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Transformative learning in engineering education: the experiential learning factor

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ABSTRACT: Transformative learning in engineering education has been rarely investigated, but it is a very important subject worthy of greater research. In a qualitative study on transformative learning in engineering education, the authors of the present article uncovered several transformative learning outcomes and the factors that caused them [1]. The outcomes were: improved people and relational skills, project management ability becoming second nature, changes in ways of thinking and increased resilience. The factors that caused them were: the need to break out of comfort zones, the need to have crucial learning experiences, which were experiential in nature, and the importance of staying motivated throughout the entire process of transformation until completion. This present article focusses on one of these factors in more detail; namely, the crucial role of experiential learning. The authors' considerations presented in this article, which constitute a new research contribution, are supported by the interview data from their earlier study [1].

Keywords: Transformative learning, engineering education, experiential learning, extracurricular activities, project-based learning, qualitative study

INTRODUCTION

In addition to technical competencies, non-technical competencies are also deemed to be crucial by various engineering education initiatives in order to equip engineering graduates to become engineers capable of confronting the complex challenges facing all of humanity in this 21st Century [2-4]. Some of these challenges were identified by the United Nations Sustainable Development Goals [5] and the 14 Grand Challenges for Engineering by the National Academy of Engineering (NAE) [6], and others.

In view of this, a study was undertaken by Tien et al on the factors that promote transformative learning (TL) in engineering students [1]. The findings revealed that TL was supported by three factors. These are the breaking out of comfort zones, the need to have crucial learning experiences, which were experiential, and in being able to stay motivated throughout the process. The TL outcomes facilitated by these factors were recognised as new and different ways of thinking, improved people and relational skills, project management ability becoming second nature and improved resilience.

In this article, the authors expand on the discussion of the role of crucial learning experiences which are experiential in nature. A discussion regarding how to apply this factor in an engineering education context is also included. This latter aspect was not previously elaborated. The educational theory that is associated with this factor is the experiential learning theory (ELT). A brief introduction to ELT follows.

Experiential learning was popularised by David Kolb. He defined it as …*the process whereby knowledge is created through the transformation of experience* [7]. The central role played by experience in knowledge creation differentiates experiential learning from learning that is mainly undertaken for the purpose of passing a written examination. Prior to Kolb, ELT was not formally named although the concepts of learning from experience were known. Kolb built upon the work of others before him such as John Dewey, Kurt Lewin and Jean Piaget [8].

Whenever ELT is mentioned, it will often lead to the mention of the Kolb cycle as Kolb's ELT model is very well-known. According to Kolb and Kolb, ELT is applicable in all areas of life, not just in the classroom because experience is considered as the source of learning [9]. The Kolb experiential learning cycle is defined as a recursive process consisting of four leaning modes, i.e. concrete experience, reflective observation, abstract conceptualisation and active experimentation [10].

According to the Kolb model, there are two dialectically opposed dimensions of learning, i.e. that of grasping the experience and that of transforming the experience. The grasping experience dimension encompasses the learning modes of concrete experience and abstract conceptualisation. Concrete experience is characterised by the more intuitive, unconscious ways of knowing, whereas abstract conceptualisation entails more rigorous and structured ways of thinking. The transforming experience dimension on the other hand comprises the learning modes of reflective observation and active experimentation. Reflective observation represents learning through careful observation, while active experimentation is about learning through active, practical applications [11].

In the Kolb cycle, concrete experiences are reflected upon which would then lead to these reflections becoming abstract concepts through conscious thought. These concepts are then actively tested in new situations, where they serve as guides in creating new experiences [11]. According to Deslauriers et al learning may start at any point in the Kolb cycle and it need not necessarily end after active experimentation [12]. The suggestion is that there is no starting or ending point in the Kolb cycle, but that it should be considered as a recursive model.

Subsequent to Kolb, Jarvis likewise made helpful contributions to ELT. Unlike Kolb who focused on the individual, Jarvis expanded his ELT to include the way that individuals learn in a social context which he termed as their *life-world* [13].

For Jarvis learning from primary experience occurs in this manner: unlike children to whom almost all things are new, adults live much of their lives in a taken for granted life-world [14]. When they encounter a disjuncture in their life-world, for example a new sensation or a new experience, they will attempt to get their disjuncture resolved. They do this by giving meaning to the sensation. As they resolve this disjuncture, the answer will be influenced by the life-world or the social context in which it has occurred. Once the answer is found it must be practiced and repeated to commit it to memory. Upon committing the socially acceptable answer to memory, the person will take their life-world for granted again. At this point the disjuncture is no longer new, but has become part of the person's taken for granted life-world [14][15].

According to Jarvis the key to such learning is the experience of a disjuncture from which all learning arise [16]. This concept of a disjuncture appears to bear some similarity to Mezirow's disorienting dilemma that undergirded the comfort zone factor [17] found in the study by Tien et al [1][18]. However, Jarvis's concept of a disjuncture is far more general in its occurrence and does not need to be particularly discomfiting as Mezirow's disorienting dilemma does.

Dyke summarised Jarvis's conception of learning from everyday life as follows: …*a person enters a learning episode or a learning cycle from his or her life-world, the social context of their learning where they may have experience disjuncture between past experience and their current situation. The person will transform that new experience through reflection, emotion and action* [13]. Reflection is an important part of experiential learning as it is the emotional element that is frequently required to drive change and action.

While most ELT literature focused on learning from primary experiences, Jarvis felt the need to appreciate the role of secondary experiences as well [19]. Secondary experiences involve learning from others through the medium of language be it through lectures, discussions, debates, etc, or through audio-visual media. Whereas primary experiences may occur anywhere and in all areas of daily life whether individually or through group interaction. It could also be gained through structured educational activities if these had made provisions for experiential learning [13].

Furthermore, Jarvis acknowledged the growth potential in practical wisdom through experiential learning [20]. It is worth stating that there is a difference between knowing about wisdom and being wise. Jarvis contended that formal education is limited to providing learners with the knowledge of wisdom, whereas experiential learning provides learners with the opportunities for growing in wisdom, i.e. in becoming wise.

Aristotle distinguished between two types of wisdom, i.e. philosophic (theoretical) wisdom and practical wisdom. Theoretical wisdom is the …*scientific knowledge, combined with intuitive reason, of the things that are highest by nature* [21]. On the other hand, with regards to practical wisdom, Aristotle opined that …*Anaxagoras, Thales, men like them have philosophic but not practical wisdom, when we see them ignorant of what is to their own advantage, and why we say that they know things that are remarkable, admirable, difficult, and divine, but useless; viz. because it is not human goods they seek* [21]. For Aristotle practical wisdom requires knowing how to live well and this goes beyond the mere acquisition of knowledge.

Aristotle was of the opinion that practical wisdom can only come with age through life experiences because …*while young men become geometricians and mathematicians and wise in matters like these, it is thought that a young man of practical wisdom cannot be found …but a young man has no experience, for it is length of time that gives experience* [21].

Nonetheless for Jarvis, it is not as much a matter of a person's age, but rather it is his or her learning from experience that provides the basis for practical wisdom to grow. Experience is undoubtedly related to age, but this need not always have to be because it is the circumstances of life that provide learning experiences and sometimes even young people can be referred to as being …*wise beyond their years* [20].

METHODOLOGY

This is a qualitative study that adopted the interpretivist/constructivist epistemology, the basic qualitative study methodology and purposeful sampling of participants who were selected for semi-structured interviews. The analysis of the interview data was performed according to prescribed qualitative procedures. The methodology is discussed and justified in papers by Tien et al [1][18].

RESULTS AND DISCUSSION

Learning that leads to transformation tends more often than not to be more than theoretical. It will likely have an experiential dimension. Unlike the comfort zone factor discussed by Tien et al crucial learning experiences, which are experiential do not need to compel a participant to come out of his or her comfort zone, but they are nonetheless transformative [18]. Hence, this theme departs from the breaking out of comfort zone theme. The theory that supports this theme is the experiential learning theory, while the transformative learning theory supported the comfort zone theme [18].

These crucial learning experiences, which are at the core of the experiential theme may be defined as follows:

Learning experiences that are primarily experiential in nature, which are able to cause a shift in a transformative learning outcome, but do not involve the discomfort of leaving one's comfort zones.

The subthemes identified included that of working with people, communicating, fully experiencing a real project, stepping out of disciplinary boundaries, applying knowledge gained in class to real projects, working with people, communicating, and experiencing different cultures and experiencing a different work ethic. Secondary learning experiences, such as learning from others' experiences are also included in this category. A sample of participants' interview responses are examined below.

Interview participant three (IP3) and interview participant five (IP5)'s responses show that there are many aspects of learning that can only be experientially learned. The transformative learning mentioned by IP3 and IP5 came from repeated experiences in project-based learning modules (PjBL), and therefore they had the opportunity to learn through each experiential learning cycle [10]. The learning cycle is repeated each semester as there were PjBLs to undertake each semester. These experiences may be regarded as transformative because they are significant to the participant and resulted in TL outcomes in self, epistemology and behaviour [22]. The PjBLs mentioned here are standalone modules that are fully project-based and not merely a project assignment within a module.

I actually find it helpful in the sense that I get to be involved in a lot of projects. I learn how to manage in a group, how to manage my project, the time management and all those. There are some skills I think you cannot learn from a textbook but you have to learn it from experience. - IP3

I mean to do that it is not something you can really learn. It is something you should really need to practice in order to actually master it. So, doing the design project, especially in doing that, after doing three design projects, I think with the number of repetitions, you get to instil those the CDIO [conceive-design-implement-operate] framework [principles] into the student better. - IP5

It is essential to include experiential learning to deliver a variety of crucial learning experiences. Such experiences can usually be found in the PjBL modules.

Because if we just learn it by theory, by just reading it, you do not get to practice it. It only gets instilled once I tried applying it on my own, and not when I am …I mean not during class or not during the tutorial but using what I learnt in class when I am doing something on my own which is the project. - IP5

Interview participants six and nine (IP6 and IP9) both emphasised the need to repeat an experience until a difficult experience became easy to them. Such skill improvement can also be considered as a transformative learning as it relates to the TL outcomes in self and behaviour [22].

As a member of Taylor's Racing Team (TRT), IP6 was able to apply experientially what she had learned in the classroom to the design of their race car.

And then having bits where we can put our learning into actual practical examples, it is actually very helpful …not just one time to do it, but like over and over again, and became like second nature. - IP6

Because we learn a lot in class like theory, lots of theory. Then I do not remember most of it, except the ones I actually use it in TRT …I still remember how to do FEA [finite element analysis]. I still remember how to do CFD [computational fluid dynamics] because we used it, most of the time …it is those kind of things because we practice in an actual context, in designing the car. - IP6

For IP9, it was in AIESEC (an international youth organisation with a chapter at Taylor's University) making cold calls to source for sponsorship. Repeating the experience is the key. This is where the Kolb cycle comes into play,

i.e. concrete experience, reflective observation, abstract conceptualisation and active experimentation [10]. Even though the participant may not always be consciously aware of the cycle at work, he or she would nonetheless be applying it at a subconscious level.

I think the main reason because you have done it like, I think I clocked out 1,200 calls in AIESEC; so, you get used to it. Once you get used to it, it is pretty easy to do, yeah, just that first few steps [were hard]. - IP9

The benefits of experiential learning are often realised later because they may escape the students' attention, while they were still actively engaged in the learning process. Interview participant eight (IP8) was a chemical engineering (CE) student who interned at an air conditioner manufacturing plant. Air conditioners are related to mechanical engineering, but she was a CE student. The experiential learning she had undergone as part of her PjBL modules and her extracurricular activities (ECA) helped transformed her sense of self [22] and increased her confidence, something which she only realised during her internship at the air conditioner plant.

I was just assigned a task to dissemble or assemble the parts, I was like okay, I will do it. Then you know, when they saw me, I was able to carry it and do it by myself, and not asking for help. Their first impression, a girl is doing mechanical work. Then their mind gets blown. Then they see a chemical engineering student knows all this. I would say, in truth, chemical engineering did not teach me this. It was the projects that taught me this. - IP8

Maybe all this while they had interns which did not know how to handle these kinds of things, but all these projects, and ECA, they sort of help me to I would say, have my own impression [at the company]. By the second and third week, even my supervisor was …he was very happy with my work as well. He was like, no, at first he could not believe that I could, does not look like I am a CE student. He just looks [at me] like a junior engineer who just joined his team. - IP8

Because when I was working with another fellow intern who was from a different university, mechanical, also a girl, I felt that there was so much of difference between the both of us. I was there only for three months. She was there three months earlier than me …I built the trust with my supervisor that he could give me independent project based in Singapore within the three months …while that girl was still doing laboratory work [at the plant]. - IP8

Even a humbling experience may have a transformative effect. IP9 participated in a community service activity, where students had to work in teams to mentor groups of underprivileged children, teaching them to design and build a product that they would need to present at a competition before a panel of judges and an audience.

Six people [IP9's team] trying to make a bubble machine work; it took like, two weeks to do it and the kids took like, two days to do it. It puts into perspective that you should not over think stuff and do not underestimate that even small kids could be very smart. That tone down my ego a bit …it is a humbling experience basically …having that is great because at first, all of us think that, okay, this is a CSR module, we should not focus so much on it. But, it turns out to be the most rewarding in terms of self. - IP9

In this instance, a Jarvis' disjuncture [14][15] rather than a disorienting dilemma had occurred for IP9 [17][18]. The concept of disjuncture by Jarvis is more general, can happen in everyday life and does not need to be very discomfiting as Mezirow's disorienting dilemma does. A disjuncture when properly processed is transformative. In this instance IP9 experienced a transformation in his worldview regarding underprivileged children and social work because of this disjuncture that he had experienced [22].

A personal experience in a different country and culture is very valuable for experiential learning as it is capable of creating a Jarvis' disjuncture in the students' life-world. An example is given by interview participant ten (IP10) who undertook a study trip to Japan as part of a Taylor's Grand Challenge Scholars Programme (TGCSP) requirement [23].

It is a totally different culture than what we are used to. We visited their schools, universities, we found out it was very different. And these Japanese, they focus a lot on renewable energy, in Malaysia we do not …we do not see it. It makes you think about why we cannot do this back home. - IP10

I think that is the most impactful one, being able to absorb their different ways of doing things. Because they are …like their university …they had new buildings and they were thinking how to utilise renewable energy in their new buildings, like they want a new library, so they will think of, oh we will use solar energy, we will use wind energy, we will conserve the water, they collect rain water. They will think of all sorts …how renewable energy plays a role in every building …It is not about how do we make this building more eco-friendly. It is more of how do we build this building in an eco-friendly way. They thought of this from the start of design. - IP10

IP10's perspective regarding the potential for more widespread application of renewable energy was transformed in a very real way through his study trip in Japan. Such exposures tended to transform a person's worldview [22].

Jarvis believed that through experiential learning a learner would be provided with the opportunities for growing in practical wisdom [20]. Growth in practical wisdom could be observed. Referring to interview participant two's (IP2)

excerpt presented by Tien et al, where she commented on her tolerance developed as a result of handling difficult team members, this tolerance can be considered as an example of practical wisdom in dealing with difficult people [18].

Likewise, interview participant four's (IP4) excerpt below, where he remarked about being able to stay calm in a crisis when everyone around him was stressed, may also be regarded as an example of practical wisdom in facing sudden crises. Knowledge about wisdom may be taught in a classroom, but being wise can only come from experience.

Yes, in a sense that if, whenever all this project-based learning or even extracurricular activities, whether we are having a project or event, there is bound to be crisis, even if we plan everything perfectly. Not everything is going to be perfect, sometimes the machine breaks down or something in the event might not show up or what not. - IP4

So, one thing that really changed me is crisis management. So, even if let us say I am taken out of the university, whenever I see a crisis let us say at home, my mom is frantic, my grandma is panicking, my father is being angry because everyone is panicking, I always act normally. I am the only one that is calm at home trying to manage everyone, because of crisis management. - IP4

Experiences need not always be first-hand. They could also be vicarious. Jarvis called for a greater appreciation of secondary experiences in experiential learning [13][19].

Interview participant eleven (IP11) acknowledged the distinction between book knowledge, which he believed he can learn on his own, versus the experience that a lecturer can offer him.

I came to the school, not only to learn the knowledge, the book knowledge. The book knowledge is easy, you can just read the slide and then you learn by yourself at home. What I want to learn is the experience or knowledge that is already experienced by those lecturers in the past. Because they have experience, so you can ask about their experience or their opinions, about how they think about some stuff or the future. - IP11

A similar remark was made by IP8 who spoke about learning from the experience of the industry speakers invited to give those talks on campus.

Experience wise …it was really connecting us to the outside world, especially we were meeting people who are in the industry. Our lecturers would bring them to give us talks …Initially we bring the project just based on the textbooks and calculations and what not, and then when you speak to them (the people from the industry), you realise there were so much of real-life criteria that you just have to pay attention to. - IP8

Crucial learning experiences which are experiential are effective for transformative learning. These are usually primary experiences, but secondary experiences should not be entirely left out. These transformative outcomes are mostly associated with the soft skills components considered essential by various engineering education initiatives. However, this in no way suggests that classroom learning is unimportant.

Engineers need to be fully equipped with the essential theoretical and technical knowledge. Nonetheless, their classroom learning should always be supplemented, wherever possible, with a diversity of crucial learning experiences.

To Facilitate Crucial Learning Experiences which are Experiential

From the interview responses, crucial learning experiences that do not necessary require breaking out of comfort zones may be further grouped as follows:

1. An experience in a foreign country and culture.
2. Working and interacting with peers who are not from engineering.
3. Participating in an activity where the members have a certain *culture* or *ethics*.
4. Participating in community service.
5. Applying theory to real-life practical applications.
6. Learning outside of one's discipline.
7. Curricular modules that are perspective transforming in content and/or delivery.
8. Repeating an experience past the comfort zone stage (when it is no longer a comfort zone issue but the participant continues with it).
9. Working on something hands-on and practical.
10. Secondary learning experiences which are significant.

For item 9, which was about working on something hands-on and practical, IP3 felt that the hands-on skills he learned in the laboratory were useful during his industrial internship. From his internship, he managed to pick up more hands-on skill, which he believed would be useful to him as a fresh graduate engineer in future. This positively affected his confidence level and his perceived identity as an engineer, which he considered as someone who also possessed the skills and not just the certificate.

Because if you only get it from the book, you only know what you think you know but because it is not what happened, right? You think, oh, this will go this way, this will go that way, but if you do hands-on, if it does not go that way, you do not know what is happening anymore. I would feel that way. So, hands-on experience is actually quite important for me. - IP3

But the confidence level, it might just bring you …like you feel like you are …you have a paper but you are not living up to it. - IP3

IP3's perception is supported by a study conducted by Sianez et al that found that technology and engineering students perceived they will learn more through hands-on compared to hands-off activities [24].

ECA may serve as a means of delivering crucial learning experiences, as well as deliver many other benefits to students. The benefits of ECA participation are manifold. According to Cox et al, ECAs play an important role in the leadership development of engineering students [25]. Young et al affirmed the role of ECA in the development of teamwork, lifelong learning, communication skills, reflective behaviour and professionalism in African-American engineering students [26]. Fisher et al attempted to link different ECAs to different professional skills of engineering students [27].

Mariasiu and Raboca reported that automotive engineering students involved in race car competitions gained professional skills and relevant technical, social and behavioural competencies [28]. All these benefits could likewise be observed to be gained by the interview participants in one way or another.

A couple of further examples regarding the use of ECA in delivering crucial learning experiences can be found from the following interview excerpts.

Of course, in my terms of leadership, I will say that I did take up like the Vice President role [in AIESEC] after this crucial moment where I take note myself as a person. As I take up these roles, became the Vice President, it was very interesting …I was required not to only work with those from Engineering School, but I met a lot of different people from the different schools and different perspectives, to groom me as a better person individually, better person and better leader. – IP1

I think one of my most significant experiences in the engineering programme, in my Foundation I joined several competitions under the Robotics Club, and when I was in my undergraduate programme, I had opportunity to go Japan, to go to the CDIO Academy to meet different people from different countries, all about using the CDIO framework in education. - IP4

The challenge facing engineering educators is not just in how to identify, design and deliver transformative learning experiences through ECA within the School, but also in how to encourage more engineering students to participate in these ECA. Furthermore, ECA participation should not be limited to those ECA within the School, but should also include ECA that are available throughout the University.

A previous suggestion was to link ECA participation to a scholarship programme or a certificate of attainment [18]. A further suggestion would be to make ECA compulsory by including it into the credit hours of the programme, ideally every semester. This way the students will participate in at least one ECA each semester with the opportunity to experience a variety of ECAs over the course of their study. To avoid the students taking their ECA lightly or for it to be considered as a burden, students should be provided with the appropriate support to identify the ECAs that align with their intrinsic interest or their life mission and with the skills and attributes that they desire to develop.

Opportunities should also be provided for learning experiences in a foreign country. Under the recently introduced New Curriculum Framework (NCF) at Taylor's University, a one semester of global mobility option is available. However, this option was not available for these interview participants who studied under the old curriculum framework. If such an opportunity is available, students should be encouraged to take it. Likewise, interdisciplinary exposure is available through the free electives offered under the NCF and students should be likewise encouraged to take these. The community service module will soon transition into an inter-school service-learning module, and this too will help deliver crucial learning experiences by exposing engineering students to the worldview of their non-engineering counterparts through having them work and serve together.

Project-based learning will continue to play a vital role in delivering crucial learning experiences, even for experiences that do not challenge a student's comfort zone. The PjBL's importance cannot be overemphasised. Nonetheless there are concerns that experiential learning approaches, which would necessarily also include PjBL, may not be as effective in helping students master knowledge fundamentals compared to the traditional teaching approach [29]. However, this is often not an *either or* prospect. Usually engineering fundamentals are fully taught in core modules, where students must pass written examinations rather than being learned in the PjBL modules. The PjBLs on the other hand allow the students to put these fundamentals into practice, thus making them real and relevant through experiential learning. The PjBLs mentioned in this study are standalone modules that are fully project-based [30] rather than a project assignment within a module.

CONCLUSIONS

A qualitative study had found that crucial learning experiences experiential in nature were capable of engendering transformative learning outcomes in engineering undergraduates. The transformative learning outcomes sought were those that mainly involved soft skills, although not entirely limited to it as reported earlier by Tien et al [1]. The factors that produce these outcomes were the need to break out of comfort zones, the need to have crucial learning experiences experiential in nature and the importance of staying motivated throughout the process of transformation [1].

These crucial learning experiences factor differed from the comfort zone factor in that the former involved experiences that do not entail students leaving their comfort zones, and which were experiential in nature, were further discussed. Hence, the ways to facilitate them were considered in this article. The entire discussion was supported by interview responses based on an appropriate qualitative research methodology.

To conclude, crucial learning experiences may occur in diverse ways with extremely beneficial transformative learning outcomes. Their occurrences cannot be left to chance, but opportunities for them to happen must be wisely and deliberately crafted into an engineering student's educational journey throughout his or her brief sojourn at the university.

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