Vanderlinde, R., Courtois, C., Schellens, T., & De Marez, L. (2014). International conference on education & educational psychology 2013 (ICEEPSY 2013) A qualitative study about the implementation of tablet computers in secondary education: The teachers' role in this process. *Procedia - Social and Behavioral Sciences, 112*, 481-488. doi:http://dx.doi.org/10.1016/j.sbspro.2014.01.1192

Bencomo, S. D. (2004). Control learning: Present and future. *Annual Reviews in Control, 28*(1), 115-136. doi:10.1016/j.arcontrol.2003.12.002

Bequette, B. W. (2003). *Process control: Modeling, design, and simulation* Prentice Hall Professional.

Biesta, G. (2012). Combining methodologies: Mixed methods. *Research Methods and Methodologies in Education.,* , 147-152.

Black, T. R. (1999). *Doing quantitative research in the social sciences: An integrated approach to research design, measurement and statistics* Sage.

Boschman, F., McKenney, S., & Voogt, J. (2015). Exploring teachers' use of TPACK in design talk: The collaborative design of technology-rich early literacy activities. *Computers & Education, 82*, 250-262. doi:http://dx.doi.org/10.1016/j.compedu.2014.11.010

Bowers, J. S., & Stephens, B. (2011). Using technology to explore mathematical relationships: A framework for orienting mathematics courses for prospective teachers. *Journal of Mathematics Teacher Education, 14*(4), 285-304.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101.

British Computer Society. (2016). Academic accreditation. Retrieved from http://www.bcs.org/category/5844

Brooks, R., Te Riele, K., & Maguire, M. (2014). *Ethics and education research* Sage.

Bryman, A. (2012). *Social research methods* Oxford university press.

Buechley, L., Eisenberg, M., Catchen, J., & Crockett, A. (2008). The LilyPad arduino: Using computational textiles to investigate engagement, aesthetics, and diversity in computer science education. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems,* 423-432.

Campbell, J., & Oblinger, D. (2007). Top-ten teaching and learning issues. Retrieved from http://er.educause.edu/articles/2007/7/topten-teaching-and-learning-issues-2007

Campbell, M. J., & Swinscow, T. D. V. (2011). *Statistics at square one* John Wiley & Sons.

Candelas, F., García, G., Puente, S., Pomares, J., Jara, C., Pérez, J., . . . Torres, F. (2015). Experiences on using arduino for laboratory experiments of automatic control and robotics. *IFAC-PapersOnLine, 48*(29), 105-110.

Cavanagh, R. F., & Koehler, M. J. (2013). A turn toward specifying validity criteria in the measurement of technological pedagogical content knowledge (TPACK). *Journal of Research on Technology in Education, 46*(2), 129-148.

Chai, C. S., Koh, J. H. L., & Tsai, C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). *Educational Technology & Society, 13*(4), 63-73.

Chai, C. S., Koh, J. H. L., & Tsai, C. (2013). A review of technological pedagogical content knowledge. *Educational Technology & Society, 16*(2), 31-51.

Chai, C. S., Lim, C. P., & Tan, C. M. (2016). Introduction: Cocreating technological pedagogical content knowledge (TPACK) for the transformation of nan chiau primary school. *Future learning in primary schools* (pp. 1-7) Springer.

Chalmers, D., & Fuller, R. (2012). *Teaching for learning at university* Routledge.

Cheng, S. (2013). Computer-aided control systems design: Practical applications using MATLAB R and simulink R.

Cheon, J., Lee, S., Crooks, S. M., & Song, J. (2012). An investigation of mobile learning readiness in higher education based on the theory of planned behavior. *Computers & Education, 59*(3), 1054-1064.

Chin, J., & Callaghan, V. (2013). Educational living labs: A novel internet-of-things based approach to teaching and research. *Intelligent Environments (IE), 2013 9th International Conference On,* 92-99.

Churches, A. (2008). Bloom's taxonomy blooms digitally. *Tech & Learning, 1*, 1-6.

Clark, L. A., & Watson, D. (1995). Constructing validity: Basic issues in objective scale development. *Psychological Assessment, 7*(3), 309.

Clark, R. C., & Mayer, R. E. (2011). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning* Pfeiffer.

Clark, R. C., & Mayer, R. E. (2016). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning* John Wiley & Sons.

Clark, S. (2016). *Digital control module leader, private communications*

Clark, V. P., & Creswell, J. W. (2011). Designing and conducting mixed methods research. *Vol, 3*, 93-94.

Cohen, L. M., & Manion, L. (2011). L. & morrison, K.(2011) research methods in education.

Cohen, L., Manion, L., & Morrison, K. (2013). *Research methods in education* Routledge.

Collins, J. W., & O'Brien, N. P. (2011). *The greenwood dictionary of education* ABC-CLIO.

Cook, J. A., & Samad, T. (2009). Controls curriculum survey. A CSS outreach task force report. *IEEE Control Systems Society,*

Cox, S. M. (2008). A conceptual analysis of technological pedagogical content knowledge.

Cox, S., & Graham, C. R. (2009). Using an elaborated model of the TPACK framework to analyze and depict teacher knowledge. *TechTrends, 53*(5), 61.

Credé, M., Roch, S. G., & Kieszczynka, U. M. (2010). Class attendance in college a meta-analytic review of the relationship of class attendance with grades and student characteristics. *Review of Educational Research, 80*(2), 272-295.

Creswell, J. W. (Ed.). (2015). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* . Pearson Education, Limited:

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.) Sage publications.

Crotty, M. (2012). The foundations of social research: Meaning and perspective in the research process. 1998. *Australia: Allen&Unwin,*

Cunningham, D., & Duffy, T. (1996). Constructivism: Implications for the design and delivery of instruction. *Handbook of Research for Educational Communications and Technology,* , 170-198.

Cynthia D'Angelo, Stephanie Touchman, Douglas Clark, Angela O'Donnell, Richard Mayer, David Dean, J. & Cindy Hmelo-Silver. (2009). *Constructivism*. Retrieved from http://www.education.com/reference/article/constructivism/

Danielson, C. (2013). The framework for teaching. *Evaluation Instrument.the Danielson Group,*

Davis Jr, F. D. (1986). A technology acceptance model for empirically testing new end-user information systems: Theory and results.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35*(8), 982-1003.

D'Cruz, H., & Jones, M. (2013). *Social work research in practice: Ethical and political contexts* Sage.

Denscombe, M. (2014). *The good research guide: For small-scale social research projects* McGraw-Hill Education (UK).

Doering, A., & Veletsianos, G. (2008). An investigation of the use of real-time, authentic geospatial data in the K–12 classroom. *Journal of Geography, 106*(6), 217-225.

Doering, A., Veletsianos, G., Scharber, C., & Miller, C. (2009). Using the technological, pedagogical, and content knowledge framework to design online learning environments and professional development. *Journal of Educational Computing Research, 41*(3), 319-346.

Doukakis, S., Psaltidou, A., Stavraki, A., Adamopoulos, N., Tsiotakis, P., & Stergou, S. (2010). Measuring the technological pedagogical content knowledge (TPACK) of in-service teachers of computer science who teach algorithms and programming in upper secondary education. *Readings in Technology and Education: Proceedings of ICICTE,* , 442-452.

Dunteman, G. H. (1989). *Principal components analysis* Sage.

Durant, E., Impagliazzo, J., Conry, S., Reese, R., Thornton, M., Lam, H., & Nelson, V. (2014). Setting the stage for CE2016: A revised body of knowledge. *Frontiers in Education Conference (FIE), 2014 IEEE,* 1-4.

Ebert, C., & Jones, C. (2009). Embedded software: Facts, figures, and future. *Computer,* (4), 42-52.

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research and Development, 53*(4), 25-39.

Ertmer, P. A., & Ottenbreit-Leftwich, A. (2013). Removing obstacles to the pedagogical changes required by jonassen's vision of authentic technology-enabled learning. *Computers & Education, 64*, 175-182.

Falchikov, N., & Goldfinch, J. (2000). Student peer assessment in higher education: A meta-analysis comparing peer and teacher marks. *Review of Educational Research, 70*(3), 287-322.

Field, R. M., Duffy, J., & Huggins, A. (2014). Independent learning skills, self-determination theory and psychological well-being: Strategies for supporting the first year university experience.

Florida Center for Instructional Technology,. (2011). Technology integration matrix. Retrieved from http://fcit.usf.edu/matrix/

Fox, R. (2002). Digital culture and educational practice. *2nd International Conference on "Knowledge and Discourse: Speculating on Disciplinary Futures", Hong Kong, June,* 25-29.

Frank, M., Lavy, I., & Elata, D. (2003). Implementing the project-based learning approach in an academic engineering course. *International Journal of Technology and Design Education, 13*(3), 273-288.

Franks, D. (2016). *Humour greatest quotes-quick, short, medium or long quotes. find the perfect humour quotations for all occasions-spicing up letters, speeches, and everyday conversations.* Emereo Publishing.

Freudenberg, J., & Krogh, B. (2005). Industry needs for embedded control education. *American Control Conference, 2005. Proceedings of the 2005,* 4543-4550.

Garrett, K. N. (2014). A quantitative study of higher education faculty self-assessments of technological, pedagogical, and content knowledge (TPaCK) and technology training.

Goddard, W., & Melville, S. (2004). *Research methodology: An introduction* Juta and Company Ltd.

Govindasamy, T. (2001). Successful implementation of e-learning: Pedagogical considerations. *The Internet and Higher Education, 4*(3), 287-299.

Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education, 57*(3), 1953-1960.

Graham, C. R., Allen, S., & Ure, D. (2005). Benefits and challenges of blended learning environments. *Benefits and Challenges of Blended Learning Environments.,*

Graham, C. R., Borup, J., & Smith, N. B. (2012). Using TPACK as a framework to understand teacher candidates' technology integration decisions. *Journal of Computer Assisted Learning, 28*(6), 530-546.

Green, A. M. (1998). Project-based learning: Moving students through the GED with meaningful learning.

Greenhow, C., Dexter, S., & Hughes, J. E. (2008). Teacher knowledge about technology integration: An examination of inservice and preservice teachers' instructional decision-making. *Science Education International, 19*(1), 9-25.

Groth, R., Spickler, D., Bergner, J., & Bardzell, M. (2009). A qualitative approach to assessing technological pedagogical content knowledge. *Contemporary Issues in Technology and Teacher Education, 9*(4), 392-411.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2006). *Multivariate data analysis* Pearson Prentice Hall Upper Saddle River, NJ.

Hamilton, L., & Corbett-Whittier, C. (2012). *Using case study in education research* Sage.

Hammond, T., & Manfra, M. (2009). Digital history with student-created multimedia: Understanding student perceptions. *Social Studies Research & Practice, 4*(3), 139-150.

Hammond, T. C., & Manfra, M. M. (2009). Giving, prompting, making: Aligning technology and pedagogy within TPACK for social studies instruction. *Contemporary Issues in Technology and Teacher Education, 9*(2), 160-185.

Harris, J., & Hofer, M. (2009). Instructional planning activity types as vehicles for curriculum-based TPACK development. *Society for Information Technology & Teacher Education International Conference, , 2009*(1) 4087-4095.

Harris, J. B., & Hofer, M. J. (2011). Technological pedagogical content knowledge (TPACK) in action: A descriptive study of secondary teachers’ curriculum-based, technology-related instructional planning. *Journal of Research on Technology in Education, 43*(3), 211-229.

Harris, J., Hofer, M., Blanchard, M., Grandgenett, N., Schmidt, D., Van Olphen, M., & Young, C. (2010). “Grounded” technology integration: Instructional planning using curriculum-based activity type taxonomies. *Journal of Technology and Teacher Education, 18*(4), 573-605.

Harris, J., Mishra, P., & Koehler, M. (2009). Teachers’ technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education, 41*(4), 393-416.

Hartas, D. (2015). *Educational research and inquiry: Qualitative and quantitative approaches* Bloomsbury Publishing.

HEA. (2014). Independent learning. Retrieved from https://www.heacademy.ac.uk/system/files/resources/independent_learning.pdf

Herring, M. C., Meacham, S., & Mourlam, D. (2016). TPACK development in higher education. *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators,* , 207.

Herring, M., Mishra, P., & Koehler, M. (2014). *Handbook of technological pedagogical content knowledge (TPCK) for educators* Routledge.

Hodges, C. B. (2016). Stakeholder-identified barriers to computer science education in rural schools.

Hofer, M., & Swan, K. O. (2008). Technological pedagogical content knowledge in action: A case study of a middle school digital documentary project. *Journal of Research on Technology in Education, 41*(2), 179-200.

Huffman, A. H., Whetten, J., & Huffman, W. H. (2013). Using technology in higher education: The influence of gender roles on technology self-efficacy. *Computers in Human Behavior, 29*(4), 1779-1786.

Jamieson, P. (2010). Arduino for teaching embedded systems. are computer scientists and engineering educators missing the boat? *Proc.FECS,* , 289-294.

Jamieson, P., & Herdtner, J. (2015). More missing the Boat—Arduino, raspberry pi, and small prototyping boards and engineering education needs them. *Frontiers in Education Conference (FIE), 2015. 32614 2015. IEEE,* 1-6.

Janssen, N., & Lazonder, A. W. (2016). Support for technology integration. *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators,* , 119.

Jazayeri, M. (2004). The education of a software engineer. *Proceedings of the 19th IEEE International Conference on Automated Software Engineering,* . 18-xxvii.

Johnson, J. (2016). Experts call for employers and universities to do more to address STEM skills shortages - press releases - GOV.UK . Retrieved from https://www.gov.uk/government/news/experts-call-for-employers-and-universities-to-do-more-to-address-stem-skills-shortages

Jwaid A.E, Clark S, & Ireson G. (2014). Understanding best practices in control engineering education using the concept of TPACK. *IEEE Integrated STEM Education Conference,* Princeton University, USA.

Kafyulilo, A. (2012). *TPACK for pre-service science and mathematics teachers* GRIN Verlag.

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika, 39*(1), 31-36.

Kamel, S. (2010). *E-strategies for technological diffusion and adoption: National ICT approaches for socioeconomic development: National ICT approaches for socioeconomic development* IGI Global.

Karadag, N. (2016). Book review technology integration and high possibility classrooms: Building from tpack. *Turkish Online Journal of Distance Education,*

Keengwe, J. (2014). *Advancing higher education with mobile learning technologies: Cases, trends, and inquiry-based methods: Cases, trends, and inquiry-based methods* IGI Global.

Kervin, L. (2006). *Research for educators* Cengage Learning Australia.

Khan, S. (2011). New pedagogies on teaching science with computer simulations. *Journal of Science Education and Technology, 20*(3), 215-232.

Kheir, N., Åström, K. J., Auslander, D., Cheok, K. C., Franklin, G. F., Masten, M., & Rabins, M. (1996). Control systems engineering education. *Automatica, 32*(2), 147-166.

Khine, M. S., Ali, N., & Afari, E. (2016). Exploring relationships among TPACK constructs and ICT achievement among trainee teachers. *Education and Information Technologies,* , 1-17.

Kisanga, D. H. (2015). Investigation of attitudinal factors towards the transition from face-to-face e-learning in tanzanian higher learning institutions: A mixed methods approach.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education, 9*(1), 60-70.

Koehler, M. J., & Mishra, P. (2005). What happens when teachers design educational technology? the development of technological pedagogical content knowledge. *Journal of Educational Computing Research, 32*(2), 131-152.

Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2014). The technological pedagogical content knowledge framework. *Handbook of research on educational communications and technology* (pp. 101-111) Springer.

Koh, J. H. L., & Chai, C. S. (2014). Teacher clusters and their perceptions of technological pedagogical content knowledge (TPACK) development through ICT lesson design. *Computers & Education, 70*, 222-232.

Kopcha, T. J., Ottenbreit-Leftwich, A., Jung, J., & Baser, D. (2014). Examining the TPACK framework through the convergent and discriminant validity of two measures. *Computers & Education, 78*, 87-96. doi:http://dx.doi.org/10.1016/j.compedu.2014.05.003

Kortuem, G., Bandara, A. K., Smith, N., Richards, M., & Petre, M. (2013). Educating the internet-of-things generation. *Computer, 46*(2), 53-61.

Kovalchick, A., & Dawson, K. (2004). *Education and technology: An encyclopedia* Abc-clio.

Krathwohl, D. R. (2002). A revision of bloom's taxonomy: An overview. *Theory into Practice, 41*(4), 212-218.

Kruger, M., & Bester, R. (2014). Mobile learning: A kaleidoscope. *Electronic Journal of E-Learning, 12*(1), 52-76.

Kuan, W., Tseng, C., Chen, S., & Wong, C. (2016). Development of a computer-assisted instrumentation curriculum for physics students: Using LabVIEW and arduino platform. *Journal of Science Education and Technology,* , 1-12.

Kumar, R. (Ed.). (2014). *Research Methodology A step-by-step guide for beginners*. London: SAGE Publications Ltd.:

Laborda, J. G., Ozdamli, F., Maasoglu, Y., Saengbanchong, V., Wiratchai, N., & Bowarnkitiwong, S. (2014). 5th world conference on educational sciences validating the technological pedagogical content knowledge appropriate for instructing students (TPACK-S) of pre-service teachers. *Procedia - Social and Behavioral Sciences, 116*, 524-530. doi:http://dx.doi.org/10.1016/j.sbspro.2014.01.252

Lackey, A. D. (2008). *The development of an instrument to determine the relevance and validity of the educational leadership constituent council (ELCC) standards for advanced programs in educational leadership* ProQuest.

LeBlanc, D. C. (2004). *Statistics: Concepts and applications for science* Jones & Bartlett Learning.

Leonard, K., Noh, E. K., & Orey, M. (2007). Introduction to emerging perspectives on learning, teaching, and technology. *Emerging Perspectives on Learning, Teaching, and Technology.[Documento En Línea] Http://Projects.Coe.Uga.Edu/Epltt/[Consultado El 1 De Mayo De 2008],*

Lilja, R., Ollikainen, T., & Laakso, P. (2003). Self-access studying environment for control engineering education. *The 6th IFAC Symposium on Advances in Control Education (ACE 2003), 16œ18 June,*

Ling Koh, J. H., Chai, C. S., & Tay, L. Y. (2014). TPACK-in-action: Unpacking the contextual influences of teachers' construction of technological pedagogical content knowledge (TPACK). *Computers & Education, 78*, 20-29. doi:http://dx.doi.org/10.1016/j.compedu.2014.04.022

Lodico, M. G., Spaulding, D. T., & Voegtle, K. H. (2010). *Methods in educational research: From theory to practice* John Wiley & Sons.

Lye, L. T. (2013). Opportunities and challenges faced by private higher education institution using the TPACK model in malaysia. *Procedia-Social and Behavioral Sciences, 91*, 294-305.

Ma, K., Ma, Y., Wang, Y., Qian, K., Zheng, Q., & Hong, L. (2015). Innovative mobile tool for engineering embedded design and security educations. *Frontiers in Education Conference (FIE), 2015. 32614 2015. IEEE,* 1-4.

Management Association. (2013). *K-12 education: Concepts, methodologies, tools, and applications: Concepts, methodologies, tools, and applications* IGI Global.

Manfra, M. M., & Hammond, T. C. (2008). Teachers' instructional choices with student-created digital documentaries: Case studies. *Journal of Research on Technology in Education, 41*(2), 223-245.

Marlow, C. (2010). *Research methods for generalist social work* Cengage Learning.

Marwedel, P. (2011). Embedded system foundations of cyber-physical systems.

Mathworks,. (2013). New report by MathWorks shows universities and industry united on extent of UK STEM skills gap. Retrieved from http://uk.mathworks.com/company/newsroom/new-report-by-mathworks-shows-universities-and-industry-united-on-extent-of-uk-stem-skills-gap.html?s_tid=gn_loc_drop&requestedDomain=uk.mathworks.com

Méndez, J. A., & González, E. J. (2010). A reactive blended learning proposal for an introductory control engineering course. *Computers & Education, 54*(4), 856-865.

Merrill, M. D., Drake, L., Lacy, M. J., Pratt, J., & ID2 Research Group. (1996). Reclaiming instructional design. *Educational Technology, 36*(5), 5-7.

Messina, L., & Tabone, S. (2012). Integrating technology into instructional practices focusing on teacher knowledge. *Procedia-Social and Behavioral Sciences, 46*, 1015-1027.

Mishra, P. (2011). TPACK newsletter 8 (feb 2011). Retrieved from http://punya.educ.msu.edu/2011/02/25/tpack-newsletter-8-feb-2011/

Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *The Teachers College Record, 108*(6), 1017-1054.

Mishra, P. (2014). Talking TPACK with dr. punya mishra . Retrieved from https://www.youtube.com/watch?v=wn4ElDeZQeM

Mohtadi, C., Kim, M., & Schlosser, J. (2013). Why integrate computational thinking into a 21 st century engineering curriculum? *Proceedings of SEFI Annual Conference,* Morrison, G. R., Ross, S. M., Kemp, J. E., & Kalman, H. (2010). *Designing effective instruction* John Wiley & Sons.

Mouza, C., Karchmer-Klein, R., Nandakumar, R., Ozden, S. Y., & Hu, L. (2014). Investigating the impact of an integrated approach to the development of preservice teachers' technological pedagogical content knowledge (TPACK). *Computers & Education, 71*, 206-221.

Müller, D. (Ed.). (2013). *Design characteristics of virtual learning environments* Springer Fachmedien Wiesbaden. doi:10.1007/978-3-658-00392-0

Murtaugh, M. C. (2011). Integrating emerging technology into the curriculum.

The lesson planning process. Neilson, D. (Director). (2009, 01/September).[Video/DVD]

Netemeyer, R. G., Bearden, W. O., & Sharma, S. (2003). *Scaling procedures: Issues and applications* Sage.

Neuman, W. L. (2009). Social research methods: Quantitative and qualitative methods.

Newby, P. (2010). *Research methods for education* Pearson Education.

Newstead, S. E., & Dennis, I. (1990). Blind marking and sex bias in student assessment. *Assessment and Evaluation in Higher Education, 15*(2), 132-139.

Ngai, E. W., Poon, J., & Chan, Y. (2007). Empirical examination of the adoption of WebCT using TAM. *Computers & Education, 48*(2), 250-267.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education, 21*(5), 509-523.

Olofson, M. W., Swallow, M. J. C., & Neumann, M. D. (2016). TPACKing: A constructivist framing of TPACK to analyze teachers' construction of knowledge. *Computers & Education, 95*, 188-201. doi:http://dx.doi.org/10.1016/j.compedu.2015.12.010

Orton, P. (2011). Gyrometric systems, private communication.

Ozgun-Koca, S. A. (2009). The views of preservice teachers about the strengths and limitations of the use of graphing calculators in mathematics instruction. *Journal of Technology and Teacher Education, 17*(2), 203-227.

Ozmantar, M. F., Akkoç, H., Bingolbali, E., Demir, S., & Ergene, B. (2010). Pre-service mathematics teachers’ use of multiple representations in technology-rich environments. *Eurasia Journal of Mathematics, Science & Technology Education, 6*(1), 19-36.

Pallant, J. (2010). A step by step guide to data analysis using the SPSS program. *SPSS Survival Manual 4th Ed, 494*

Palomba, C. A., & Banta, T. W. (1999). *Assessment essentials: Planning, implementing, and improving assessment in higher education. higher and adult education series.* ERIC.

Pamuk, S., Ergun, M., Cakir, R., Yilmaz, H. B., & Ayas, C. (2015). Exploring relationships among TPACK components and development of the TPACK instrument. *Education and Information Technologies, 20*(2), 241-263.

Park, S. Y. (2009). An analysis of the technology acceptance model in understanding university students' behavioral intention to use e-learning. *Educational Technology & Society, 12*(3), 150-162.

Phelan, K. V. (2008). *Benchmarking an undergraduate convention curriculum: An analysis of convention industry growth and human resource needs* ProQuest.

Polit, D. F., & Beck, C. T. (2006). The content validity index: Are you sure you know what's being reported? critique and recommendations. *Research in Nursing & Health, 29*(5), 489-497.

Polly, D., Mims, C., Shepherd, C. E., & Inan, F. (2010). Evidence of impact: Transforming teacher education with preparing tomorrow's teachers to teach with technology (PT3) grants. *Teaching and Teacher Education, 26*(4), 863-870.

Polly, D., & Orrill, C. H. (2016). Designing professional development to support teachers’ TPACK in elementary school mathematics. *Handbook of Technological Pedagogical Content Knowledge,* , 259-268.

Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of Engineering Education, 95*(2), 123-138. doi:10.1002/j.2168-9830.2006.tb00884.x

Punch, K. F. (2009). *Introduction to research methods in education* Sage.

Race, P., Brown, S., & Smith, B. D. (2005). *500 tips on assessment* Psychology Press.

Rafik, T., Treadwell, P., Triki, N., Gupta, N., & Najah, R. (2010). An investigation into the technical skills gaps in the libyan manufacturing industry.

Ramanathan, T. (2009). *The role of organisational change management in offshore outsourcing of information technology services: Qualitative case studies from a multinational pharmaceutical company* Universal-Publishers.

Ramsden, P. (2003). *Learning to teach in higher education* Routledge.

Reese, R. B., & Jones, B. A. (2010). Improving the effectiveness of microcontroller education. *IEEE SoutheastCon 2010 (SoutheastCon), Proceedings of The,* 172-175.

Ricks, K. G., Jackson, D. J., & Stapleton, W. A. (2008). An embedded systems curriculum based on the IEEE/ACM model curriculum. *Education, IEEE Transactions On, 51*(2), 262-270.

Riegler, A. (2012). Constructivism. *Paradigms in theory construction* (pp. 235-255) Springer.

Rienties, B., Brouwer, N., & Lygo-Baker, S. (2013). The effects of online professional development on higher education teachers' beliefs and intentions towards learning facilitation and technology. *Teaching and Teacher Education, 29*, 122-131.

Rodgers, J. R. (2001). A panel-data study of the effect of student attendance on university performance. *Australian Journal of Education, 45*(3), 284-295.

Romiszowski, A. J. (2016). *Designing instructional systems: Decision making in course planning and curriculum design* Routledge.

Roney, S. D., & Woods, D. R. (2003). Ideas to minimize exam anxiety. *Journal of Engineering Education, 92*(3)

RSS. (2016). Response to the department for business innovation and skills' technical consultation (year 2) on the teaching excellence framework. Retrieved from http://www.rss.org.uk/Images/PDF/influencing-change/2016/RSS-response-to-BIS-Technical-Consultation-on-Teaching-Excellence-Framework-year-2.pdf

Sahami, M., Roach, S., Cuadros-Vargas, E., & LeBlanc, R. (2013). Acm/ieee-cs computer science curriculum 2013: Reviewing the ironman report. *Proceeding of the 44th ACM Technical Symposium on Computer Science Education,* 13-14.

Sahin, I. (2011). Development of survey of technological pedagogical and content knowledge (TPACK). *Turkish Online Journal of Educational Technology-TOJET, 10*(1), 97-105.

Saunders, M. N. (2011). *Research methods for business students, 5/e* Pearson Education India.

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009). Technological pedagogical content knowledge (TPACK) the development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education, 42*(2), 123-149.

Schmidt-Crawford, D. A., Tai, S. D., Wang, W., & Jin, Y. (2016). Understanding teachers' TPACK through observation. *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators,* , 107.

Schofield, J. W. (1993). *Increasing the generalizability of qualitative research.* Open University Press.

Schul, J. E. (2010a). The mergence of CHAT with TPCK: A new framework for researching the integration of desktop documentary making in history teaching and learning. *THEN: Technology, Humanities, Education & Narrative, 7*, 9-25.

Schul, J. E. (2010b). Necessity is the mother of invention: An experienced history teacher's integration of desktop documentary making. *International Journal of Technology in Teaching & Learning, 6*(1), 14-32.

Severance, C. (2014). Massimo banzi: Building arduino. *Computer, 47*(1), 11-12.

Shackelford, R., McGettrick, A., Sloan, R., Topi, H., Davies, G., Kamali, R., . . . Lunt, B. (2006). Computing curricula 2005: The overview report. *ACM SIGCSE Bulletin, , 38*(1) 456-457.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Sieber, J. E., O'Neil Jr, H. F., & Tobias, S. (2013). *Anxiety, learning, and instruction* Routledge.

Singh, H. (2015). *Project management analytics: A data-driven approach to making rational and effective project decisions* FT Press.

Singh, Y. K., & Bajpai, R. (2008). *Research methodology: Techniques and trends* APH Pub.

Smith, N. M. (2010). Investigating the reliability and construct validity of a measure of preservice teachers' self-efficacy for TPACK.

So, H., & Kim, B. (2009). Learning about problem based learning: Student teachers integrating technology, pedagogy and content knowledge. *Australasian Journal of Educational Technology, 25*(1), 101-116.

Stanca, L. (2006). The effects of attendance on academic performance: Panel data evidence for introductory microeconomics. *The Journal of Economic Education, 37*(3), 251-266.

Stehle, S., Spinath, B., & Kadmon, M. (2012). Measuring teaching effectiveness: Correspondence between students’ evaluations of teaching and different measures of student learning. *Research in Higher Education, 53*(8), 888-904.

Stephenson, J. (2013). 25 common characteristics of successful entrepreneurs. *Entrepreneur.Entrepreneur, Nd Web, 5*

Stes, A., Min-Leliveld, M., Gijbels, D., & Van Petegem, P. (2010). The impact of instructional development in higher education: The state-of-the-art of the research. *Educational Research Review, 5*(1), 25-49.

Streiner, D. L., Norman, G. R., & Cairney, J. (2014). *Health measurement scales: A practical guide to their development and use* Oxford University Press, USA.

Tai, H., Pan, M., & Lee, B. (2015). Applying technological pedagogical and content knowledge (TPACK) model to develop an online english writing course for nursing students. *Nurse Education Today, 35*(6), 782-788. doi:http://dx.doi.org/10.1016/j.nedt.2015.02.016

Tamtam, A., Gallagher, F., Olabi, A. G., & Naher, S. (2011). Higher education in libya, system under stress. *Procedia - Social and Behavioral Sciences, 29*(0), 742-751. doi:http://dx.doi.org/10.1016/j.sbspro.2011.11.300

Teigen, K. H., & Jørgensen, M. (2005). When 90% confidence intervals are 50% certain: On the credibility of credible intervals. *Applied Cognitive Psychology, 19*(4), 455-475.

Thomas, J. W. (2000). A review of research on project-based learning.

Tømte, C., Enochsson, A., Buskqvist, U., & Kårstein, A. (2015). Educating online student teachers to master professional digital competence: The TPACK-framework goes online. *Computers & Education, 84*, 26-35.

Tondeur, J., van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing pre-service teachers to integrate technology in education: A synthesis of qualitative evidence. *Computers & Education, 59*(1), 134-144. doi:http://dx.doi.org/10.1016/j.compedu.2011.10.009

Tongco, M. D. C. (2007). Purposive sampling as a tool for informant selection.

UKCES,. (2015). High level STEM skills requirements in the UK labour market - publications - GOV.UK. UK commission for employment and skills. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/444052/stem_review_evidence_report_final.pdf

UoB, U. o. B. (2017). Differences between school and university transcript. Retrieved from http://www.birmingham.ac.uk/accessibility/transcripts/school-uni-differences.aspx

Vaishnav, R. S. (2013). Learning style and academic achievement of secondary school students. *Voice of Research, 1*(4), 1-4.

van Rooij, S. W., & Zirkle, K. (2016). Balancing pedagogy, student readiness and accessibility: A case study in collaborative online course development. *The Internet and Higher Education, 28*, 1-7.

Watt, S., Simpson, C., McKillop, C., & Nunn, V. (2002). Electronic course surveys: Does automating feedback and reporting give better results? *Assessment & Evaluation in Higher Education, 27*(4), 325-337.

Wilson, E., & Wright, V. (2010). Images over time: The intersection of social studies through technology, content, and pedagogy. *Contemporary Issues in Technology and Teacher Education, 10*(2), 220-233.

Wilson, J. (2014). *Essentials of business research: A guide to doing your research project* Sage.

Wu, R., Liu, H., & Yin, F. (2015). Teaching model reform and practice in embedded system experiment. *Computer Science & Education (ICCSE), 2015 10th International Conference On,* 889-892.

Wuensch, K. L., Jenkins, K. W., & Poteat, G. M. (2002). Misanthropy, idealism and attitudes towards animals. *Anthrozoös, 15*(2), 139-149.

Wyse, S. (2011). What is the difference between qualitative research and quantitative research? Retrieved from http://www.snapsurveys.com/blog/what-is-the-difference-between-qualitative-research-and-quantitative-research/

Yeh, Y., Hsu, Y., Wu, H., Hwang, F., & Lin, T. (2014). Developing and validating technological pedagogical content knowledge-practical (TPACK-practical) through the delphi survey technique. *British Journal of Educational Technology, 45*(4), 707-722.

Yin, R. K. (2011). *Applications of case study research* Sage.

Yin, R. K. (2013). *Case study research: Design and methods* Sage publications.

Yurdakul, I. K., Odabasi, H. F., Kilicer, K., Coklar, A. N., Birinci, G., & Kurt, A. A. (2012). The development, validity and reliability of TPACK-deep: A technological pedagogical content knowledge scale. *Computers & Education, 58*(3), 964-977.

Zabaleta, F. (2007). The use and misuse of student evaluations of teaching. *Teaching in Higher Education, 12*(1), 55-76.

Zaharias, P., & Poylymenakou, A. (2009). Developing a usability evaluation method for e-learning applications: Beyond functional usability. *Intl.Journal of Human–Computer Interaction, 25*(1), 75-98.

Appendices

Appendix A

English version of the TPACK HE, AJ instrument questionnaire

Thank you for taking time to complete this questionnaire. Please answer each question to the best of your knowledge. Your thoughtfulness and candid responses will be greatly appreciated. Your responses will be kept completely confidential.

Content Knowledge: the subjects we teach.

Pedagogy: the art of teaching.

Technology: an educational tool.

*ICT: Information and communication technology

Demographic information

1- Nationality:

Please specify:……………………………….

2- In which country are you teaching now?

Please specify:……………………………….

3- What is the University or institution’s Name?

Please specify:……………………………….

4- Gender
   a. Male
   b. Female
5- Age range
   a. 22-26
   b. 27-32
   c. 33-37
   d. 38-42
   e. 43+
6- What is your academic department?
   a. Engineering (which department?...................................)
   b. Chemistry
   c. Biology
   d. Medical
   e. Business
   f. Mathematics
   g. Physics
   h. Education
   i. Other, please specify: ……………………………….

7- Years of experience in teaching in Higher Education
   a. 0
   b. 1-3
   c. 4-6
   d. 7-10
   e. 11-15
   f. 16-20
   g. 21+
   •

8- What do you find most important in teaching?
   a. Theoretical (lectures)
   b. Practical (seminars, workshops, labs,…)
   c. Both

9- Have you attended any teaching and pedagogy training course?
   a. Yes.
   b. No.

Please answer all of the questions, and if you are uncertain of or neutral about your response, you may always select "Neither agree nor disagree."

Strongly Disagree = SD	Disagree = D	Neither Agree/Disagree = N	Agree = A	Strongly Agree = SA

Content Knowledge (CK)		SD	D	N	A	SA
10	I have sufficient content knowledge in my first teaching subject.					
11	I can think about the content knowledge of my first teaching subject like a subject matter expert.					
12	I have some difficulties in improving the content to be processioned (updated) to the industrial needs					
13	I am able to gain deeper understanding about the content knowledge of my first teaching subject on my own.					
14	I am confident to teach the content knowledge for my first teaching subject.					
15	I am confident to update the content linking it to real life needs.					

Pedagogical Knowledge (PK)		SD	D	N	A	SA
16	I know how to organize and maintain classroom management.					
17	I am able to stretch my students' thinking by creating challenging tasks for them.					
18	I am able to help my students to reflect on their learning strategies.					
19	I am able to guide my students to adopt appropriate learning strategies.					
20	I am able to plan group activities for my students.					
21	I am able to guide my students to discuss effectively during group work.					

Pedagogical Knowledge (PK)		SD	D	N	A	SA
22	I am able to help my students to monitor their own learning.					
23	I know how to assess student performance in the classroom.					
24	I know how to assess students' understanding based-upon real life needs.					
25	I can adapt my teaching based-upon what students currently understand or do not understand.					
26	I can adapt my teaching style to different learners.					
27	I can assess student learning in multiple ways.					
28	I can use a wide range of teaching approaches in a classroom setting.					
29	I am familiar with common student understandings and misconceptions.					
30	I am confident to adapt the teaching approaches based-upon real life needs.					

Technological Knowledge (TK)		SD	D	N	A	SA
31	I have the technical skills to use computers effectively.					
32	I can learn technology easily.					
33	I know how to solve my own technical problems when using technology.					
34	I keep up with important new technologies.					
35	I am able to use social media (e.g. Blog, Wiki, Facebook).					
36	I am able to use collaboration tools (e.g. Google Sites, Google Doc).					
37	I am confident to use appropriate technology linking it to real life needs.					

Pedagogical Content Knowledge (PCK)		SD	D	N	A	SA
38	I am able to select appropriate and effective teaching strategies for my content area.					
39	I can select effective teaching approaches to guide student thinking and learning.					
40	Without using technology, I can help my students to understand the content knowledge of my first teaching subject through various ways.					
41	Without using technology, I know how to select effective teaching approaches to guide student thinking and learning of the subject matter for my first teaching subject.					
42	Without using technology, I can address the common misconceptions my students have for my first teaching subject.					
43	Without using technology, I can address the common learning difficulties my students have for my first teaching subject.					

Technological Content Knowledge (TCK)		SD	D	N	A	SA
44	I know about technologies that I can use for understanding and delivering my content area.					
45	I know about the technologies that I have to use for the research of content of my teaching subject.					
46	I can use appropriate technologies (e.g. multimedia resources, simulation) to represent the content of my teaching subject.					
47	I can choose appropriate technologies (hardware, software, simulation) to be useful to real life needs.					

Technological Pedagogical Knowledge (TPK)		SD	D	N	A	SA
48	I can choose technologies that enhance the teaching approaches for a lesson.					
49	I can choose technologies that enhance students' learning for a lesson.					
50	I think critically about how to use technology in my classroom.					
51	I can adapt the use of the technologies to different teaching activities.					
52	I can select technologies to use in my classroom that enhance what I teach, how I teach and what students learn.					
53	I am able to facilitate my students to use technology to find more information on their own.					
54	I am able to facilitate my students to use technology to plan and monitor their own learning.					
55	I am able to facilitate my students to use technology to construct different forms of knowledge representation.					
56	I am able to facilitate my students to collaborate with each other using technology.					
57	I can evaluate the appropriateness of a new technology for teaching and learning.					
58	I am able to use technology to introduce my students to real world scenarios.					

Technological Pedagogical And Content Knowledge (TPACK)		SD	D	N	A	SA
59	I can use strategies that combine content, technologies and teaching approaches in my coursework in my classroom.					
60	I can provide leadership in helping others to coordinate the use of content, technologies and teaching approaches at my school and/or district.					
61	I can choose technologies that enhance the content for a lesson.					

Technological Pedagogical And Content Knowledge (TPACK)		SD	D	N	A	SA
62	I can teach lessons that appropriately combine content subject “ content area”, technologies and teaching approaches.					
63	I can create self-directed learning activities of the content knowledge with appropriate ICT tools (e.g. Blog, Webquest).					
64	I can design inquiry activities to guide students to make sense of the content knowledge with appropriate ICT tools (e.g. simulations, web-based materials).					
65	I can design lessons that appropriately integrate content, technology and pedagogy for student-centered learning.					
66	I am able to combine content, pedagogy and technology to introduce my students to real world scenarios.					

The AJ Framework		SD	D	N	A	SA
67	I think that there is a cooperation at the present time between education and industry sector in my country.					
68	I think that the outputs of the educational process suit the needs of the labour market in my country.					
69	I think that industrial development has a direct impact on the educational content.					
70	I think that industrial development has a direct impact on the technology used in the educational process in my country.					
71	I think that industrial development has a direct impact on the educational teaching methods used in the educational process in my country.					
72	I think that the outputs of the educational process would be more appropriate for the needs of the labour market, if technology employed to teach the content is used in pedagogical ways in my country.					
73	I think that the industry sector ought to offer needs and resources that are needed by the educational process in my country.					
74	I think that the industry sector ought to offer technologies that are needed by the educational process in my country.					

75. If you have any comments or suggestions, please write them here.

Thank you for taking our survey. Your response is very important to us.

Arabic version of the TPACK HE, AJ instrument questionnaire

استبيان إطار العمل TPACK , AJ

الغرض من الاستبيان: هو التحقق وتطوير أداة مصممة لقياس الذاتي للمحاضرين في التعليم العالي لاستخدامهم إطار العمل التكنولوجيا والتربية والمحتوى (TPACK framework) و المعرفة ذات العلاقة.

(TPACK): يستخدم لوصف المعرفة التي يحتاجها المُحاضر والتي تدمج التكنولوجيا في ممارسات التدريس مع الأخذ في عين الاعتبار احتياجات الحياة العملية /الصناعية (احتياجات سوق العمل).

الفئة المستهدفة من هذه الاستبيان هي: المحاضرون في قطاع التعليم العالي.

بيانات الباحث:

علي الصديق جويد

ali.jwaid@ntu.ac.uk

00447414050281 موبايل (وفايبر أيضا)

00218925873707

=====-======

شكرا على مشاركتك ونقدر بذل وقتك لإكمال في هذا الاستبيان. الرجاء التأكد من إجابة كل سؤال. وسيتم الاحتفاظ بردودكم بكل سرية تامة.

الرجاء ترك بياناتك وطريقة التواصل في حالة الرغبة في إجراء مقابلة تمكن الباحث من الحصول على معلومات إضافية.

....

تعريفات:

المحتوى: المواضيع التي تُدرس.

التربية: فن وعلم التدريس.

التكنولوجيا: الأدوات المستخدمة في العملية التعليمة

تقنية المعلومات والاتصالات (ICT)

البيانات الشخصية

1- الجنسية :...
2- في أي بلد تدرس : ....
3- في أي مؤسسة : ....
4- الجنس
   أ. ذكر
   ب. أنثى
5- العمر :
   أ. 26-22

ب. 27-32
ج. 33-37
د. 38-42
ه. 43+

6- التخصص: ....

•

7- سنوات خبرة التدريس في التعليم العالي:

أ. 1-3
ب. 4-6
ج. 7-10
د. 11-15
ه. 16-20
و. 21+

•

8- ما الذي تعتقد أنه أكثر أهمية في التدريس:

أ. الجانب النظري فقط (ألقاء محاضرات)
ب. الجانب العملي فقط (ورش عمل – ندوات- معامل،...)
ج. كلاهما

•

9- هل سبق وأن تحصلت على دورات تدريبية في التدريس والتربية؟

أ. نعم.
ب. لا.

غير موفق بشدة (SD) ، غير موفق (D)، محايد (N)،موافق (A)، موافق بشدة (SA)

SA	A	N	D	SD	Content Knowledge (CK)المحتوى	
					لدي القدرة على التفكير في المحتوى التعليمي الذي أدرسُهُ للمرة الأولى كشخص له الخبرة في تدريس المادة.	10
					لدي صعوبات في تحديث المحتوى التعليمي ليواكب التطور الحاصل في التخصص.	11
					لدي القدرة على التفكير في المحتوى التعليمي الذي أدرسُهُ للمرة الأولى كشخص له الخبرة في تدريس المادة	12
					لدي القدرة على كسب فهم أعمق للمحتوى التعليمي الذي أدرسُهُ للمرة الأولى.	13
					لدي الثقة في تدريس مواد لم يسبق وأن قمت بتدريسها.	14
					لدي القدرة على تحديث المحتوى العلمي بما يتناسب مع احتياجات سوق العمل.	15

•

SA	A	N	D	SD	Pedagogical Knowledge (PK) التربية	
					لدي معرفة بكيفية تنظيم وإدارة الصف الدراسي.	16
					لدي القدرة على توسيع قدرة الطلبة على التفكير من خلال اعطائهم مسائل تمثل تحدي بالنسبة لهم.	17
					لدي القدرة على مساعدة الطلبة في التأمل والتفكير في استراتيجيات تعليمهم.	18
					لدي القدرة على توجيه الطلبة لتبني استراتيجيات التعليم المناسبة لهم.	19
					لدي القدرة على تخطيط مجموعة أنشطة دراسية.	20
					لدي القدرة على ارشاد الطلبة للمناقشة الفعالة أثناء العمل في مجموعات.	21
					لدي القدرة على مساعدة الطلبة على مراقبة تعليمهم.	22
					لدي المعرفة على تقييم أداء الطلبة في الصف.	23
					لدي القدرة على تقييم فهم الطلبة اعتماد على متطلبات الحياة العملية.	24
					لدي القدرة على تكييف طريقة تدريسي بناءً على ما فهمهُ الطلبة وما لم يفهموهُ حاليا.	25
					لدي القدرة على تكييف أسلوب تدريسي بمراعاة اختلاف فهم الطلبة.	26
					لدي القدرة على تقييم تعلم بأساليب متعددة.	27
					استطيع استخدام مدى واسع من طرق التدريس في ضبط الصف.	28
					لدي معرفة بالفهم الصحيح والخاطئ للطلبة.	29
					لدي الثقة لتعديل أساليب التدريس اعتمادا على احتياجات الحياة العملية.	30

SA	A	N	D	SD	Technological Knowledge (TK) التكنولوجيا	
					لدي المهارات التقنية لاستخدام الحاسوب بكفاءة.	31
					استطيع تعلم التقنية بسهولة.	32
					أعرف كيف أُصْلِحُ المشاكل التقنية بمفردي.	33
					أنا مواكب للتقنيات الحديثة المهمة.	34
					لدي القدرة على استخدام مواقع التواصل الاجتماعية (فيس بوك، بلوق، ويكيبيديا، و ....)	35
					لدي القدرة على الأدوات المساعدة (قوقول سايتس، و قوقول دوك)	36
					لدي الثقة لاستخدام التقنية المناسبة وربطها مع احتياجات سوق العمل.	37

SA	A	N	D	SD	Pedagogical Content Knowledge (PCK) المحتوى والتربية	
					لدي القدرة على اختيار أسلوب التدريس المناسب والفعال لتدريس المحتوى.	38
					لدي القدرة على اختيار أسلوب التدريس الفعال لإرشاد تعليم وتفكير الطلبة.	39
					ا ستطيع مساعدة الطلبة في فهم المحتوى الذي أدرسه للمرة الأولى من خلال طرق متنوعة وبدون استخدام التقنية.	40
					استطيع بدون استخدام التقنية اختيار أسلوب التعليم الفعال لإرشاد تعليم وتفكير الطلبة في الموضوع الذي ادرسه للمرة الأولى.	41
					استطيع بدون استخدام التقنية معالجة أخطاء الفهم الشائعة والتي قد تحدث في أول موضوع أدرسه.	42
					استطيع بدون استخدام التقنية معالجة صعوبات التعلم الشائعة والتي قد تحدث في أول موضوع أدرسه.	43

SA	A	N	D	SD	Technological Content Knowledge (TCK) المحتوى والتكنولوجيا	
					أعلم التقنيات التي يمكن أن تستخدم لجعل المحتوى مفهوم ومطبق.	44
					أعلم التقنيات التي يجب أن استخدمها للبحث عن المحتوى الذي سوف ادرسه.	45
					استطيع استخدام التقنيات المناسبة (الوسائط المتعددة والمحاكاة) لعرض المحتوى الذي سوف ادرسه.	46
					استطيع اختيار التقنيات المناسبة (برمجيات، ومعدات، ومحاكاة) لتكون مفيدة لحاجة الحياة العملية/ سوق العمل.	47

SA	A	N	D	SD	Technological Pedagogical Knowledge (TPK) التكنولوجيا والتربية	
					استطيع اختيار التقنيات التي تحسن أساليب التدريس.	48
					استطيع اختيار التقنيات التي تحسن تعليم الطلبة.	49
					افكر بشكل حرج حول كيفية استخدام التقنية في الصف الدراسي.	50
					استطيع تعديل التقنيات المستخدمة للقيام بفعاليات تدريس مختلفة.	51
					استطيع اختيار التقنيات لاستخدامها في الصف الدراسي والتي تحسن (ما ادرسه، وكيف ادرس، وكيف يتعلم الطالب).	52
					استطيع التسهيل على الطلبة استخدام التقنية لإيجاد معلومات أكثر بأنفسهم.	53
					استطيع التسهيل على الطلبة استخدام التقنية لتخطيط ومراقبة تعليمهم بأنفسهم.	54
					استطيع التسهيل على الطلبة استخدام التقنية لبناء أشكال مختلفة لإعادة تقديم المحتوى.	55
					استطيع التسهيل على الطلبة استخدام التعاون مع بعضهم باستخدام التقنية.	56
					استطيع تقييم مدى ملائمة التقنية الجديدة للتدريس والتعليم.	57
					استطيع استخدام التقنية لتقديم نماذج الحياة العملية للطلبة.	58

SA	A	N	D	SD	Technological Pedagogical and Contact Knowledge المحتوى والتعليم والتكنولوجيا (TPACK)	
					استطيع استخدام الاستراتيجيات التي تدمج المحتوى والتقنية وأساليب التدريس في الصف.	59
					استطيع قيادة تزويد زملائي في استخدام الاستراتيجيات التي تدمج المحتوى والتقنية وأساليب التدريس في الصف.	60
					استطيع اختيار التقنيات التي تحسن في المحتوى لعرض المحاضرة.	61
					استطيع تدريس المحاضرة التي تدمج المحتوى (الموضوع) والتقنية وأساليب التدريس بالشكل المناسب.	62
					استطيع إنشاء نشاطات تعليمية موجه ذاتيا للمحتوى مع أدوات (ICT) تقنية الاتصالات والمعلومات (مثل بلوق(Blog) وويب كوست).	63
					استطيع تصميم نشاطات استفهامية لإرشاد الطلبة لتكوين إحساس بالمحتوى مع استخدام أدوات تقنية الاتصالات والمعلومات المناسبة (محاكاة، وموارد مبنية على الويب).	64
					استطيع تصميم الدروس التي تدمج بشكل مناسب المحتوى والتكنولوجيا وطرق التدريس من أجل التعلم المتمحورة حول الطالب.	65
					استطيع دمج المحتوى والتقنية وأسس التربية والتعليم لتقديم نماذج الحياة العملية للطلبة.	66

SA	A	N	D	SD	The AJ Framework (AJ) نموذج أي جي	
					أنا اعتقد أن هناك تعاون في الوقت الحالي بين قطاعي التعليم والصناعة في بلادي	67
					أنا اعتقد أن مخرجات العملية التعليمة تلائم احتياجات سوق العمل في بلادي.	68
					أنا اعتقد أن التطور الصناعي يؤثر بشكل مباشر على المحتوى التعليمي.	69
					أنا اعتقد أن التطور الصناعي يؤثر بشكل مباشر على التقنية المستخدمة في العملية التعليمية	70
					أنا اعتقد أن التطور الصناعي يؤثر بشكل مباشر على طرق التدريس التربوية المستخدمة في العملية التعليمية.	71
					أنا اعتقد أن مخرجات العملية التعليمية ستكون أكثر ملائمة لاحتياجات سوق العمل إذا ما تم تسخير التقنية لتدريس المحتوى التعليمية بالطرق التربوية في بلادي.	72
					أنا اعتقد أن قطاع الصناعة يوفر الاحتياجات والموارد التي تحتاجها العملية التعليمية في بلادي.	73
					أنا اعتقد أن قطاع الصناعة يوفر التقنيات التي تحتاجها العملية التعليمية في بلادي.	74
					أنا اعتقد أن قطاع الصناعة يجب أن يوفر الاحتياجات والموارد التي تحتاجها العملية التعليمية في بلادي.	75
					أنا اعتقد أن قطاع الصناعة يجب أن يوفر التقنيات التي تحتاجها العملية التعليمية في بلادي.	76

إذا لديك أي إضافة أو ملاحظة:

....
....
....
....
....
....
....

....
....

Back translation

<u>Back translation1 Ms Baakeer</u>

	Content Knowledge	SA	A	N	D	SD
10	I have the ability to think in the content that I teach for the first time as someone who has experience in teaching the module					
11	I have difficulties in updating the content to keep up with the development that is taken place in the specialization (the major)					
13	I have the ability to gain a deeper understanding of the content that I teach for the first time					
14	I am confident enough to teach subjects (or modules) that I have never taught before					
15	I have the ability to (or simply, I can) update the scientific content in line with labour market needs					

	Pedagogical knowledge	SA	A	N	D	SD
16	I know how to organize and maintain classroom management					
17	I have the ability to promote students' way of thinking by giving them tasks that represent a challenge for them					

	Pedagogical knowledge	SA	A	N	D	SD
18	I have the ability to assess students reflect on their own learning strategies					
19	I can guide students to adopt the appropriate learning strategies that suit them					
20	I can plan for a wide range of teaching activities					
21	I can guide the students to effective way of discussion while working in small group					
22	I can assess students monitor their learning in multiple ways.					
23	I know how to assess students' performance in the classroom					
24	I can assess common students' understanding based upon the learning needs and requirements					
25	I can adapt my teaching approaches based upon students' current understanding and misconception					
26	I can adopt my teaching style to different learners					
27	I can assess students' learning in multiple ways					
28	I can use a wide range of teaching methods in order to manage the classroom					
29	I am familiar with common students' understanding and misconception					
30	I am confident enough to modify my teaching methods depending on the needs of the scientific life					

	Technological Knowledge	SA	A	N	D	SD
31	I have the technical skills I need to use the computer efficiently					
32	I can learn technology easily					
33	I know how to solve the technical problems on my own.					
34	I keep up with the important new technologies					
35	I have the ability to use social networking sites (Facebook, blogs, Wikipedia, etc.)					
36	I can use other helpful sites (e.g. google sites, google docs)					
37	I am confident enough to use the appropriate technology with accord to the labour market needs					

	Pedagogical Content Knowledge (PCK)	SA	A	N	D	SD
38	I can choose the appropriate and effective teaching methods for the teaching content					
39	I can choose the effective teaching method to guide the students in their thinking and learning					
40	I can assess the students understand the content that I teach for the first time through a variety of methods and without the use of technology					
41	I can (without the use of technology) to choose effective teaching approaches to guide student learning and thinking in the subject content that I teach for the first time					

	Pedagogical Content Knowledge (PCK)	SA	A	N	D	SD
42	I can, and without the use of technology, to address common misunderstanding which may occur during the first Subject I teach.					
43	I can (without the use of technology) to address common learning difficulties which may occur during the first subject I teach					

	Technological Content Knowledge	SA	A	N	D	SD
44	I know about technologies that can be used to make the subject content understandable and applicable					
45	I know about technologies that I should use to search for the content that I will teach					
46	I can use the range of technologies (i.e. multimedia and simulation) that are suitable for teaching the subject content					
47	I know how to select effective technologies (i.e. software, equipment, and simulation) that meets the needs of the working life and the labour market					

	Technological Pedagogical Knowledge	SA	A	N	D	SD
48	I know how to select effective technologies that that improve teaching methods					
49	I know how to select effective technologies that enhance student learning					
50	I think critically about how to use technology in the classroom					
51	I can adjust the use of technology in order to perform different teaching activities					
52	I can select technologies to be used in the classroom that improves (what I teach, how to teach and how students are learning)					
53	I can make it easier for the students to use technology to find more information on their own					
54	I can make it easier for the students to use technology for planning and controlling their learning					
55	I can make it easier for students to use technology to build different forms to re-submit the content					
56	I can make it easier for the students to cooperate with each other using technology					
57	I can assess the suitability of the new technology for teaching and learning					
58	I can use technology to provide students with examples concerning the practical life					

	Technological Pedagogical and Contact Knowledge	SA	A	N	D	SD
59	I can use strategies that integrate content, technology and teaching methods in the classroom					
60	I can lead and assess my colleagues in the use of technology that integrates the content, technologies and teaching methods in the classroom					
61	I can select technologies that improve the content that I deliver in the class					
62	I can teach classes in an appropriate way that integrates content (subject), technology and teaching methods					
63	I can create teaching activities with self- directed content by using tools of Information and Communication Technology (ICT) such as blogs and Web Coast					
64	I can design thought-provoking activities to guide students to create a sense of the content with the use of appropriate communication and information technology tools (e.g. simulation and resources based on the web).					

	Technological Pedagogical and Contact Knowledge	SA	A	N	D	SD
65	I can design lessons that appropriately incorporate the content, technology and teaching methods in order to enhance student-centred learning					
66	I can integrate content, technology and the fundamental roles of teaching and pedagogy in order to provide students with examples of the practical life					

	The AJ Framework	SA	A	N	D	SD
67	I think that there is collaboration at the moment among the sectors of education and industry in my country					
68	I think that the outputs of the pedagogical process matched the needs of the labour market in my country					
69	I think that the industrial development has a direct impact on the content knowledge					
70	I think that the industrial development has a direct impact on the technology used in the pedagogical process					
71	I think that the industrial development has a direct impact on the					

	The AJ Framework	SA	A	N	D	SD
	pedagogical teaching methods that are used in the teaching process					
72	I think that the outputs of the teaching process in my country can be more appropriate to the needs of the labour market if they use technology to teach the content in a pedagogical manner					
73	I think that the industrial sector in my country provides the resources needed by the pedagogical process					
74	I think that the industrial sector in my country provides the technology needed by the pedagogical process					
75	I think that the industrial sector in my country should provide the needs and the resources that are necessary for the pedagogical and educational process					
76	I think that the industrial sector in my country should provide the technology that are necessary for the pedagogical and educational process					

Back translation, Mr Mohammed Habbes

Content Knowledge

10) I have the ability to think in the educational content that I teach for the first time as someone who has experience in teaching

11) I have difficulties in updating the educational content for to keep up with development in the specialty.

12) I have the ability to gain a deeper understanding of the educational content that I teach for the first time.

14) I am confident in teaching materials that I have never taught before .

15) I have the ability to update the scientific content in line with the job market needs

Pedagogical Content

16) I am able to organize and manage a classroom .

17) I am able to expand the students' ability to think by challenging them.

18) I am able to help students reflect and think about their education strategies.

19) I am able in guiding students adopt teaching strategies relating to them.

20) I am able in planning study group activities.

21) I am able to guide students discuss effectively while working in groups.

22) I am able to help students monitor their education.

23) I know how to evaluate the students’ performance in class.

24) I am able to assess students thinking depending on the job requirements.

25) I am able to tailor my teaching method based on what the students understand and did not understand it.

26) I am able in tailoring a teaching style while considering the difference of students abilities.

27) I am able in evaluating learning in several ways .

28) I can use a wide range of teaching methods to control classroom.

29) I know how to spot the right and wrong understanding of students.

30) I am confident in adjusting teaching ways depending on job requirements.

Technological knowledge

31) I have the technical skills in using the computer efficiently.

32) I can easily learn the technology.

33) I know how to rectify technological problems by myself.

34) I am update with important modern technologies.

35) I have the ability in using social medias such as WikiLeaks, Facebook, Blogs and many others.

36) I have the abilities in help materials such as Google Sites and Google Doc

37) I am confident in using appropriate technology and connect it with the job market needs.

Pedagogical content knowledge

38) I am able to choose an appropriate and practical teaching style to teach course content.

39) I am able to choose an appropriate and practical teaching to guide students thinking style.

40) I can help students understand the content that I teach for the first time through a variety of methods and without the use of technology

41) Without using technology I can choose the appropriate teaching method to guide and teach the students think about the subject that I teach for the first time .

42) Without using technology I can address common understanding errors which may occur while teaching my first subject.

43) Without using technology I can address common difficulties in learning that may occur while teaching my first subject.

Technological Content knowledge

44) I teach technologies that can be used in making the content understandable and practical.

45) I teach technologies that should be used in research for the content I intend to teach.

46) I can use the appropriate technologies (multimedia and simulation) to show the content that I want to teach .

47) I can choose the appropriate technologies (programs, equipment , and simulation) to be useful to the needs of working life / labour market.

Technological Pedagogical knowledge

48) I can choose the technologies that improves the methods of teaching.

49) I can choose the technologies that improves the teaching for the students.

50) Thinking critically about how to use technology in the

classroom.

51) I can alter the used techniques to carry out effectively different teaching.

52) I can choose the technologies to be used in the classroom and that improves (what I teach, how I teach and how the students learn) .

53) I can make it easier for students to use technology to find more information on their own.

54) I can make it easier for students to use technology to plan and control their education on their own.

55) I can make it easier for students to use technology to build different models in order to resubmit the content.

56) I can make it easier for students to use teamwork with each other using technology .

57) I can evaluate the convenience of new technology for teaching and education.

58) I can use the technology for presenting labour life for students

Technological Pedagogical and Contact knowledge

59) I can use strategies that integrate content , technology and teaching methods in the classroom .

60) I can provide the leadership of my colleagues in the use of strategies that integrate content, technology and teaching methods in the classroom .

61) I can choose the technologies that improve the content to present the lecture.

62) I can teach lecture that integrates content (subject), technology and appropriate teaching methods.

63) I can create a self- directed content with educational ICT tools activities: communication and information technology (such as Blog and Web Coast).

64) I can create questionnaire activities to guide students to create a sense of the content with the use of appropriate communication and information technology tools (simulation, and resources based on the web) .

65) I can design lessons that integrate appropriately with the content, technology and methods of teaching for student-centered learning .

66) I can integrate content, technology and educational foundations to provide the prototype labour life models for students .

AJ Framework (AJ)

67) I think there is a cooperation between the educational sector and industry in my country nowadays.

68) I think the outcome of the educational operation is convenient for the labour market in my country.

69) I think that the industrial development has a direct impact on the educational content.

70) I think that the industrial development has a direct impact on the technology used in the educational process.

71) I think that the industrial development has a direct impact on the educational teaching methods used in the educational process.

72) I believe that the outcome of the educational process will be mostly convenient for the job market needs when harnessing technology to teach educational content and educational means in my country.

73) I think that the industrial sector provide needs and resources needed by the educational process in my country.

74) I think that the industrial sector provide technology needed for the educational process in my country.

75) I think that the industrial sector must provide the needs and the resources needed

by the educational process in my country.

76) I think that the industrial sector must provide the technology needed by the educational process in my country.

EvaSys Questionnaire

	Statement	Definitely Agree	Agree	Neither agree nor disagree	Disagree	Definitely disagree
1	My tutor is well organised					
2	My tutor is supportive					
3	My tutor is good at explaining things					
4	I feel able to ask questions					
5	Module teaching staff are enthusiastic about what they are teaching					
6	Module teaching staff are good at explaining things					
7	Module teaching staff have made the subject interesting					
8	The range of teaching methods used on this module have helped my learning					
9	The teaching sessions are well structured					
10	Overall, I am satisfied with the teaching quality on this module					
11	The assessment criteria have been clearly communicated					
12	Feedback on my work has been prompt					
13	I have received detailed comments on my work					
14	Feedback has identified areas that I can improve on in the future					
15	I understand the aims and learning outcomes of the module					
16	The NOW online resources for this module have helped support my learning					
17	The module is well organised and running smoothly					
18	I understand how this module links in with the rest of my course					
19	I find the module to be a valuable learning experience					
20	I find the module intellectually stimulating					
21	I've been able to access specialist equipment/ facilities when I needed to					

	Statement	Definitely Agree	Agree	Neither agree nor disagree	Disagree	Definitely disagree
22	The rooms and learning resources for this module have been Satisfactory learning					
23	I've been able to access specialist equipment/ facilities when I needed to					
24	The rooms and learning resources for this module have been Satisfactory learning					
25	Overall, I am satisfied with this module					

Appendix B

Extracts of Digital Control Module leader semi-structured interview post AJ framework implementation:

Q.1 How did you become involved in the original module?
I took it over when the previous lecturer was moving away from teaching to concentrate on a spin off company in the Process Control area. After a broad discussion about content, pedagogy and technological application in the module I was very impressed and more than happy to adapt much of his material and try to continue his ethos. Broadly speaking he was trying to give a flavour of real world applications of real time process control and digital signal processing to MSc students fairly new to the area (but with a good engineering background). The technology involved (MATLAB and Agilent VEE and associated real time monitoring and programmed devices) was used to help students worry less about some complex mathematics by moving them quickly to industrial case studies in the area. The module was very 'hands-on' in this, respect to ensure the directed study (mainly on the two software packages) was well understood and directed.

Q.2:How did the AIPC module run after you took it over?

Very well. I was pleased that the students understood the ethos I had continued from the previous lecturer. He had suggested changes to the module that I incorporated, which worked well (a third assignment had proved difficult to run and was very tricky for the weaker half of the class and led them to lose a little interest in our core ideas, so we adapted the other two assignments to meet the same learning outcomes and improve the focus on the industrially related work being a rigorous but enjoyable insight. The performance of students was good as expected, with no fails. They said they enjoyed the module and particularly the real industrial examples and the integrated way we introduced digital sampling mathematics was almost a revelation compared to their previous disappointing experience of the teaching of engineering mathematics that they applied in other modules on their BSc and BEng courses.

Q3 Why did the AIPC module transform into the current Digital Control module and what are your views on this?

When the MSc courses were reviewed the course team decided AIPC was perhaps too specialist as a module to attract students and hard to link in to the course learning outcomes as a core module on a relatively general degree title like MSc Electronics Engineering and was not as good a fit for the MSc Communications and Cybernetics course. As module leader I defended the significant benefits the AIPC module had delivered, in particular the high level of support from students as a successful and enjoyable industrially linked module. As such I was allowed to transfer much of module ethos, teaching and learning strategies, lesson planning (mixed delivery), some content and parts of the successful assessment to the new module title. Quite a few of the lectures and much assessment needed rewriting to emphasise control theory aspects as a change from a previous stronger emphasis on DSP. Plus the process control content was slightly reduced. Your input as a PhD student was very useful in organising this quite detailed change along more formalised sound pedagogical lines. I was satisfied with the end result, and very happy after the DC module ran successfully with similar outcomes and student views to the last cohort on AIPC and that the transformation had been possible in part due to research led ideas around the investigation of the suitability of application of TPACK to such HE modules.

You say the research helped the formation of the new successful DC module but how are you so sure you knew. Also can you explain how you became interested in this research and why did you recruit me as a PhD student?

I knew from my experience. I've been working as an academic at NTU for 32 years and have served at all levels in the NTU committee structures that initiate, design, validate, monitor, enhance and modify the courses we run. I am a current (long-standing) elected member of Academic Board (one of two representing academics across the whole of NTU). I've served on one or other (or both) of the NTU Academic Standards and Quality sub-committees for most of the last two decades. I have been actively involved in course validation panels across all subject areas of NTU academic programmes. I am a current member of the school SASQC and various sub-committees, that deal with SST quality arrangements and teaching and learning enhancements. From a subject perspective I've been teaching in the control and digital signal processing areas on and off for more than two decades. This has linked with direct research experience in the area working alongside colleagues who started two separate spin-off companies relating to the subject area. As for my interest in engineering pedagogy my cross NTU experience, my desire to design and deliver courses as well as I could, and my support for engineering, computing and technology students by running projects in their niche area of interest to help them move to potential careers in teaching or academia as a profession, all led in this direction. I have a long research record, albeit mainly in support roles at NTU, predominantly in the areas of electronic materials science and electronics.

As for recruiting you I think it was rather the other way round but I have no regrets and am very grateful that your work has helped me design and run improved modules for my students and opened opportunities in a new research area in collaboration with Prof. Gren Ireson in the School of Education.

Can you give more details on how this research and the AJ framework has helped your DC module?

Well obviously it made the transformation that generated the DC module, without losing the good practice of the AIPC module, much easier. Thinking about the TPACK domains led to an improved balance of approach to the module structure, content and delivery, and assessment; even in an area of success and good practice for industrial contextualization, led by a very experienced practitioner.

This research led module design was a bit of a luxury as an academic. In my experience, in the last decade in particular, time pressures too often forced academics, including myself, into more ad-hoc methods of module design; which is ironic, as, like most universities, NTU formalised approaches to course design with sound pedagogical backing has never been more prevalent. Yet life is so busy that the time for proper staff development even within the subject area of expertise let alone the staff development of pedagogy is rather limited (unless it links to research interests or is a scheduled duty, like the recent work to obtain HEA fellowship).

The benefits continued as the subsequent iterations of the TPACK/AJ framework were undertaken. The current version of the module is probably the most well designed I have been involved with and has the best student feedback of any module I have ever led. This 2015/16 academic year we had major problems at the start of the module due to students arriving three weeks late on a ten week delivery (due to visa issues) but these were surprisingly easily dealt with due to the teaching and learning strategies making the initial work so easy to pick up in some parallel-scheduled catch-up sessions. The results of the second assignment were slightly disappointing indicating some of the late arrival students had rather 'run out of steam', maybe partly due to the intense workload of catching up, but most achieved merit status in the module all the same and all indicated they thoroughly enjoyed the module in all aspects of the EvaSys feedback areas.

Appendix C

Model for developing preservice teachers' TPACK through ICT courses

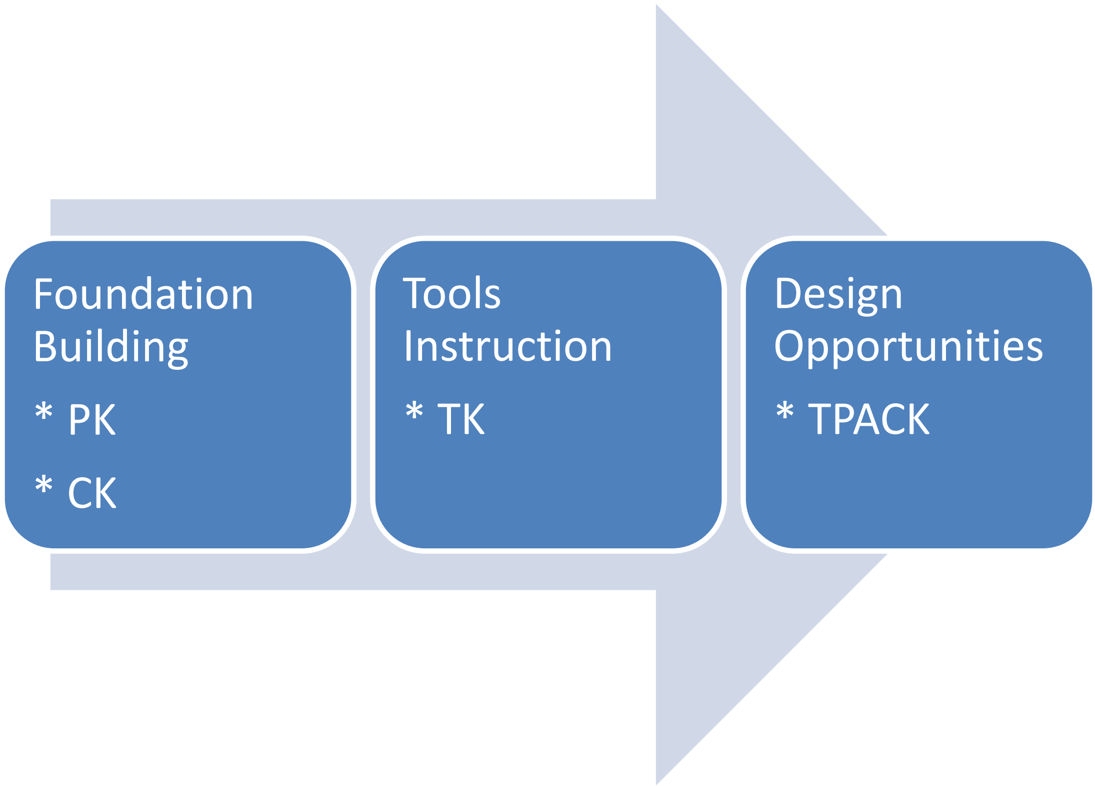


Figure 0.1 Model for developing preservice teachers' TPACK through ICT courses (Chai et al., 2010)

Bloom’s Taxonomy (Bloom's Revised Taxonomy)

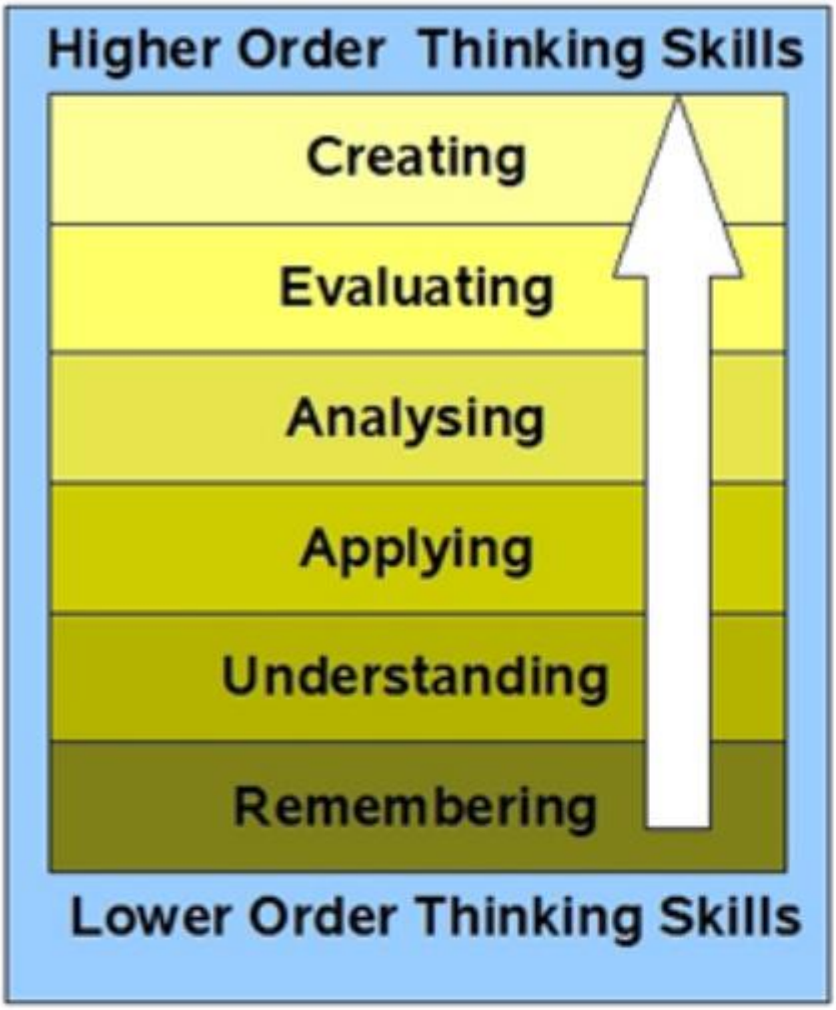


Figure 0.2 Bloom's Taxonomy (Churches, 2008)

“In the 1990's, a former student of Bloom, Lorin Anderson, revised Bloom's Taxonomy and published this- Bloom's Revised Taxonomy in 2001.Key to this is the use of verbs rather than nouns for each of the categories and a rearrangement of the sequence within the taxonomy. They are arranged below in increasing order, from low to high.”

Table C.1

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

http://www.socscistatistics.com/tests/ztest/Default2.aspx

Why should we assess?

" If we think clearly about our reasons for assessment, it helps to clarify which particular methods are best suited for our purposes, as well as helping to identify who is best placed to carry out the assessment, and when and where to do it. This section lists some of the most common reasons for assessing students. You might find it useful to look at these and decide which are the most important ones in the context of your own discipline, with your own students, at their particular level of study.

1. To guide students' improvement. The feedback students receive helps them to improve. Assessment that is primarily formative need not necessarily count towards any final award and can therefore be ungraded in some instances. The more detailed the feedback we provide, the greater is the likelihood that students will have opportunities for further development.
2. To help students to decide which options to choose. For example, if students have to select electives within a programme, an understanding of how well (or otherwise) they are doing in foundation studies will enable them to have a firmer understanding of their current abilities in different subject areas. This can provide them with guidance on which options to select next.
3. To help students to learn from their mistakes or difficulties. Many forms of formative assessment can be useful to students to help them to diagnose errors or weaknesses, and enable them to rectify mistakes. Nothing is more demotivating than struggling on getting bad marks and not knowing what is going wrong. Effective assessment lets students know where their problems lie, and provides them with information to help them to put things right.
4. To allow students to check out how well they are developing as learners. Assessment does not just test subject-specific skills and knowledge, but provides an ongoing measure of how well students are developing their learning skills and techniques. Students themselves can use assessment

opportunities to check out how they are developing their study skills and can make adjustments as appropriate.

5. To classify or grade students. There are frequently good reasons for us to classify the level of achievements of students individually and comparatively within a cohort. Assessment methods to achieve this will normally be summative and involve working out numerical marks or letter grades for students' work of one kind or another. However, continuous assessment processes can address the classifying or grading of students, yet still provide opportunities for formative developmental feedback along the way.
6. To set standards. The best way to estimate the standard of an educational course or module is to look at the various ways in which students' achievement is measured. The standard of the course is illustrated by the nature of the assessment tasks, and of course by the quality of students' work associated with the various tasks.
7. To allow students to make realistic decisions about whether they are up to the demands of a course or module. Students sometimes choose a module because they are interested in part of the subject, but then find that substantial parts of the module are too difficult for them, or not interesting enough. When the assessment profile of the module is clearly spelled out in advance, students can see how much the part they are interested in actually counts in the overall picture, and can be alerted to other important things they may need to master to succeed in the module.
8. To determine fitness for entry to a programme. Students often cannot undertake a course of study unless they have a sound foundation of prior knowledge or skills. Assessment methods to enable student progression therefore need to give a clear idea of students' current levels of achievement, so they – and we – can know if they are ready to move on.
9. To give us feedback on how our teaching is going. If there are generally significant gaps in student knowledge, these often indicate faults in the teaching of the areas concerned. Excellent achievement by a high

proportion of students is often due to high-quality facilitation of student learning.

10. To cause students to get down to some serious learning. As students find themselves under increasing pressure, they tend to become more and more strategic in their approaches to learning, putting their energies only into work that counts. Assessment methods can be designed to maximise student motivation, and prompt their efforts towards important achievements.
11. To translate intended learning outcomes into reality. Assessment tasks and the feedback students receive on their work can show them what the intended learning outcomes mean in practice. Often it is only when students undertake tasks in which their evidence of achievement of the learning outcomes is being measured that they fully appreciate the nature and level of the competences they need to attain.
12. To add variety to students' learning experience. Utilising a range of different assessment methods spurs students to develop different skills and processes. This can promote more effective – and enjoyable – teaching and learning, and can help us to ensure that all students can demonstrate their strengths in those assessment contexts they find most comfortable and appropriate for them.
13. To help us to structure our teaching and constructively align learning outcomes to assessments. While 'teaching to the exam' is regarded as poor practice, it is very useful to keep in mind an overview of the various ways in which students' knowledge and skills will be assessed, so we can help students to strike a sensible balance regarding the time and energy they devote to each specific element of their study.
14. To allow students to place themselves in the overall class picture. Assessment can give students a frame of reference whereby they can compare their achievements with those of their peers. Students get a great deal of feedback from each other – more than their teachers can give them. Assessment helps them to find out how they are placed in the

cohort, and can encourage them to make adjustments to get into a better position.

15. To provide statistics for the course, or for the institution. Educational institutions need to provide funding bodies and quality assurance agencies with data about student achievement and progression, and assessment systems need to take account of the need for appropriate statistical information.
16. To lead towards a licence to practise. In some professions, a degree or other qualification is taken as a measure of fitness to practise. It then becomes particularly important to ensure that validity and authenticity are achieved in the design of the assessment processes and instruments.
17. To lead to appropriate qualifications. Unlike some overseas universities, UK universities still maintain the degree classification system. However, some universities are continuing to ponder the introduction of a no-classifications system coupled with the production of student portfolios. Meanwhile, it is vitally important that we do everything we can to ensure that the students who deserve first-class degrees gain such awards, and that all students are judged fairly on the evidence of their achievement which we assess." (Race et al., 2005, p 5-7)

Appendix D

Ethical clearance

NOTTINGHAM
TRENT UNIVERSITY

Jwaid Ali
c/o Graduate School Office
203 CELS
Nottingham Trent University

Dawn Brown
Research Administrator/JICEC Committee Officer
College Research Support Team - Art & Design
and Built Environment/Arts & Science
Nottingham Trent University, Burton Street,
Nottingham NG1 4BU
Tel: +44(0) 115 848 2301
Fax: +44(0) 115 848 4298
Email: dawn.brown@ntu.ac.uk

13 February 2013

Dear Ali

I am writing to confirm that your ethical clearance checklist was seen by Professor Michael White, chair for the Joint Inter-College Ethics Committee (JICEC) in Art & Design and Built Environment/Arts and Science on 28 January 2013, and was signed off clear on that same day.

If you have any further queries regarding the JICEC, it's methods and procedures, then please do not hesitate to contact me.

Yours sincerely

Dawn Brown
Research Administrator

Nottingham Trent University
Burton Street, Nottingham NG1 4BU
Tel. +44 (0)115 941 8418 www.ntu.ac.uk

Appendix E

Relation between total mark and average attendance (Labs, lectures)

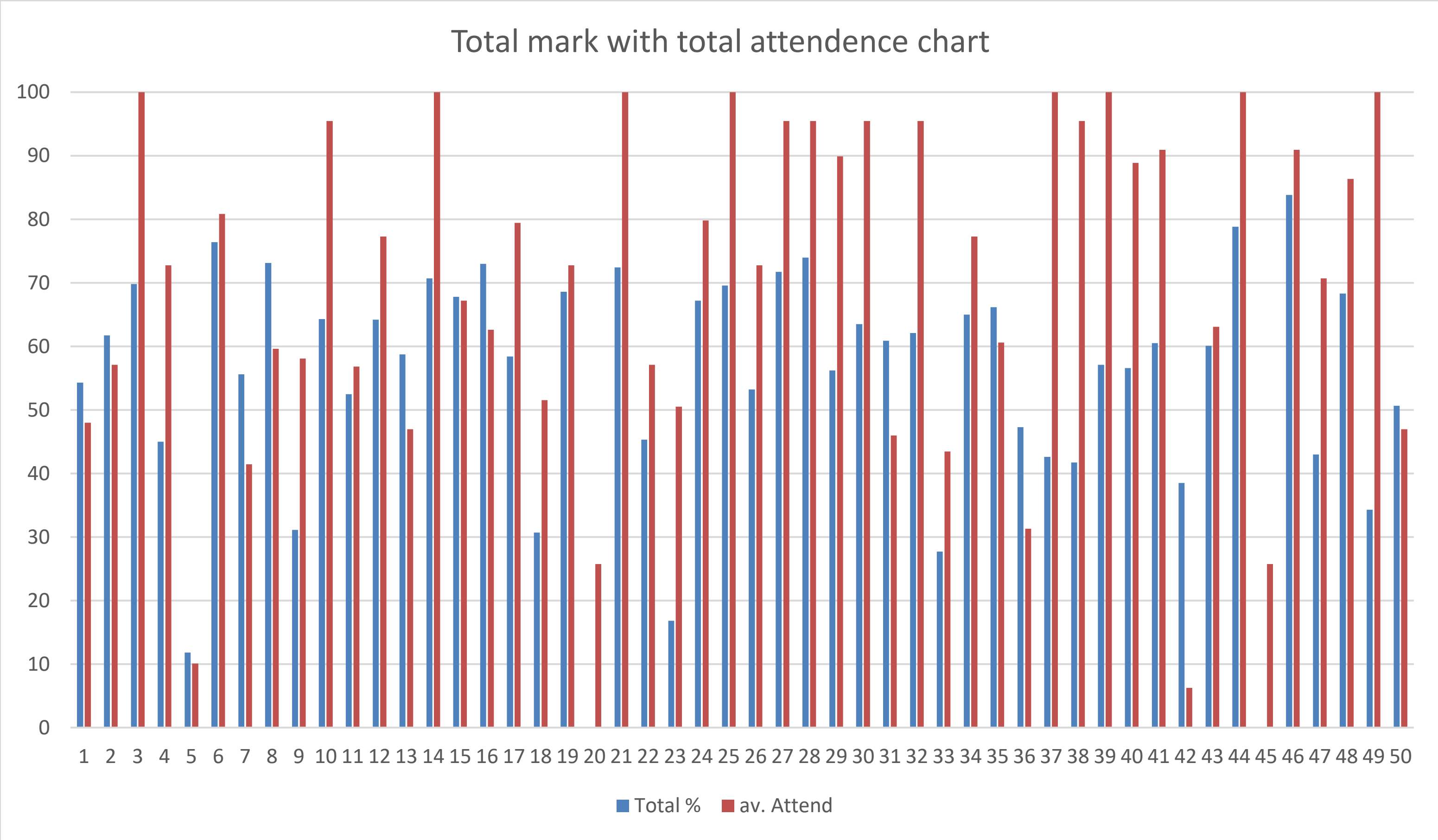


Figure F.1 in Relation between total mark and average attendance (Labs, lectures)

Appendix F

The Technology Integration Matrix (TIM) framework

	Technology Integration Matrix	Levels of Technology Integration into the Curriculum				
		Entry: The teacher uses technology to deliver curriculum content to students.	**Adoption:** The teacher directs students in the conventional use of tool-based software. If such software is available, this level is the recommended entry point.	**Adaptation:** The teacher encourages adaptation of tool-based software by allowing students to select a tool and modify its use to accomplish the task at hand.	**Infusion:** The teacher creates a learning environment that infuses the power of technology tools throughout the day and across subject areas.	**Transformation:** The teacher creates a rich learning environment in which students regularly engage in activities that would have been impossible to achieve without technology.
Characteristics of the Learning Environment	**Active**: Students are actively engaged in using technology as a tool rather than passively receiving information from the technology.	Students use technology for drill and practice and computer based training.	Students begin to utilize technology tools to create products, for example using a word processor to create a report.	Students have opportunities to select and modify technology tools to accomplish specific purposes, for example using colored cells on a spreadsheet to plan a garden.	Throughout the school day, students are empowered to select appropriate technology tools and actively apply them to the tasks at hand.	Given ongoing access to online resources, students actively select and pursue topics beyond the limitations of even the best school library.
	Collaborative: Students use technology tools to collaborate with others rather than working individually at all times.	Students primarily work alone when using technology.	Students have opportunities to utilize collaborative tools, such as email, in conventional ways.	Students have opportunities to select and modify technology tools to facilitate collaborative work.	Throughout the day and across subject areas, students utilize technology tools to facilitate collaborative learning.	Technology enables students to collaborate with peers and experts irrespective of time zone or physical distances.
	Constructive: Students use technology tools to build understanding rather than simply receive information.	Technology is used to deliver information to students.	Students begin to utilize constructive tools such as graphic organizers to build upon prior knowledge and construct meaning.	Students have opportunities to select and modify technology tools to assist them in the construction of understanding.	Students utilize technology to make connections and construct understanding across disciplines and throughout the day.	Students use technology to construct, share, and publish knowledge to a worldwide audience.
	Authentic: Students use technology tools to solve real-world problems meaningful to them rather than working on artificial assignments.	Students use technology to complete assigned activities that are generally unrelated to real-world problems.	Students have opportunities to apply technology tools to some content-specific activities that are based on real-world problems.	Students have opportunities to select and modify technology tools to solve problems based on real-world issues.	Students select appropriate technology tools to complete authentic tasks across disciplines.	By means of technology tools, students participate in outside-of-school projects and problem-solving activities that have meaning for the students and the community.
	Goal Directed: Students use technology tools to set goals, plan activities, monitor progress, and evaluate results rather than simply completing assignments without reflection.	Students receive directions, guidance, and feedback from technology, rather than using technology tools to set goals, plan activities, monitor progress, or self-evaluate.	From time to time, students have the opportunity to use technology to either plan, monitor, or evaluate an activity.	Students have opportunities to select and modify the use of technology tools to facilitate goal-setting, planning, monitoring, and evaluating specific activities.	Students use technology tools to set goals, plan activities, monitor progress, and evaluate results throughout the curriculum.	Students engage in ongoing metacognative activities at a level that would be unattainable without the support of technology tools.