2022-03-07

Interpreting Multi-stage Teaching and Learning Initiatives for Mechanical Engineering Students - A Knowledge Management Perspective for Students

Kevin Delaney
Technological University Dublin, kevin.delaney@tudublin.ie

Ger Nagle
Technological University Dublin

Mingzhu Chen
Technological University Dublin, mingzhu.chen@tudublin.ie

Recommended Citation

K. Delaney, G. Nagle, M. Chen (2022) INTERPRETING MULTI-STAGE TEACHING AND LEARNING INITIATIVES FOR MECHANICAL ENGINEERING STUDENTS – A KNOWLEDGE MANAGEMENT PERSPECTIVE FOR STUDENTS, INTED2022 Proceedings, pp. 9900-9907. DOI: 10.21125/inted.2022.2609

Funder: Technological University Dublin

INTERPRETING MULTI-STAGE TEACHING AND LEARNING INITIATIVES FOR MECHANICAL ENGINEERING STUDENTS – A KNOWLEDGE MANAGEMENT PERSPECTIVE FOR STUDENTS

Delaney, Kevin; Nagle, Gerard and Chen, Mingzhu

School of Mechanical and Design Engineering, Technological University Dublin (IRELAND)

Abstract

Encouraging students to "think differently", to "think like an engineer", to "just solve the problem" is challenging and depends upon many factors such as the prior learning and experiences of the particular students involved. Sometimes it is difficult to convince students to really engage with activities outside their own comfort zones if they cannot see the potential benefits that might accrue through such engagement.

This paper describes a paradigm, inspired by knowledge management, which the authors have used to explain the importance of engaging with teaching and learning activities to undergraduate students. More importantly it helps these students to understand how each stage of the program builds upon the previous stage, how their learning moves up the levels of Blooms taxonomy to an extended abstract level of understanding, and how this will help them be more effective engineers once they enter the workplace. It has broader significance for the students in that it helps and encourages them to critically reflect upon their learning and really consider the importance of this learning for their future.

Keywords: Engineering education, critical reflection, multi-stage learning

1 INTRODUCTION

As educators we encourage our students to "think differently", to "think like engineers", to "solve the problem(s)". We know this is challenging and that their ability to do so depends upon many factors such as the prior learning and experiences of the particular student(s) involved. Sometimes it is difficult to convince students to really engage with activities if they cannot clearly see the potential benefits that might accrue through such engagement. It can be even more complicated if students don't realise that the acquisition of experience is progressive and must be contextualised appropriately to be truly useful.

A paradigm, inspired by knowledge management, which the authors have used to explain the importance of engaging with teaching and learning activities to undergraduate students is proposed. This approach is constructed to help students understand how each stage of the program builds upon the previous stage and how their learning will progress as they approach a topic or subject from the lowest level and remember and master that, before moving on to higher levels of thinking. This reflects how students will master each stage and move up the levels of Blooms taxonomy so that they are capable of creating something original or substantially new and will be more effective engineers once they enter the workplace [1].

This work considers how we, as educators, can help our students to:

1. Understand the importance of their prior experiences
2. Develop more experiences and
3. Reflect upon these experiences to really learn from them to help them in their future careers

While not necessarily a formal learning outcome on a lot of engineering related modules, it has broad long-term significance for the students. It helps and encourages them to critically reflect upon their learning and is a programme outcome and expectation for accreditation requirements of relevant accreditation bodies such as Engineers Ireland [2] In doing so they learn to consider the importance of ongoing learning and Continuing Professional Development (CPD) activities for their future careers as engineers.

2 THE BENEFITS OF HINDSIGHT: LEARNING FROM PRIOR EXPERIENCE

The terms 'an old head on young shoulders', or 'a wise head on young shoulders' are often used to describe a young person who behaves like an older person with more experience. Employers often want to hire engineering graduates with experience since they perceive that they can make a significant contribution to the business faster; but where can our students get this experience? How can our engineering students contextualise the experience they have and perform as more experienced engineers might?

One approach is to learn from past failures, particularly ones which have caused significant loss or injury to others such as building or bridge collapses, plane and car crashes and medical device failures. There is a need to learn from such incidents; for moral, regulatory (particularly in certain highly-regulated sectors) and practical reasons. However learning should not require the occurrence of such unwanted or dangerous events which we hope are sporadic; we can, and must, learn from everyday work, education and life experiences. As engineering educators we want our students to be able to control, or at least reflect upon, their own individual learning when they graduate from University.

Many different learning styles have been identified [3]. Examples of ways of learning which specifically relate to learning directly from prior events or actions include:

1) By **discovery:** An undirected approach where people explore the problem area and try to discover facts and relationships for themselves without prior knowledge of what the objective is. Even though problem based learning is based upon the theory of discovery learning the approach is not well understood and is often considered difficult to teach.

2) By **experience:** A mark of intelligence. Experts have spent years reworking problems from different viewpoints. Experts can recall facts about a problem area very easily and very quickly compared to a non-expert. Learning by experiencing things first hand can be rather time consuming.

3) By **example**: Good for accumulating knowledge over time. Learning is based on particular structured examples, not a broad range of experience. Classroom teaching falls into this category. Learning by examples is much more efficient than learning by experience.

It is important to note that not all knowledge that a student has within his or her head can be codified or written down and it is very important that this be explained to students in a clear and coherent way. The iceberg analogy is commonly used in the study of knowledge management to illustrate that only a small portion of our knowledge (our explicit knowledge) is visible above the ocean's surface while most of our knowledge (tacit knowledge), which is typically more valuable, is not visible. This knowledge is buried in our heads and can be difficult to share since it resists being articulated. The iceberg analogy can also be extended to reflect our students' learning, at least for an instant in time, as indicated in Figure 1.

Students' formal learning, guided by course details such as module learning outcomes, is normally quite visible in the form of reports, sketches, drawings, simulations, etc that students create. We as educators can typically measure the performance of our students (relative to their peers) in creating these artifacts. Their informal learning on the other hand is much less visible, not well understood and is often difficult for us as educators to quantify. However it will typically make a huge difference to the future success of our engineering graduates once they enter the workforce. For example their ability to critically reflect on what they are experiencing will help them to question the current organisational norms and assumptions to establish a new set of norms. This continuous questioning, or explorative behaviour, will lead to new ways of working and acting.

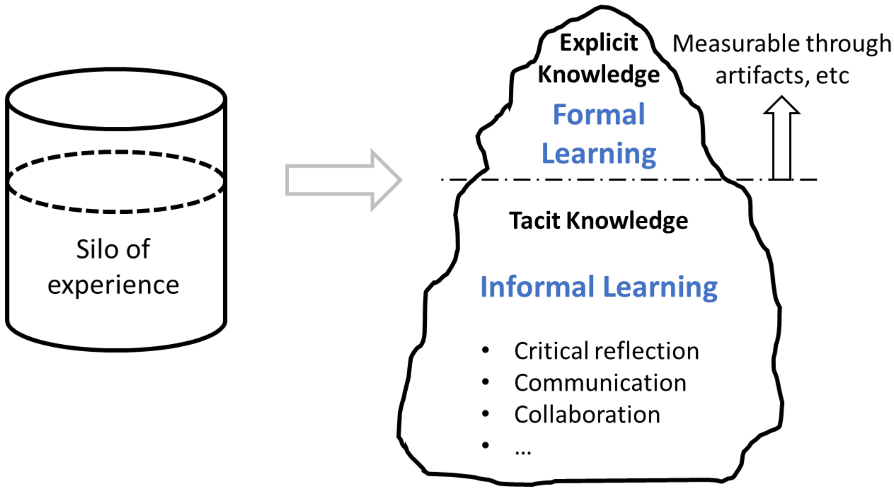

Figure 1: Iceberg analogy from Knowledge Management for formal and informal learning

Regardless of how they learn, undergraduate students often "cram" for examinations. This can lead to them developing shallow knowledge where they can readily recall knowledge that resides in short-term memory. Unfortunately this indicates minimal understanding of the problem area and is of no real long-term benefit to the students. Students don't always realise that what they learn in one stage of a program is "relevant" for subsequent stage(s). In addition, recent research suggests that undergraduates are unable to appreciate the transferable skills that employers are seeking without them being prompted [4], much less the importance of attitudes, or the normative, values-based dimension of engineering practice. Educators want them to develop deep knowledge based on the fundamental structure, function and behaviour of objects. They will acquire this through years of experience by following a structured programme of study [5].

The idea of learning sequentially through a series of smaller milestones can be seen across many different aspects of learning. For example the phrase *"Éist, tuiscint, leabhairt, léamh agus scríobh"* as written in the Irish language becomes "Listen, understand, speak, read and write" once translated into English. This lists the various phases that teachers expect children learning Irish to progress through as their proficiency improves even though they might progress through these phases at different rates. In becoming engineers students must follow a comparable series of steps or phases through which they can develop their learning as engineers.

Once students have some appropriate and valid prior experience they can use this to consider and guide their decisions regarding appropriate future actions. For example when practicing engineers design new products they typically begin by studying what worked and didn't work in the past. In doing so they might try to learn lessons from manufacturing previous products to identify best practices, which may have evolved from refining and problem solving the manufacturing processes, that could be incorporated into new designs. After analyzing prior efforts the design process begins and when the new product is complete engineers can, in turn, measure or review their experience and then refine or retain this knowledge to inform future designs. A model of this, adapted from [6], is shown schematically in Figure 2. It is important to note that this moves in time as indicated by the text "today's insight is tomorrow's hindsight".

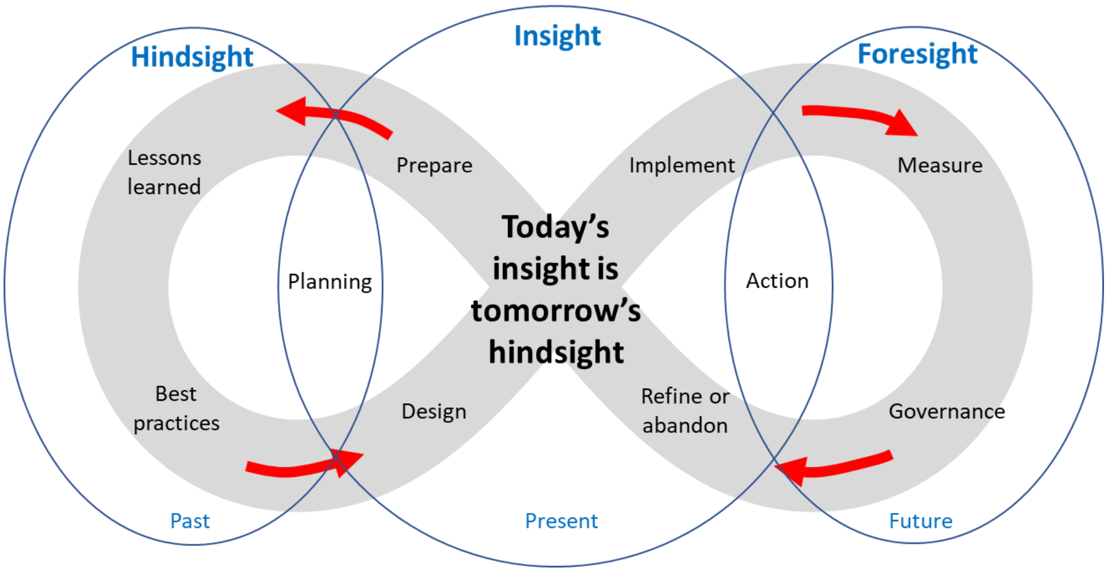

Figure 2: Model showing how a mechanical designer relies on hindsight from previous problems encountered or learnt about when undertaking new problems

This model is intuitive for engineering students and they can readily understand how it might apply at a specific instant in time. Furthermore they can understand that it applies for and can be interpreted from both an individual engineer and/or from a company or university-wide perspective.

Unfortunately the time-scale is not obvious and the model as presented is insufficient to make students fully aware of the importance of engaging with their studies over several years. Thus a new model or framework which allows students to understand how their learning is progressive and gives them the opportunity to develop self-management skills, such as active learning, is needed.

3 A KM-INSPIRED MULTI-STAGE HINDSIGHT-INSIGHT-FORESIGHT PARADIGM

To overcome the deficiencies of the model presented in Figure 2 to truly reflect how students progress through different stages during their formal learning in university a new model is proposed. For ease of understanding a single stage representation is shown first and this is then expanded to more fully reflect the real multi-stage experience of students when they study engineering over several academic years.

Single stage representation

If the students in stage 1 of an engineering course are assigned a problem to consider they will look back at their own unique set of prior experiences. They will try to learn from these past experiences and bring the best practices forward to help with the problem currently being addressed. Upon completion of the project students can reflect appropriately on what they have implemented and in so doing can create additional content for their own “store” of experience. A schematic of how a single stage of this model works is introduced in Figure 3.

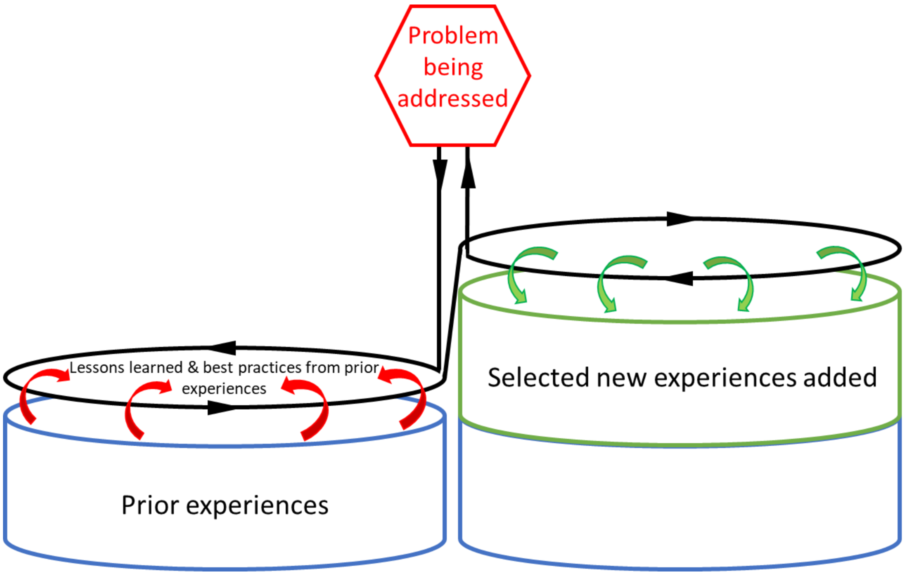

Figure 3: Single stage representation of new Knowledge Management inspired model

Multi stage representation

Once the students progress to the next programme stage they will have an increased store of experience to draw upon which will enable them to undertake and solve problems of increasing complexity. This will continue as they progress through their full programme resulting in them having a broad and accessible store of experience to draw from when they enter the workforce after graduation as shown in Figure 4.

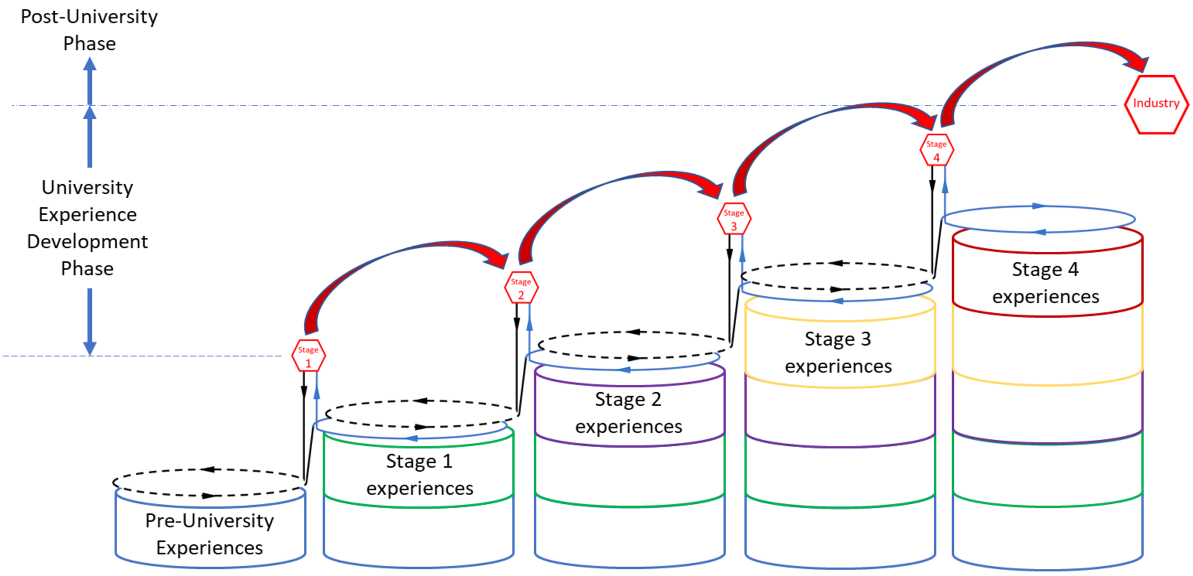

Figure 4: Expansion of model to show muti-stage representation of new proposed Knowledge Management inspired model.

It is noted that, even though the model might suggest that new experiences are only created once per year or per stage, in reality this is an ongoing continuous, or semi-continuous, process.

It is also important students be made aware that at certain times old knowledge must be discarded through a process of unlearning. “Unlearning” is defined as a process through which learners discard knowledge. Unlearning makes way for new responses and mental maps [7]. This can happen for various reasons such as changes to regulations or standards, improved understanding of the application of certain components, the availability of new tools or software, etc.

4 USING THE MULTI-STAGE HINDSIGHT-INSIGHT-FORESIGHT PARADIGM

Collaborative engagement has been identified as being integral to tackling future societal challenges, such as sustainability, which our students will need to address. Effective teamwork is critical to facilitate this and stage three mechanical engineering students in TU Dublin have been developing teamwork skills through problem based learning since 2008 [8,9]. To understand the effectiveness of their team students must reflect on their team's performance. The concept of reflecting on the performance of their team is initially introduced to engineering students (taking a module in which they design and build a small robot) as part of a gamified ice-breaker activity presented by Delaney et al at INTED2021 [10]. Table 1 reproduces a list of typical student comments reflecting on their performance from this work and is analogous to the prior experience which students might have at any point in time.

Table 1: Typical comments from student groups after reflecting on their performance

Team positives	Team negatives
Everyone got involved	Too ambitious with the size
Good use of resources	Needed a stronger base
Low centre of gravity	Should have brainstormed ideas more
Good communication	Time management was poor
Defined the problem well	Not enough sketching and planning
Good use of prototype	Poor execution of design
	Poor problem definition at the start
	Distracted by competitors presence
	Did not test enough

Having the students reflect on their work and understanding what they did well and what they could have improved upon and documenting this work (as shown in Table 1) as part of a group is very important. However it is being able to integrate these reflections into future projects that really define the effectiveness of this initiative and enable students to fully realize the benefits of this activity. The overall paradigm has been introduced to this group using a three step process as described below:

Step 1: Critical reflection of appropriate past actions

Once students are given their formal assignment, typically the week after the ice-breaking activity, they are asked to review all their experience to date and how it might align with the assignment. Students are advised to consider all their previous experience from multiple sources including part-time jobs, previous training courses, abilities and interests. Students are advised to critically reflect on everything they feel might be useful such as the attributes of people who were very effective and also to probe why projects they were involved with were successful. Typically their experience from the ice-breaking activity the week before features highly in their considerations. The outcome from this step is typically a list of advice which is considered to be relevant for the assignment being undertaken. Lecturing staff have an important role as facilitators and advisors but deliberately try not to interfere in what the students are doing.

Step 2: Integration into current activities to solve problems

In this step the students must actually try to follow their own advice as they progress to prepare and plan their future activities. It is noted that initially only half of the model, representing the use of prior experiences to plan for the future, is shown to the students. This is shown schematically in Figure 5.

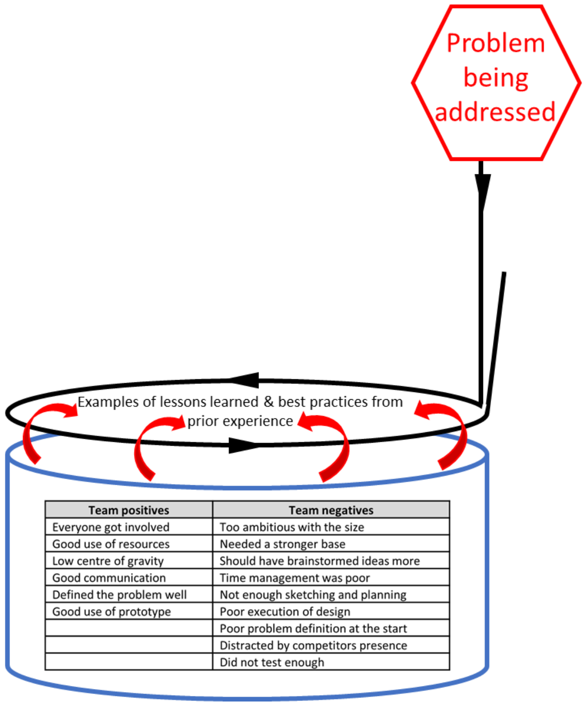

Figure 5: Half of one stage of the model representing use of prior experience to plan for the future.

<u>Step 3: Critical reflection, selecting and storing experiences for future use</u>

As the project progresses students are expected to deliver a series of intermediate milestones. As part of the submissions for these formative assessments students are encouraged to consider and reflect on their own performance with a view to considering how they can improve their performance as they move towards the next milestone. Once the project has been completed, hopefully successfully, the students are again encouraged to reflect on their performance throughout the overall project and consider the experiences that are worth integrating into future projects. These new experiences can then be added into the students' personal store of experience as shown schematically in Figure 6.

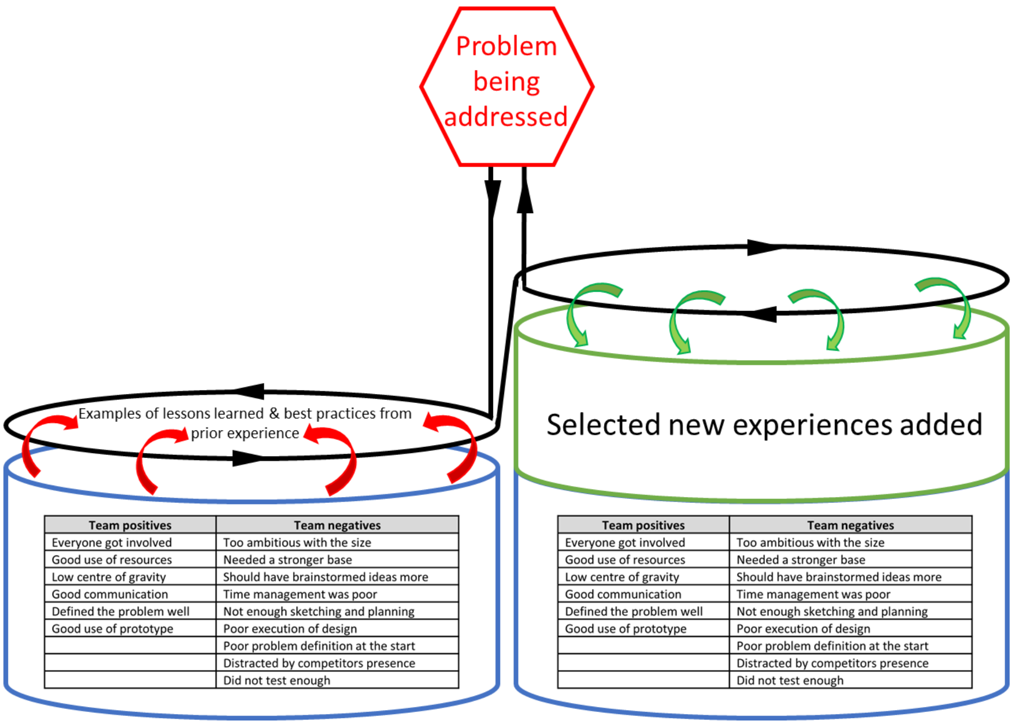

Figure 6: Showing how certain experience from undertaking the project is used to create new experiences for the student's "experience store"

4 DISCUSSION

As educators we must facilitate our students to develop both their formal and informal learning. It is hoped that exposing our students to the theory behind why they should consider, and indeed manage, their education will help them in their future careers. This is not to pretend they have experience when they don't, but to be able to contextualise their learning and experience more appropriately; in so doing they will become more effective engineers.

Benefits achievable by learning from past experiences have been repeatedly mentioned in this work, but it is important to note the potential risk of hindsight bias. This is the belief that someone might have that they could have more accurately predicted past events than is actually the case [11]. Essentially it is where knowing what has actually happened can degrade the evaluations of forecasts. The hindsightful judge possesses outcome knowledge and knows how things actually turned out whereas the foresightful judge does not. This can reduce forecasters' ability to learn from experience. Ambiguous forecasts which lack clarity and detail also make it difficult to know what was really predicted and how accurate those predictions were.

5 CONCLUDING REMARKS

The set of models, theories, assumptions, and ideas presented will contribute to the worldview of our students and create a framework from which they can operate every day to improve their learning. As such it will constitute a paradigm that will serve as a foundation of how the students can view or interact with the world around them and through which the students will learn the value of CPD for their entire careers.

In conclusion it is hoped that our students will have the hindsight to know where they've been, the foresight to know where they are going (to think about, debate and shape the future), and the insight to know when they have gone too far!

ACKNOWLEDGEMENTS

The authors acknowledge funding made available through the TU Dublin Engineering and Built Environment programmes' Teaching Champion Awards for the academic year 2021/22 which facilitated part of the work presented here.

REFERENCES

[1] L.W. Anderson, D.R. Krathwohl, P.W. Airasian, K.A. Cruikshank, R.E. Mayer, P.R. Pintrich, M.C. Wittrock, *A taxonomy of learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.* New York, NY: Longman (2001).

[2] D. Owens and R. Manton, "Accreditation requirements", 21 January 2021. Retrieved from https://www.engineersireland.ie/listings/resource/519.

[3] D.A. Kolb, D. A. *Experiential learning: Experience as the source of learning and development.* New Jersey: Prentice-Hall (1984).

[4] M. Hill, T. Overton, C. Thompson, R. Kitson, P. Coppo, "Undergraduate recognition of curriculum-related skill development and the skills employers are seeking". *Chemistry Education Research and Practice (2018).* https://doi.org/68-84 10.1039/C8RP00105G

[5] D. Leonard, 29 September 2016, "Develop Deep Knowledge in Your Organization — and Keep It" *Harvard Business Review*. Retrieved January 11, 2022, from https://hbr.org/2016/09/develop-deep-knowledge-in-your-organization-and-keep-it

[6] R.J. Frid, *Frid Framework for Enterprise Knowledge Management: A Common KM Framework for the Government of Canada.* Lincoln, NE: iUniverse (2004). ISBN-10: 0595306993 ISBN-13: 978-0595306992

[7] B. Hedberg, "How Organizations Learn and Unlearn," In: P. Nystrom and W. Starbuck, Eds., Handbook of Organizational Design: Adapting Organisations to Their Environment, New York: Oxford University Press, Oxford, 1981, pp. 1-27

[8] K. Delaney, and J.B. Kelleher, "Real-World Process Design for Mechanical Engineering Students: A Case Study of PBL in DIT", 2008. https://arrow.dit.ie/engschmeccon/16

[9] K. Delaney, and G. Nagle, "Teaching Approximations of Mechanical Engineering Practice through Designing and Building Robots: An Approach Inspired by Monozukuri". WERA 2019,Tokyo (Japan) 5th-8th August 2019. doi:10.21427/3r4d-jx53

[10] K. Delaney, G. Nagle, and M. Chen, (2021), Gamification of Icebreaking Activities for Mechanical Engineering Students Embarking on a Problem Based Learning Module. *INTED 2021,* 8-9 March 2021. doi: 10.21125/inted.2021.2221

[11] B. Fischhoff, B. Hindsight is not equal to foresight: The effect of outcome knowledge on judgment under uncertainty. *Journal of Experimental Psychology: Human Perception and Performance, 1*(3), 288–299 (1975). https://doi.org/10.1037/0096-1523.1.3.288