LIFELONG LEARNING AS EXPLICIT PART OF ENGINEERING PROGRAMMES: A CASE STUDY

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ABSTRACT

Today's workplace is characterized by continuous technological advancements and shifting requirements in the labour market, increasing the need for lifelong learning (LLL) competencies for engineers. By focusing on LLL in the curriculum, engineering students are made aware of the importance of LLL competencies, preparing them for their future as an engineer in the working field. To carefully and concretely formulate learning outcomes is considered good practice in education, especially for professional competencies. In this study, the learning outcomes of three engineering specialisation tracks were analysed. Firstly, the learning outcomes are mapped against five LLL competencies, namely (1) self-monitoring, (2) locating and scrutinizing information, (3) self-reflection, (4) creating a learning plan and (5) willingness, motivation, and curiosity to learn. Secondly, heat maps were created to visualise cold and hotspots of learning outcomes on LLL throughout the engineering programme. In line with the general view that professional competencies are only occasionally integrated into learning outcomes, findings show that LLL competencies are not fully embedded in the learning outcomes. Two out of five LLL competencies, namely creating a learning plan and willingness, motivation, and curiosity to learn, are not present in any of the learning outcomes. Additionally, hotspots of learning outcomes on LLL are limited to the first and/or final year of the programme. This case study is a first step towards enhancing our knowledge on how LLL is implemented in learning outcomes. The selected mapping technique and heat map visualisation can be used in future work to evaluate study programmes and to inform curriculum development.

KEYWORDS

Lifelong Learning, Engineering Education, Curriculum, Competencies, Learning outcomes, Standards: 2,12

INTRODUCTION

Lifelong learning (LLL) in the workplace has become increasingly more important during the last century and its importance will only increase further (Mourtos, 2003; Uden & Dix, 2004). Changing worldviews and technological advancements require employees to continuously update their knowledge, skills and attitudes (Uden & Dix, 2004). In a field like engineering, where technology and science play a central part, LLL is even more vital (Martínez-Mediano & Lord, 2012). By the time students graduate, parts of the course content will be dated or incomplete (Uden & Dix, 2004). Today, higher education institutions are faced with the challenge of preparing engineering students for a life full of learning (Cheah et al., 2019; Martínez-Mediano & Lord, 2012; Uden & Dix, 2004).

Lifelong Learning and Higher Education

Higher education curricula need to be developed in accordance with the society and workplace engineering students end up in (Peat et al., 2005; Walkington, 2002). Considering the importance of LLL, higher education institutions have a responsibility to prepare engineering students for LLL in the workplace (Cheah et al., 2019; Martínez-Mediano & Lord, 2012; Uden & Dix, 2004).

Traditionally, engineering curricula have focused on the transfer of typical engineering competencies, such as technological and scientific knowledge. Today, the core function of education is no longer restricted to the transfer of field-specific knowledge. Professional competencies and more specifically LLL receive more attention in the curriculum and are increasingly becoming a central part of education (Kovacs et al., 2020; Martínez-Mediano & Lord, 2012; Yap & Tan, 2022).

Learning Outcomes

The first step in implementing LLL in an engineering programme, should be to include learning outcomes containing LLL competencies. Learning outcomes are the explicit written goals for each course within a programme. They indicate what the student should know and be able to do after completing the course (Adam, 2008). Learning outcomes support the recent focus on student-centred education as opposed to teacher-centred education (Fitzpatrick et al., 2009; Kennedy, 2006). In the latter education is structured in terms of which practices a teacher is going to use and what content they will be teaching. Learning outcomes follow a student-centred approach by focusing on outcomes for students.

Historically, learning outcomes were slowly introduced during the Bologna process (Gaebel, M., Zhang, T., Bunescu, L., & Stoeber, 2018). Initially, learning outcomes were mentioned sporadically in ministerial communiqués on mobility and cooperation in tertiary education, such as the Berlin communiqué of 2003. Learning outcomes were first introduced as mere tools to internationally compare educational programs, but later they became central to the student-centred and outcome-based philosophy of the Bologna reforms (Adam, 2008). Today, learning outcomes are a standard in all universities in the European Union (Kennedy, 2006).

Establishing clear learning outcomes has a positive impact on education for both lecturers and students (see Kennedy, 2006 for an overview). For lecturers, the learning outcomes provide a clear framework to guide curriculum and course design (Adam, 2004, 2008; Jenkins, Alan & Unwin, 2001). For students, they create more accurate expectations of the content of courses (Adam, 2008; Fitzpatrick et al., 2009; Jenkins, Alan & Unwin, 2001). The student-centred nature of learning outcomes also puts students at the centre of their learning process which can increase motivation, responsibility and enthusiasm for learning (Adam, 2004; Maher, 2004). In the context of international education, which was the original focus of the Bologna reforms (Gaebel, M., Zhang, T., Bunescu, L., & Stoeber, 2018), learning outcomes also increase the comparability of course content between universities (Adam, 2004). Taken together, learning outcomes and the associated view on education are expected to improve the learning process.

One important caveat is that learning outcomes do not equal educational practice and a discrepancy between the two is possible. Firstly, not all learning outcomes are implemented in educational practice. Lecturers are obligated to write learning outcomes, but the degree to which they stick to these outcomes is not always monitored (Kovacs et al., 2020; Maher, 2004). Secondly, not all educational practices are always translated to learning outcomes (Armstrong & Niewoehner, 2008). Lecturers might trigger a wide range of competencies during the lectures, the so-called hidden curriculum (Orón Semper & Blasco, 2018), but only the competencies they deem to be important are in the formal learning outcomes. Learning outcomes thus offer an insight into what goes on in a study programme but are almost never a perfect reflection.

The Current Study

The current case study aims to assess the presence of LLL competencies in the learning outcomes of an English-speaking engineering technology programme at a European university. The research questions are the following:

1. To what extent are LLL competencies present in the learning outcomes of an engineering programme?
2. How does the presence of LLL competencies in learning outcomes differ within and between specialization tracks?

These research questions are answered by mapping learning outcomes in the engineering technology programme against a predefined set of LLL competencies. The presence of LLL competencies in the learning outcomes (RQ1) and differences within and between programmes (RQ2) are visualised using heat maps.

Based on a systematic literature review on competency measurement methods in engineering education (Cruz et al., 2020a), the following LLL competencies are included: (1) self-monitoring, (2) locating and scrutinizing information, (3) self-reflection, (4) creating a learning plan and (5) willingness, motivation and curiosity to learn.

1. Self-monitoring is to monitor the learning process by periodically assessing performance and progression (Cruz et al., 2020a).
2. Locating and scrutinizing information is a LLL competency that includes independently searching, identifying and interpreting new information or knowledge (Cruz et al., 2020a).
3. Self-reflection is the inspection and evaluation of one’s thoughts, feelings and behaviour (Grant et al., 2002).
4. Creating a learning plan means making a plan to prepare for future learning activities by identifying learning goals and planning steps to reach them (Cruz et al., 2020a).
5. The willingness, motivation, and curiosity to learn is a collection of attitudes towards learning that proceed and guide the learning process. The willingness to learn is an impulse or desire to acquire new competencies (Hotifah et al., 2020). The motivation to learn is an internal state that serves to activate learning behaviour and give it direction (Huitt, 2011). The motivation to learn as a LLL competency is mostly related to intrinsic motivation as opposed to extrinsic motivation. The curiosity to learn is the desire to learn new information, experiences or knowledge (Grossnickle, 2016).

METHOD

This case study reviews the learning outcomes of an Engineering Technology programme with three specialisation tracks, namely Electronics engineering, Electromechanical engineering, and Chemical engineering. The programme exists, regardless of the track, of three bachelor years and one master year, with each year consisting of 60 ECTS (European Credit Transfer and Accumulation System) and the full programme consisting of 240 ECTS (4 times 60 ECTS). The first bachelor year is the same for all tracks and the second bachelor year also largely overlaps between the tracks. The third bachelor and the master year are predominantly separate.

For each track, a list of courses with accompanying learning outcomes is available on the university website. Additionally, an ECTS credit is assigned to each course. The complete study programmes were extracted which includes all courses in each year of the track with the accompanying learning outcomes and ECTS of each course. The number of learning outcomes in het total programme differ slightly between the specialization tracks ($N_{\text{Electronics engineering}}$ = 1,635; $N_{\text{Electromechanical engineering}}$ = 1,702; $N_{\text{Chemical engineering}}$ = 1,667).

In the mapping stage, each individual learning outcome is mapped against the five LLL competencies as defined by Cruz et al. (2020), namely (1) self-monitoring, (2) locating and scrutinizing information, (3) self-reflection, (4) creating a learning plan and (5) willingness, motivation and curiosity to learn. The mapping is completed in a flexible manner, meaning that different wordings or synonyms can be used to describe the LLL competencies. Specific terminology that applied to each of the competencies was agreed upon so that consistency in the mapping process was achieved. Table 1 provides some examples of different wordings that were identified as acceptable for each competency.

A learning outcome is ascribed a mapping score of 0 or 1 depending on the absence or presence of a certain LLL competency. A learning outcome can have a 0 mapping score for each of the LLL competencies or multiple 1 mapping scores. Then, the mapping scores are summarized on both year-level and programme-level for each LLL competency. These mapping scores indicate the number of learning outcomes in one year of the programme (for example the first bachelor) or the full programme that include the LLL competencies.

However, these mapping scores do not take the course load into account. A learning outcome in a 20 ECTS course will possibly have a larger presence in the curriculum than in a 3 ECTS course. Based on this assumption, the mapping scores are also multiplied by the ECTS of the respective course before summarizing to create ECTS weighted mapping scores. Both the unweighted mapping scores and the ECTS weighted mapping scores are included in the analysis.

Finally, the weighted and unweighted mapping scores are visualised using heatmaps. In this visualisation, the colour of a cell varies based on the mapping scores creating hot and cold spots. The colour scheme was defined using a colour scale generator (An, 2020). The middle point of the scale was set at a bright orange (#FC7419) with a light yellow at the lower end of the scale (luminosity: 87%, hue angle: - 25º, saturation: 14%) and a dark red at the higher end of the scale (luminosity: 59%, hue angle: 25º, saturation: 14%).

Table 1. LLL competency example learning outcomes

LLL competency	Example learning outcomes
Self-reflection	1. (…) think critically, rationally, and logically coherently about the role and responsibilities of engineers (…) 2. (…) explain their responsibility and their call as engineers in the society of the future
Locating and scrutinizing information	1. (…) find and summarize relevant information on recent biomedical research 2. (…) collect, critically process, and interpret new information and knowledge
Self-monitoring	1. (…) solve problems, can respect deadlines, be flexible and shows perseverance 2. (…) can divide the work in his lab team and can take his responsibility in preparation, execution, and reporting

Note. Example learning outcomes of 'Creating a learning plan' and 'Willingness, motivation and curiosity to learn' are not included because none were found.

RESULTS

Table 2 shows the presence of the LLL competencies in each of the three specialization tracks. Both the competencies 'Creating a learning plan' and 'Willingness, motivation and curiosity to learn' are not included in any of the learning outcomes. From the other competencies, 'Self-reflection' ($\bar{x}$ = 5 (21)) is included the least. 'Self-monitoring' ($\bar{x}$ = 6.67 (45)) is included slightly more and 'Locating and scrutinizing information' ($\bar{x}$ = 10.33 (77.33)) the most. When comparing between programmes, minimal differences can be recognized.

The presence of LLL competencies can be assessed across the years of the programme. Table 3 visualises this using the unweighted mapping scores showing hotspots of the competencies within each track. 'Self-monitoring' is the most spread out of the three competencies with learning outcomes included in bachelor courses such as 'Dynamics and energy' and 'Engineering experience' as well as in the master's thesis. 'Locating and scrutinizing information' is included in the first bachelor as well as in the final years. 'Locating and scrutinizing information' is also included in different courses such as 'Chemistry', 'Trends and innovations in the biomedical sector' and 'Master's thesis'. Hotspots of self-reflection are present in the bachelor years in the courses 'Enterprises and ethics' and 'Religions'.

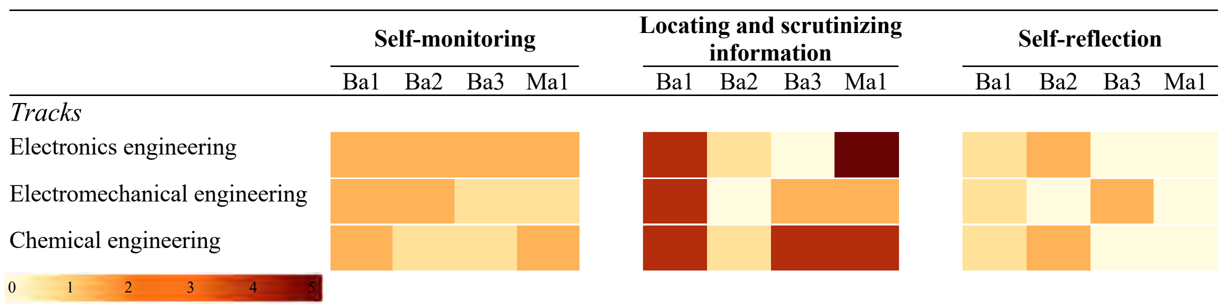
The heat maps in Table 4 contain the ECTS weighted mapping scores, taking course load into account. For 'Self-monitoring' the hotspots shift towards the final master year. This is in contrast with the more spread-out picture in Table 3. For 'Locating and scrutinizing information' the heat map in Table 4 shows comparable results. Both shifts can be explained by the 20 ECTS weight of the master's thesis. 'Self-reflection' is now slightly more emphasized in the first bachelor year.

Table 2. Mapping Scores on Programme-level

	Self-monitoring	Locating and scrutinizing information	Self-reflection	Creating a learning plan	Willingness, motivation, and curiosity to learn
Tracks ($\bar{x}$)	6.7 (45)	10.3 (77.3)	5 (21)	0 (0)	0 (0)
Electronics engineering	8 (40)	10 (73)	5 (21)	0 (0)	0 (0)
Electromechanical engineering	6 (41)	8 (79)	5 (21)	0 (0)	0 (0)
Chemical engineering	6 (54)	13 (80)	5 (21)	0 (0)	0 (0)

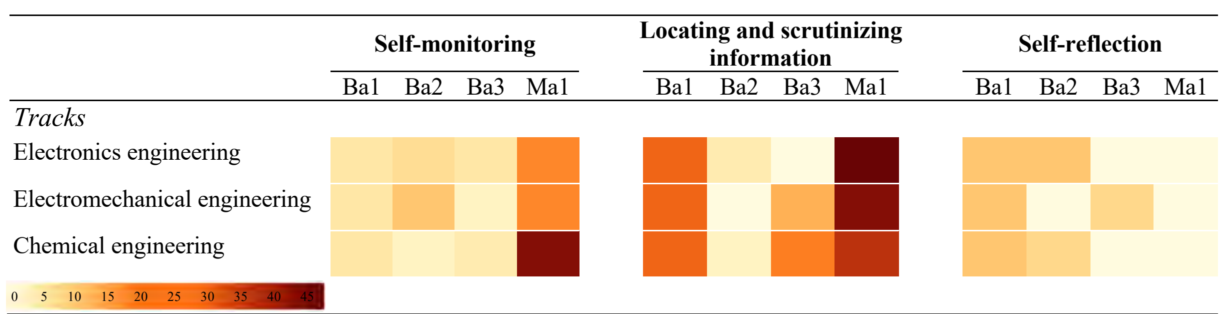
Note. Unweighted mapping scores with the corresponding ECTS weighted mapping scores in brackets.

Table 3. Heat map unweighted mapping scores



Note. 'Creating a learning plan' and 'willingness, motivation and curiosity to learn' are not included in the heat maps because they are not present in any of the learning outcomes. Ba1, Ba2 and Ba3 refer to the first, second and third bachelor year and Ma1 is the master year.

Table 4. Heat map ECTS weighted mapping scores



Note. 'Creating a learning plan' and 'willingness, motivation and curiosity to learn' are not included in the heat maps because they are not present in any of the learning outcomes. Ba1, Ba2 and Ba3 refer to the first, second and third bachelor year and Ma1 is the master year.

DISCUSSION

This case study examines the presence of LLL competencies in the learning outcomes of an engineering technology programme. Firstly, the learning outcomes are mapped against five LLL competencies, namely (1) self-monitoring, (2) locating and scrutinizing information, (3) self-reflection, (4) creating a learning plan and (5) willingness, motivation, and curiosity to learn. The LLL competency 'Locating and scrutinizing information' in the chemical engineering track has the highest mapping score (N = 13) on the programme-level. However, this means that out of the 1,667 learning outcomes in the chemical engineering track, less than 1% focuses on this LLL competency. The 'hotspots' that are shown in the heat maps thus only reflect a small number of learning outcomes in comparison with the total number of learning outcomes. Additionally, two out of five LLL competencies, 'creating a learning plan' and 'willingness, motivation and curiosity to learn' were not detected in the learning outcomes of the programme. A benchmark or reference point that determines the number of learning outcomes that should be devoted to LLL does not exist which makes it difficult to draw strong conclusions. However, it can be concluded that LLL competencies are not fully embedded in the learning outcomes. Considering the importance of LLL (Martínez-Mediano & Lord, 2012; Uden & Dix, 2004) and the responsibility of higher education institutions in teaching LLL competencies (Cheah et al., 2019; Martínez-Mediano & Lord, 2012; Uden & Dix, 2004), the further implementation of LLL competencies in learning outcomes is something to devote more attention to.

When looking at the courses that include LLL competencies in their learning outcomes, several of those courses are not part of the core engineering curriculum. In particular, self-reflection is included exclusively in the courses 'Enterprises and ethics' and 'Religions'. This is in line with the finding of Kovacs et al. (2020) on professional competencies in an engineering programme. When Social and Human sciences courses were excluded from their analysis, the number of learning outcomes on professional competencies reduced drastically. They argue that along with the positive impact of teaching professional competencies to engineering students there can be an additional negative impact on the way students perceive professional competencies. By not including professional competencies in the core curriculum, the idea of professional competencies being a by-product of engineering education and subordinate to the typical engineering competencies is reinforced.

Related to the second research question, the heat maps visualise differences between and within the tracks. The differences between the tracks are minimal with a similar distribution of LLL competencies across the tracks. For the first years of the tracks this was expected considering the joint first year and mostly joint second year of the bachelor. In the final bachelor and master year no differences between the tracks stand out. However, within the programme clear changes can be found. Learning outcomes on self-reflection are included exclusively in the bachelor year with a stronger presence in the first years. 'Locating and scrutinizing information' is emphasized in both the first and last year of the programme. Finally, self-monitoring learning outcomes are more spread out and when taking the ECTS weights into account hotspots of 'Self-monitoring' are found in the master year. In general, it can be concluded that learning outcomes on LLL competencies are more likely to be included in the learning outcomes of the first and final year of the programme.

For the typical engineering competencies, it is considered self-evident to develop competencies over the course of the programme. For example, all knowledge an engineer needs on mathematics will be divided over a couple of courses. Throughout the programme, engineering students follow these mathematics courses building on the knowledge from the previous course. However, this careful development is in sharp contrast with the sporadic implementation of LLL competencies in learning outcomes. The heat maps demonstrate the lack of competency development over the course of the programme for LLL competencies. To solve this issue, a programme wide initiative is necessary. Since the introduction of learning outcomes, authors have been pointing out the need for a top-down strategy for implementing learning outcomes (Armstrong & Niewoehner, 2008; Walkington, 2002). However, today lecturers are responsible for both formulating and implementing professional and LLL competencies in the learning outcomes of their courses. Walkington (2002) argued that both strategies are necessary, a top-down strategic plan that takes the whole programme into account as well as bottom-up input from lecturers and educational practitioners. A top-down strategy for higher education institutions to implement LLL competencies can support the step-by-step and progressive development throughout the programme.

It is important to point out that this case study only provides one perspective on the implementation of LLL competencies in the programmes. Learning outcomes are not always a perfect representation of what goes on in the lecture hall and in the minds of students (Armstrong & Niewoehner, 2008; Maher, 2004; Orón Semper & Blasco, 2018). Educational practice can be much richer than these written statements. A lecturer might attach great importance to self-monitoring and lets students prepare the material before class. In the learning outcomes, it is likely that only content-related statements are included. This is especially plausible for professional competencies since they are often considered to be a by-product of education and part of the hidden curriculum (Orón Semper & Blasco, 2018). Further, what students learn in a programme also goes beyond what they learn in their classes. The competency of creating a learning plan for example can also be supported by study guidance or faculty-provided resources (Wingate & London, 2007). The degree to which the results of the heat maps resonate with the experience of both students and lecturers needs to be explored in future research. Combining the perspectives of students and lecturers with learning outcome analysis can further inform institutional action and strategy.

Although learning outcomes are not identical to educational practice, they are an important aspect of it and deserve careful attention. Students often read them before the start of the course, which can influence their expectations and the way they look at the course and education by extension (Adam, 2008; Fitzpatrick et al., 2009; Jenkins, Alan & Unwin, 2001). For lecturers, the learning outcomes are expected to guide the way they teach a course and partially reflect their perspective on the course (Adam, 2004, 2008; Jenkins, Alan & Unwin, 2001). Considering the importance of LLL for engineers, the implementation of LLL in higher education deserves careful attention and this should be reflected in the learning outcomes.

CONCLUSION

This case study shows the intensity with which lifelong learning competencies are currently implemented in the learning outcomes of an engineering technology programme. LLL competencies are currently not fully embedded in the learning outcomes and are mostly limited to the first and final year of the programme. This study is a first step towards enhancing our understanding of how lifelong learning is implemented in education. The mapping technique and heat maps provide a tool to evaluate the learning outcomes of study programmes. This method indicates hot and coldspots in the curriculum which can be used to inform curriculum development. The degree to which the results resonate with the experience of both students and lecturers needs to be explored in future research. The combination of heat maps and the perspectives of lecturers and students can serve as a basis to inform the further implementation of lifelong learning competencies.

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BIOGRAPHICAL INFORMATION

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