ENGINEERING TECHNOLOGY STUDENTS' SELF-REGULATION: A BASELINE

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ABSTRACT

Technology is evolving at a very rapid rate in today's society. Even though engineering students get acquainted with state-of-the-art technological advancements, these often get outdated during the engineers' careers. It is therefore of major importance that engineers learn to learn for a lifetime, in order to train their personal competencies and to keep up with technological innovations. Currently, there is no framework that defines the umbrella competency lifelong learning (LLL). It is certain, however, that self-regulation is a core and malleable competency for LLL. This research presents Flemish engineering students' self-regulation levels, measured using the Self-Reflection and Insight Scale (SRIS). The SRIS consists of three subscales: engagement in self-reflection, need for self-reflection, and insight. The scores are looked at from different angles, such as across study phases and by taking into account background variables like secondary education (SE) type and sex. In general, master students report the highest level of self-regulation. Most notably, students with a more technical SE-background report higher levels of self-regulation in the master year than in the bachelor years, whereas students with a more general SE-background do not. Male and female students' self-regulation is at roughly the same level, but influenced by the underlying subscales.

KEYWORDS

Engineering Education, Lifelong Learning, Self-Regulation, Standards: 2, 3

INTRODUCTION

Lifelong learning has become an important competency for engineers in today's society (Guest, 2006). Even though engineering students get acquainted with state of the art technology as part of their studies, those technological advances evolve at a very rapid rate and can become obsolete long before the engineers finish their careers. In addition, engineers are also expected to develop their professional competencies throughout their careers, as the levels they attain when graduating are not sufficient for the industry (Hirudayaraj, Baker, Baker, & Eastman, 2021). In short, engineers are expected to engage in both personal and professional development and in order to do so successfully, they need lifelong learning skills. As higher education has a great responsibility in the training of engineers, it is desirable that lifelong learning competencies are included in engineering programs' learning outcomes to help ensure that these competencies are adequately developed (Crawley, Malmqvist, Ostlund, Brodeur, & Edstrom, 2007). Ideally, these non-technical competencies are included in the curriculum in an integrated manner as a reflection of their importance (Crawley et al., 2007).

Unfortunately, there is no consensus yet as to what lifelong learning entails precisely, nor as to what competencies underlie it or contribute to it (Qalehsari, Khaghanizadeh, & Ebadi, 2017) (Cruz, Saunders-Smits, & Groen, 2020). Supporting competencies include intrinsic motivation (Lüftenegger et al., 2012), curiosity (Bayrakçi & Dindar, 2015), and goal setting (Kirby, Knapper, Lamon, & Egnatoff, 2010). Self-regulation has been established as a core competency for lifelong learning and according to Lord, Prince, Stefanou, Stolk, and Chen (2012) it can even be used as a proxy for it in educational contexts.

Zimmerman and Moylan (2009) have defined a cyclical model for self-regulation based on three phases: the forethought phase, the performance phase and the self-reflection phase. First comes the forethought phase, in which students prepare for what they wish to learn or do. They may engage in goal setting and planning, for example. This phase is followed by the performance phase, in which the actual execution of tasks occurs, along with self-monitoring and other processes. After this, the student enters the self-reflection phase. At this point the student evaluates their work and outcome expectations, gauges whether or not their goals have been accomplished, and pinpoints what to do better next time. After the self-reflection phase, the cycle is completed by going back to the forethought phase - the student effectively takes their lessons learned into account when preparing for existing or new goals and desired outcomes.

In absence of a complete framework of lifelong learning, this research will utilize self-regulation as a proxy. In order to get an overview of students' lifelong learning capacities, their self-regulation levels will be measured instead. This paper presents a baseline for Flemish engineering students' self-regulation levels and contributes to the future establishment of a possible natural growth model by delivery of the first measurements. Such a model may later be used to help interpret the impact of self-regulation interventions.

In this paper, these research questions will be addressed: (RQ1) What are Flemish engineering students' baseline self-regulation levels? Can any differences be observed between students of different study phases (RQ2), of different educational backgrounds (RQ3), and male and female students (RQ4)? First, this research's methodology will be presented, including context, participants and data collection, processing and analysis. Second, the results will be presented both graphically and in table format per research question. A discussion will follow to shed more light, followed by a concluding summary of the paper and a brief look ahead.

METHODOLOGY

Context and Participants

In Belgium, Engineering Technology students typically follow a three-year bachelor's program, after which they enroll in a one-year master program. We refer to the progress they've made in the university program as their study phase: they may either be in one of their bachelor program years (BA 1, 2 or 3) or in their master year (MA). A questionnaire on self-regulation was offered to students of all study phases at three Engineering Technology campuses (Sint-Katelijne-Waver, Leuven and Ghent).

Secondary education programs are grouped into a few large categories in Belgium. General Secondary Education (GSE, *Algemeen Secundair Onderwijs*), for example, offers more general theoretical courses and mainly prepares students for higher education, whereas Technical Secondary Education (TSE, *Technisch Secundair Onderwijs*) generally offers more practice-based and technical courses.

Survey and Collected Data

Grant, Franklin, and Langford (2002) developed the 20-item Self-Reflection and Insight Scale (SRIS), which consists of three subscales: the need for self-reflection ($n = 6$), actual engagement in self-reflection ($n = 6$), and insight ($n = 8$). In their work, self-reflection is defined as "*(...) the inspection and evaluation of one's thoughts, feelings and behavior*" and insight as "*(...) the clarity of understanding of one's thoughts, feelings and behavior*". Both play a crucial role in self-regulation and the SRIS can thus be used to measure it (Grant et al., 2002). Participants can rate the statements on a 1-5 Likert scale to indicate to what extent they agree with them. A score of 1 corresponds to 'Strongly disagree' and a 5 to 'Strongly agree'. The survey contains both positively worded statements and negative ones. This survey has been validated for use with engineering students by Van den Broeck and Langie (2022). On the one hand, Grant et al. (2002)'s original factor analysis resulted in only two factors: self-reflection (SR) and insight. These results were based on SRIS data from psychology students. Roberts and Stark (2008), on the other hand, confirmed that the three subscales behave as factors for medicine students. As Engineering Technology can be considered a 'hard science' and therefore more similar to medicine than to psychology, the three subscales will be treated as factors for this research. A Dutch translation of the SRIS was used for this research, as this is the native language of most Flemish students.

Students' university ID number and e-mail addresses were also collected, in order to match their results with background variables stored in the university's database. This background data consists of the student's sex as it is listed on their personal ID, the study program they are enrolled in along with their current study phase, and what educational background they have (secondary school education type). The Social and Societal Ethics Committee (SMEC) has approved this use of data in the file G-2022-5676.

Data was collected as part of a lecture and to mitigate sampling bias, the survey was also distributed via the online platform used by the university. Still, students that are not actively involved in their studies in either of those ways may not be properly represented by the collected data.

Data Processing and Analysis

The obtained data was analyzed using R version 4.2.0. In total, 875 survey responses were collected, which corresponds to a response rate of 26.21%. Only fully completed entries were withheld, resulting in 783 usable submissions. Entries were then matched with background data obtained from KU Leuven's database and negative statement scores were inverted.

Based on the students' provided ratings, a score for each of the self-regulation factors was calculated by taking the average over the items loaded on that factor. In addition, an average over all 20 statements was calculated to summarize the students' level of self-regulation as a whole. These averages can take any continuous value in the $[1, 5]$ interval.

To answer the stated research questions, nonparametric Kruskal-Wallis tests were employed. If these indicated that differences might exist, post-hoc paired Wilcoxon tests were run for confirmation. For any differences found, Cohen's d was calculated to gauge the effect size. To this end, the values were compared to the interpretations suggested by Cohen (2013) and Sawilowsky (2009).

RESULTS

RQ1: What are Flemish engineering students' baseline self-regulation levels?

Table 1 presents the baseline for self-regulation as means of the students' scores, per factor and study phase.

Table 1. Engineering Technology students' self-regulation levels (scale 1-5) per study phase.

Study phase	Engagement in SR		Need for SR		Insight		Self-regulation		*n*
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	
1st (Bachelor)	3.32	0.70	3.40	0.69	3.32	0.59	3.34	0.44	389
2nd (Bachelor)	3.33	0.66	3.33	0.74	3.35	0.69	3.34	0.41	137
3rd (Bachelor)	3.24	0.77	3.31	0.75	3.40	0.67	3.32	0.50	112
Master	3.43	0.80	3.57	0.74	3.39	0.66	3.46	0.47	145
All	3.33	0.72	3.41	0.72	3.35	0.63	3.36	0.45	783

RQ2: Can any differences be observed when looking at students of different study phases?

Figure 1 shows the distribution of scores per study phase. Only slight differences can be observed, with a general increase towards the master year.

In terms of *Engagement in self-reflection*, no significant differences could be found ($H(3) = 3.83$, $p = .28$). However, students of different study phases experienced different levels of *Need for self-reflection* ($H(3) = 11.23$, $p = .01$), with small differences between master students ($M_{MA} = 3.43$) and all bachelor phases ($M_{BA1} = 3.32$, $d_{BA1} = 0.24$, $p_{BA1} = .04$; $M_{BA2} = 3.33$, $d_{BA2} = 0.33$, $p_{BA2} = .03$; $M_{BA3} = 3.24$, $d_{BA3} = 0.36$, $p_{BA3} = .03$).

Insight did not significantly differ between cohorts ($H(3) = 3.81$, $p = .28$) and even though a Kruskal-Wallis test on *Self-regulation* as a whole signaled differences ($H(3) = 7.85$, $p = .05$), post-hoc tests failed to confirm any.

RQ3: Can any differences be observed between students of different educational backgrounds?

Most of the surveyed students had a GSE ($n = 542$, 69%) or a TSE ($n = 231$, 30%) diploma. The remaining 10 students whose educational background was not known were excluded from this part of the analysis.

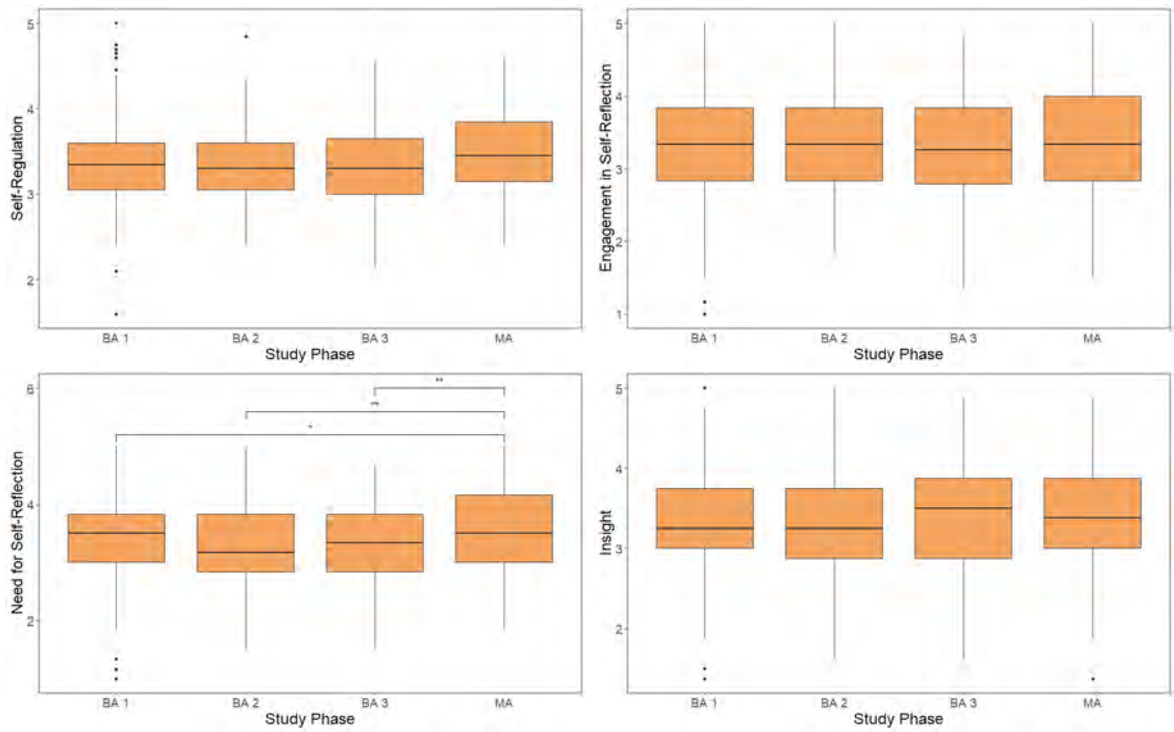

Figure 1. Distribution of scores per study phase. Left to right, top to bottom: Self-Regulation, Engagement in Self-Reflection, Need for Self-Reflection, Insight.

In research question 1, students of all educational backgrounds were grouped together. When discerning between them, it is clear that not all student populations evolve in the same way. Considering GSE students only, no significant differences can be found between the different study phases for any of the factors, nor for self-regulation as a whole. TSE students on the other hand may differ in their *Need for self-reflection* between study phases ($H(3) = 8.06$, $p = .05$) and in their *Self-regulation* as a whole ($H(3) = 11.01$, $p = 0.01$). The former could not be confirmed by post-hoc tests, whereas in the latter case master student scores ($M_{MA} = 3.51$) exhibited a medium increase from bachelor scores ($M_{BA1} = 3.33$, $d_{BA1} = 0.36$, $p_{BA1} = .04$; $M_{BA2} = 3.25$, $d_{BA2} = 0.65$, $p_{BA2} = .02$; $M_{BA3} = 3.19$, $d_{BA3} = 0.70$, $p_{BA3} = .02$).

RQ4: Can any differences be observed between male and female students?

Most of the Engineering Technology students are listed as male ($n = 678$, 86.6%) and the rest of them as female ($n = 105$, 13.4%). Figure 3 shows the score distributions across study phases. Visually, it is clear that females tend to engage more in self-reflection as well as generally feel a greater need to do so. Their reported insight levels are lower than their male peers', averaging out their whole *Self-regulation* scores to be somewhat similar.

Table 2. Male and female Engineering Technology students' average self-regulation levels.

Sex	Engagement in SR		Need for SR		Insight		Self-regulation		*n*
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	
Male	3.29	0.72	3.39	0.72	3.39	0.62	3.36	0.45	678
Female	3.60	0.68	3.54	0.73	3.12	0.68	3.39	0.47	105

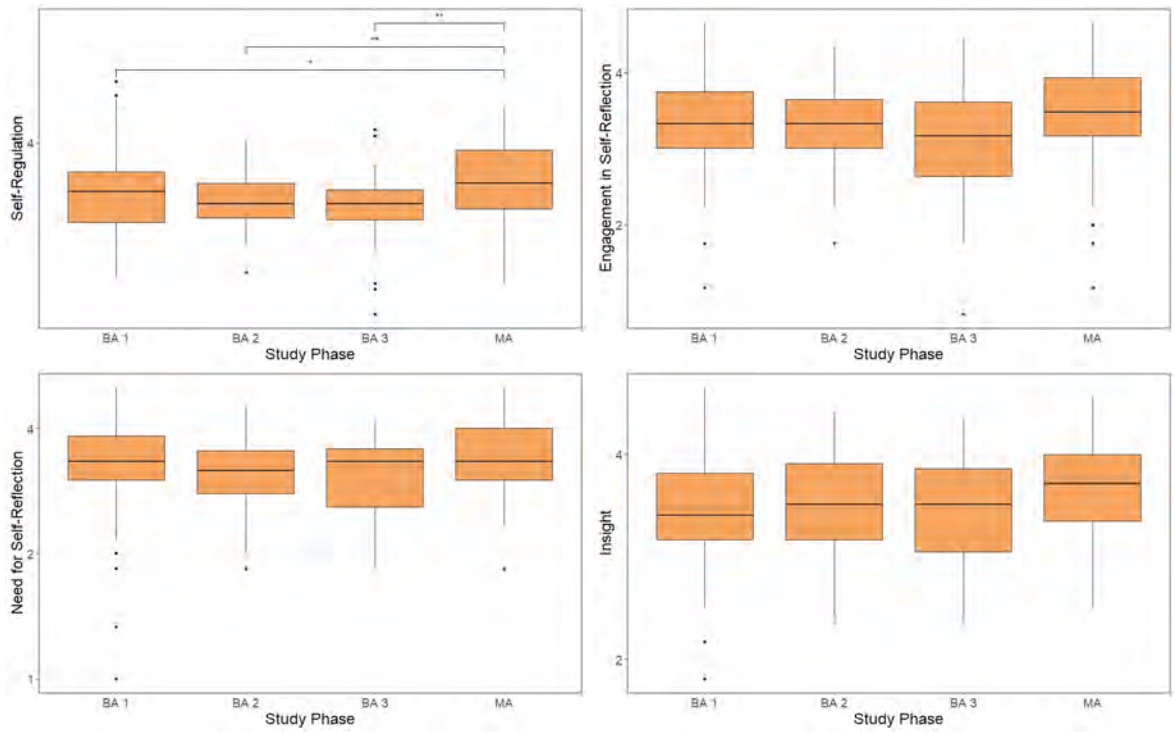

Figure 2. Comparison of scores, TSE students only. Left to right, top to bottom: Self-Regulation, Engagement in Self-Reflection, Need for Self-Reflection, Insight.

When looking at all study phases combined, as in Table 2, the same tendencies can be observed. Their overall *Self-regulation* scores are not significantly different, but the underlying factors beg to differ. Females' *Engagement in self-reflection* is somewhat higher than males' ($d = 0.44$, $p < .001$), and they show a slightly higher perceived need for it ($d = 0.22$, $p = .04$). In contrast, females report less *Insight* than males ($d = 0.43$, $p < .001$).

DISCUSSION

To allow for a meaningful interpretation of these SRIS scores, they were compared to the results reported by Grant et al. (2002), Roberts and Stark (2008) and Naeimi et al. (2019). Their results are presented in Table 3, rescaled to the $[1, 5]$ interval. The engineers' self-reflection scores were similar to the psychology undergraduates' results reported by Grant et al. (2002), yet the former rated their insight levels higher than the psychologists did. When comparing the engineers' scores to those of medicine students, as presented by Naeimi et al. (2019) and Roberts and Stark (2008), the latter group rates themselves higher on all subscales.

In general, Engineering Technology students' *Need for self-reflection* appears to increase slightly towards their senior year, whereas no significant differences could be found in terms of *Engagement in self-reflection*, *Insight* or *Self-regulation* as a whole. This is largely in line with findings from Roberts and Stark (2008), who report no differences in any subscale across cohorts. This paper's data analysis, however, contrasts theirs with a higher need for reflection in students' senior year. This does not necessarily imply that individual students experience a growth, as

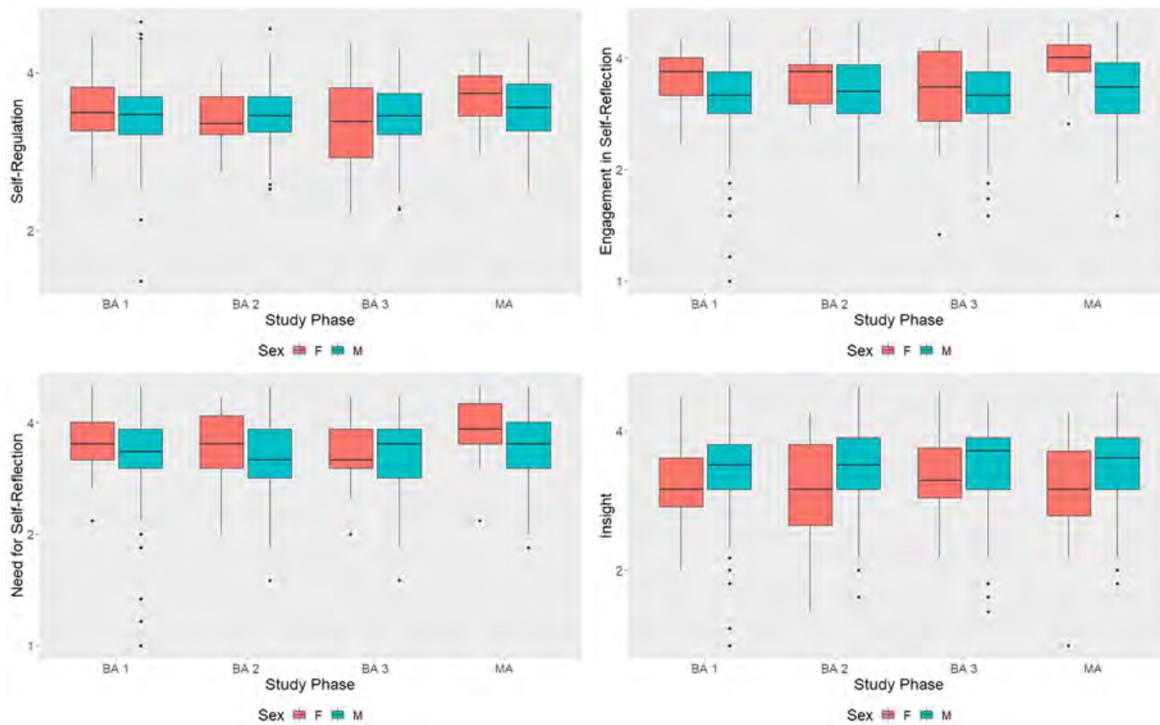

Figure 3. Comparison of scores per study phase, grouped by students' sex. Red: females, turquoise: males. Left to right, top to bottom: Self-Regulation, Engagement in Self-Reflection, Need for Self-Reflection, Insight.

these differences may also be caused by differences in student population composition. To confirm an actual individual growth, it is necessary to collect and analyze longitudinal data.

The picture gets more interesting when we look at the details underneath. Students' educational background, for example, appears to influence self-regulation levels. Students with a more general background (GSE) do not show too much progression in *Self-regulation* across cohorts, whereas students with a more technical background (TSE) possess significantly higher levels in their senior year. A possible explanation for this may lie in the secondary education institution's focus (or lack thereof) on self-regulation competencies. When looking up the learning goals for mathematics as defined on Onderwijsdoelen.be (h.d.), GSE students are expected to "*(...) develop self-regulation concerning the acquisition and processing of mathematical information and problem solving*". TSE students, on the other hand, should "*(...) be willing to adapt their learning process based on reflection on their used methods to solve mathematical problems and on the way they acquire and process mathematical information*". Despite these two learning goals sounding quite similar to one another, it can be noted that GSE students are more explicitly expected to develop self-regulation. It is possible that these programs pay more explicit attention to self-regulation than TSE programs do due to the way these learning goals are formulated, which may explain the former's higher levels when entering higher education and the latter's apparent growth. It would be interesting to know whether GSE students have somehow reached a ceiling level of self-regulation by the time they start their higher education studies, and that therefore there is no apparent increase in their levels over the years; or that their levels are too high to be impacted by any attention given to the skill as part of the program,

Table 3. Engineering Technology students' average SRIS scores, repeated from Table 1, compared to those found in the literature. Grant et al. (2002) only reported a score for self-reflection as a whole, i.e. for a combination of engagement in and need for it.

Study	Domain	Country	Engagement	Need	Insight
KU Leuven	Engineering	Belgium	3.33	3.41	3.35
Grant et al. (2002)	Psychology	Australia	3.40	3.40	2.66
Roberts and Stark (2008)	Medicine	UK	3.90	3.75	3.64
Naeimi et al. (2019)	Medicine	Iran	3.88	3.96	3.62

implying that if suitable interventions were implemented, they too would develop further.

When looking at male and female students separately as in Figure 3, it is clear that their self-report scores are differently distributed. In the case of *Engagement in self-reflection*, for example, males' scores appear to vary little over the years, whereas females' seem to rise in their senior year. Some trends can be observed, such as that females generally have a higher level of need for, and engagement in, reflection. This is in contrast to the findings of Roberts and Stark (2008) and Grant et al. (2002), who report no statistical differences between males and females in terms of self-reflection. On the other hand, females' reported insight levels are found to be lower than males', confirming Roberts and Stark (2008)'s earlier work. Grant et al. (2002), however, reported an absence of significant differences between males and females, also in terms of insight. As males and females score differently on all three subscales, it makes sense to remain cautious and to treat them as separate groups in future work.

Self-report instruments have their limitations (Paulhus, 1984) (Crandall, 1973) and it is unclear to what extent this influences the results. As these scores are based on a self-report, one has to be cautious to conclude that, for example, females engage more in self-reflection or possess less insight; they may just be prone to under- or overestimating themselves. Self-report scores are ideally accompanied by qualitative results that help make sense of them.

CONCLUSIONS AND FUTURE WORK

This paper presents baseline results for Flemish Engineering Technology students' self-regulation levels, both per underlying factor and as a whole. In general, master students experience a slightly greater need for self-reflection than bachelor students do. Discerning between student profiles leads to a few more insights.

Educational background plays a part in Engineering Technology students' development of self-regulation at KU Leuven. There were no significant differences in GSE students' population scores over the years, yet TSE students' self-regulation showed a clear increase towards the end of their study program. Male and female students also differ in their self-report scores, with females generally ranking their insight lower than male students do. Females, however, report to spend more time in self-reflection and feel a greater need to do so. In consequence, males' and females' self-regulation levels are comparable as a whole, but caused by a different distribution of scores on the underlying factors.

To measure a possible growth in engineering students' self-regulation levels, the SRIS survey will be administered to the same cohorts of students every year for four years. These results are the first measurement and will be used for longitudinal analysis with future data. They will also be used for future work involving the design, development, and piloting of interventions focusing on self-regulation. This baseline will be used in combination with qualitative methods to allow for a correct and reliable measurement of their effectiveness in higher engineering education.

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BIOGRAPHICAL INFORMATION

Ir. Shan Tuyaerts joined the ETHER research group as a PhD candidate in October 2022. She combines her background in Engineering Science (Computer Science) with her passion for education in the topic of engineering education. In the context of the REFL³ECT project, she researches lifelong learning for engineers, with a focus on self-regulation.

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Dr. ing. Lynn Van den Broeck holds a master's degree in Chemical Engineering Technology and a PhD in Engineering Education Research. Her PhD research focused on improving the guidance and support of transfer students in Engineering via the development of a validated diagnostic test and effective interventions. Her research interests focus on study guidance, effectiveness and efficiency of educational interventions, LLL and professional competencies, and feedback.

Prof. dr. Greet Langie is a professor at the Faculty of Engineering Technology, KU Leuven. She's a physicist by training and the chair of the research group focusing on Engineering Education Research on Campus De Nayer. She performs research in various fields related to the transition from secondary education to higher education and from higher education to professional life. She was the vice dean of education of the Faculty of Engineering Technology at KU Leuven from 2012 until 2020 and is now the vice chair of education of Campus De Nayer.

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