Supporting Learner Development Through Self-Assessment

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Abstract

Given the scale and pace of change of sustainability challenges in the world today, it is vital for students to develop into expert learners who can assess their abilities and knowledge and identify future learning needs. Self-assessment is not a straightforward task and requires support to develop. The current study examined the effect of using self-assessment over time, combined with reflection, on students' abilities to develop self-assessment skills. The study was conducted in an undergraduate course that uses project-based, problem-based learning to engage students in real-world projects regarding sustainability. The findings indicate that while students can engage in quantitative self-assessment, there are concerns with accuracy and metacognition. Reflection regarding their self-assessment contributes to addressing these issues. In addition, to be effective, students require guidance on how to recognize and explore what they do not yet know. Finally, they also need support in recognizing learning as an active process that occurs over time. This study frames self-assessment as a tool for developing informed judgment of their own learning and future learning needs rather than as a tool for summative assessment of past learning. Implications for future research are discussed.

Keywords: sustainability education, sustainable assessment, self-assessment, reflection, informed judgment

Introduction

A key critique of higher education by employers is that graduates are not prepared to use their knowledge and skills in new situations (Boud, 2020). Critical thinking and complex problem-solving have both been identified as limiting factors for new graduates by employers (Finley, 2023, p. 2). Often students learn to take on a passive role: they are told what they should learn, sometimes how they will learn, and how they will be assessed (Boud, 2020). We require a shift to support the development of learners. According to Boud (2020), a learner is able "to take the initiative in deciding what to focus on and to judge one's own performance in the process" (p. 9). This aligns with the intention of universal design for learning (UDL) (CAST, 2017). The UDL framework supports the design of learning environments that support the development of expert learners. Expert learners are those who can engage in activities like self-monitoring, reflection, and goal-setting (Novak & Rodriguez, 2018).

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Clearly, many aspects of curriculum and pedagogy will "form and sustain learners who will be able to operate effectively in a complex society" (Boud & Soler, 2016, p. 400). In this study, we have chosen to focus on the role of self-assessment for two main reasons. First, assessment in which students develop their own informed judgment abilities is key to their graduate success (Boud & Falchikov, 2007b; Boud & Soler, 2016; Tai et al., 2018). It also responds to the calls from UDL to support the development of expert learners. Second, within sustainability education, where this study is situated, there has been a critique regarding the overuse of self-assessment in assessing key sustainability competencies (Redman & Wiek, 2021). Rather than reject self-assessment, we argue that we need to reframe it as a tool for learners to develop to become lifelong learners, a necessity to address current and future sustainability challenges (Wals & Benavot, 2017).

The research questions guiding this project are as follows:

1. How does the use of pre- and post-self-assessment impact students' perceptions of their self-assessment abilities?
2. How can reflection contribute to a learner's ability to self-assess based on performance?

Literature Review

Self-assessment

Self-assessment is not clearly defined in the literature (Andrade, 2019; León et al., 2023). It can include many different forms, including reflective writing, Likert-scale assessments, assessments using rubrics, identifying the clearest point and most confusing point, estimating the number of correct answers on a test, and indicating the confidence level in responses on an assessment (León et al., 2023). In reviewing the literature on self-assessment, Andrade (2019) concluded that self-assessment is assessing "one's abilities, processes, and products… [for the purpose of generating] feedback that promotes learning and improvements in performance" (p. 2, emphasis in original). This led to the development of a taxonomy of self-assessment that identifies formative and summative assessments of processes and products.

Drawing on Andrade's (2019) taxonomy of self-assessment and building on the sustainability competency literature, which we shall discuss shortly, the current study focused on self-assessment of competency using task-specific self-efficacy ratings. Key to this approach is that students have opportunities to respond to their perceived low competence (Andrade, 2019). This requires that we view self-assessment as contributing to learning processes rather than solely as evaluating past performance.

Building on this background and definition, self-assessment is considered within the framework of sustainable assessment. Sustainable assessment is "assessment that meets the needs of the present without compromising the ability of students to meet their own future learning needs" (Boud, 2000, p. 151). Encouraging students, intentionally or not, to take a passive role in their learning and rely on an external force, often an instructor, to determine what

they should learn and whether they have learned it, can potentially compromise students' ability to meet their future learning needs. This occurs because they end up unprepared "to undertake [an] assessment of the tasks they face throughout their lives" (Boud, 2000, p. 152). Therefore, we must consider how to support students in developing informed judgment. Boud and Falchikov (2007a) propose five key elements for this:

1. Identifying self as an active learner.
2. Identifying own level of knowledge and the gaps in this; finding ways of moving from what is known to what it is desirable to know.
3. Practicing testing and judging.
4. Developing judgment skills over time.
5. Embodying reflexivity and commitment.

Self-assessment supports these five elements when used within the context of Andrade's (2019) definition, particularly when examining competency assessment because of the importance of students being able to respond to their perceived low competence.

Assessing sustainability competencies

Agenda 2030 (United Nations Department of Economic and Social Affairs, 2015) sets out 17 sustainable development goals (SDGs). Goal 4 is to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. In part, this is in recognition of the skills, knowledge, and competencies that will be required in the future that are not currently known. Therefore, it is pertinent to approach assessment through the lens of sustainable assessment to ensure that students can meet their future learning needs.

The key sustainability competencies were first established by Wiek et al. (2011) and recently updated by Redman and Wiek (2021). They include five established competencies:

- Systems thinking – the ability to analyze complex systems by integrating different domains (society, environment, economy, and culture) and scales (local to global). Feedback loops, leverage points, and other systemic features are considered
- Anticipatory thinking – the ability to think about the future in terms of forecasting from current scenarios and anticipating the future outcomes of sustainability action plans or strategies
- Normative thinking – the ability to map, apply, and negotiate sustainability values, principles, goals, and targets, particularly concerning current and/or future systems states
- Strategic thinking – the ability to apply knowledge of complex systems to construct and test action plans for sustainability

- Interpersonal – the ability to collaborate and participate in meaningful ways to contribute to teams and work with diverse stakeholders

There is agreement within sustainability education around this set of competencies (Brundiers et al., 2021). In the recent update, Redman and Wiek (2021) added three emerging competencies: implementation, intrapersonal, and integration. These were not addressed in the current study. Within each of the key competencies is a need to engage in lifelong learning to continue to "seek critical information, embrace innovation and identify where change is needed" (Wals & Benavot, 2017, pp. 408–409).

While there is agreement surrounding how these competencies may be supported through learning experiences (Evans, 2019; Lozano et al., 2017), what is less established is how the competencies should be assessed (Redman et al., 2021). An important critique is that the assessment tools used are "an apparent afterthought" (p. 127). Further, "assessment as such is used to produce some empirical evidence to validate [pedagogical] initiatives' success" (p. 127). This positions assessment exclusively as a summative tool and ignores the potential of formative use and sustainable assessment.

Within the research reviewed, self-assessment using a pre-determined scale is the most common tool used, followed distantly by reflective writing (Redman et al., 2021). Redman et al. (2021) argue that self-assessment is not reliable or valid enough to warrant such high use. Its popularity is associated with the ease of both administration and analysis. They are certainly not alone in critiquing self-assessment.

Accuracy is the most common study area in the self-assessment literature (León et al., 2023). Compared with evaluations by experts, usually teachers, students tend to slightly overestimate themselves in self-assessment regardless of whether it is used for formative or summative purposes (León et al., 2023). However, features such as experience with self-assessment and the provision of feedback to the students both improve self-assessment accuracy (León et al., 2023).

Framing self-assessment within sustainable assessment helps to address these concerns. Self-assessment is intentionally developed to support learning within the course and beyond. It is not seen as a substitute for expert assessment of competence but rather part of the process of developing students' abilities to identify their own level of knowledge and the gaps in that knowledge, plan a path forward, and develop judgment skills. Therefore, the intention is to provide self-assessment experience.

Operationalizing student self-assessment

As mentioned earlier, self-assessment can take many different forms. To engage in sustainable assessment, "there is a need to design self-assessment practices that can develop and sustain students' self-assessment ability beyond its immediate programme of study" (Tan, 2007, p. 115). The focus in this context is less on the degree of correlation between the students' and experts' judgment and more on developing learners who can take initiative and use self-

assessment to examine their current abilities and identify future learning needs. To this end, the current study used two forms of self-assessment that are intended to support the five key elements to develop informed judgment: scaled self-assessment, administered as a pre- and post-activity at the beginning and end of the course, and reflective writing at the end of the course to support reflexivity about their self-assessment and identify future learning needs.

Case Study – "Sustainability Challenges" Course, MacEwan University

The current study was conducted in an interdisciplinary sustainability course, Sustainability (SUST) 301: Sustainability Challenges. Students in the course work in teams to develop a project for a community partner in support of the United Nations sustainable development goals. The course has two key features relevant to the current study.

Project-based and problem-based learning

SUST 301 incorporates project-based and problem-based learning (PPBL) by engaging with community partners to create real-world projects. PPBL was identified as an effective approach to teaching sustainability competencies (Alm et al., 2022; Evans, 2019; Lozano et al., 2017). Students worked in teams to apply sustainability competencies to address real-world challenges and develop a concrete project to solidify their learning, as Birdman et al. (2022) recommends. Further, using PPBL supports self-assessment of task-specific competencies as students discover knowledge gaps and work to overcome them through self-directed learning (Loyens et al., 2023). The projects addressed environmental, social, cultural, and economic aspects of sustainability.

Specifications grading

Specifications grading is a form of mastery-based assessment (Nilson, 2014) that supports students in achieving mastery of the learning outcomes. In this approach, assignments are assessed as "complete" or "needs revisions." Any assignment receiving a grade of "needs revisions" is returned to the student with feedback. The student then uses the feedback to guide their revisions and resubmit. This process is continued until the assignment is assessed as "complete." This approach is appropriate for competency-based educational experiences because it ensures that students meet the appropriate level of competence on all required competencies to earn a passing grade (Nilson, 2014; Wasniewski et al., 2021). Further, it supports the integration of self-assessment and feedback to revise and address weaknesses with subsequent revisions.

Two assignments are included within the current study: a scaled self-assessment, referred to hereafter as self-assessment, regarding sustainability competencies and a reflective writing assignment that focused on interpreting the self-assessment and goal setting. These are further described in data collection.

This study was approved by the MacEwan University Research Ethics Board (File no. 101937).

Methods

A case study is used because of the real-world context for the course and the research (Yin, 2018). The structure of the course and the instructor are inseparable from the use of specific pedagogical strategies. The single case study approach supported an in-depth inquiry in a context with many intersecting factors (Baxter & Jack, 2008).

The case selected is based on a specified population, thus constituting a theoretical sampling (Eisenhardt, 1989). The case selection is justified by the interdisciplinary setting that supports students in being active decision-makers and the use of specifications grading. This is appropriate to address the research objectives of this study. The case supports the extension of emergent theory regarding the role of self-assessment in developing informed judgment and lifelong learning. Participants were not randomly assigned; therefore, we cannot guarantee that there are no confounding variables in this study.

Data collection

The sample was determined by the defined case. As described earlier, the course includes PPBL. Students work with community partners to develop a project related to the SDGs for the partner. Coursework includes conducting research, developing systems maps, and collaborating with classmates. In addition, students are asked to reflect on their learning through two specific assignments. These latter assignments consist of the data for this study.

Scaled self-assessment, where students reflect on their skills, ability, and knowledge and rank themselves on a Likert scale, is a common approach for assessing sustainability competencies (Redman et al., 2021). The survey instrument used was adapted from Molderez and Fonseca (2018) who developed the tool to assess sustainability competency development in a service-learning project and real-world experience. Each competency, derived from Wiek et al. (2011), was assessed with multiple items. Items were reworded to allow for a pre- and post-test condition to address a limitation identified by Molderez and Fonseca (2018). One item was removed as it did not apply to the current case. Students could also select 0 for “no experience” for each item. The items are listed in Table I. This data was collected via a Google form leveraging the institutional Google access.

Table I. Self-assessment items grouped by competency

Competency	**Item**
Interpersonal Communication	I am comfortable with communicating with people who are different from myself.
	I am able to listen and respect others’ opinions and values.
	I consistently critically evaluate different positions, perspectives, and preferences.

	When I'm working with a team, I contribute to helping my team members stay focused.
	I am able to work effectively on interdisciplinary teams.
	I am able to contribute to the leadership of a group.
Systems Thinking	I consistently consider the stakeholders involved in a project.
	I am able to contribute to solving complex issues.
	I am able to deal with uncertainty.
	I am able to be creative.
	I am able to think holistically.
	I am able to think in systems.
	I am able to think in patterns and relationships rather than in isolated elements and parts.
	I am able to consider societal, environmental, economical, and cultural aspects of an issue.
Anticipatory Thinking	I am able to consider how present choices have impact on the future.
	I am able to analyze, evaluate, and craft rich pictures of the future.
	I am able to think in different geographical scales (local to global).
	I am able to analyze future scenarios.
	I am able to envision future scenarios.
Normative Thinking	I am able to compare and contrast several alternatives for a project.
	I am able to collectively create and craft sustainability visions for a project.
Strategic Thinking	I am able to learn new skills and connect them to my professional goals/plans.
	I am able to see real world situations and relationships.

The self-assessment was completed at the beginning and end of the semester. The self-assessment was a data source. In addition, it formed one source of evidence that students used in completing their reflective writing at the end of the course.

After completing the post-self-assessment at the end of the term, students completed a reflective writing assignment. Students were asked to reflect on items from the pre- and post-self-assessment that they had over- or underestimated, ones that were most improved, and areas that they wanted to continue to develop. The students used the self-assessments, as well as their other work in the course, as information in the reflective writing to identify specific areas of development within each competency, thus supporting reflection on performance (Leise, 2010). Further, the combination of the pre- and post-self-assessment with reflection contributes to the development of informed judgment that is required for sustainable assessment (Tan, 2007). This data was collected as files submitted through the institutional learning management system.

Both data sources were submitted by students as part of their coursework. Following the conclusion of the course and allowing sufficient time for grade appeals, the data for participants who consented to participate in the research were then identified and examined.

Participants. All students registered in the course in fall 2021 were invited to participate in the research by the co-investigator who was not involved in the course otherwise. The instructor for the course, who is also one of the authors, was unaware of who consented to participate in the research until after the appeals period for final grades had passed.

Twenty-eight students consented to participate in the research. Participants' pronouns were she/her (70%), he/him (20%), they/them (10%). Students came from multiple programs: Bachelor of Commerce (30%), Bachelor of Arts (15%), Bachelor of Communications (10%), Open Studies (10%), Bachelor of Design (5%), Bachelor of Social Work (5%), Bachelor of Music (5%), Bachelor of Nursing Studies (5%), and Sustainability Certificate (5%). The year of study was not collected. Due to the small sample size, these categories were not used for sub-analysis.

Data analysis

Statistical analysis. Due to the small sample size, non-parametric tests were conducted on the pre- and post-self-assessment results for each of the five competencies. The five competencies were analyzed individually and combined. Individual items from the questionnaire were not analyzed separately due to the sample size. Descriptive statistics (mean, standard deviation, median, and interquartile range of scores before and after taking the course) were computed. A series of Wilcoxon signed-rank non-parametric tests were conducted to assess whether there was a significant improvement in the median competencies. Analysis of the scaled self-assessments was completed using R (version 4.1.2).

Qualitative analysis*.* In qualitative research, it is generally recommended that the researcher begins data analysis while still collecting data (Merriam & Tisdell, 2016). The instructor engaged in informal analysis of student work throughout data collection to adapt the course to the needs of the students. This followed an inductive process to

identify codes (Merriam & Tisdell, 2016). In an inductive process, the codes are derived from the data rather than preconceived notions of the codes based on theory or prior research. Codes were applied to text segments to examine the context of the emerging themes. These codes were formalized and sorted into categories by the researchers following the completion of the course and closure of the appeals period. The final process was based on the material from students who had consented to participate in the research; however, the original codes were all represented within this sample. Dedoose (version 9.0.107) was used to support the coding. The categorization process and the development of themes followed the constant comparative method (Charmaz, 2014). The data was coded, and then data and codes were compared before condensing the codes into categories, themes, and findings.

Results

Self-assessment

Twenty students completed the pre- and post-self-assessment of their sustainability competencies. The questions and competency groups are listed in Table I. The self-assessment results showed the mean overall score increased from 104.6 (SD = 16.3) to 118.1 (SD =16.4) between the beginning and end of the course. As summarized in Table II, the median scores for each of the five competencies also increased. Wilcoxon signed-rank tests demonstrated statistically significant improvements for all competencies based on a standard p-value of 0.05: interpersonal (W = 118, p = .0005), systems thinking (W = 173.5, p = .0055), anticipatory thinking (W = 168, p = .00171), normative thinking (W= 153, p = .00015), and strategic thinking (W = 57, p = .01561), and overall scores (W = 163.5, p = .00037).

Table II. Comparison of questionnaire scores before and after taking the sustainability course

	Pre M SD	Post M SD	Pre Mdn IQR	Post Mdn IQR	W	P-value
Competencies						
Interpersonal	25.7±2.74	27.9±2.22	25.5±4.0	28.0±4.0	118	0.00050***
Systems thinking	30.7±6.22	35.9±3.84	31.5±9.5	37.0±4.25	173.5	0.00550**
Anticipatory thinking	18.5±3.52	21.4±3.39	18.5±5.25	21.5±6.0	168	0.00171**

Normative thinking	6.50±2.40	9.00±0.86	7.0±2.5	9.0±2.0	153	0.00015***
Strategic thinking	8.65±1.23	9.30±0.92	8.5±2.0	10.0±2.0	57	0.01561*
Overall	104.6±16.3	118.1±16.4	107.5±22.3	123.0±23.8	163.5	0.00037***

M = mean, SD = standard deviation, Mdn = median, IQR = Interquartile Range, W = Wilcoxon signed-rank test statistic. Significance cut-offs: * p <.05, **p<.01, ***p<.001

Reflective writing

In their reflective writing, students were asked to reflect on their pre- and post-self-assessments, including identifying overestimations, underestimations, most improved areas, and areas for future improvement. This approach helped frame the self-assessments as a formative learning tool for the students. Twenty-eight students completed the final reflection. However, eight of those did not complete the pre- and post-assessment and, therefore, could not compare their results from the beginning and end of the semester.

The final reflection summary data is presented in Table III. These results are elaborated on in the following sections.

Table III. Summary of student final reflections on competency overestimation, underestimation, most improved, and future goals

Competency	Overestimate (# of students)	Underestimate (# of students)	Most improved (# of students)	Future Goal (# of students)
Systems-thinking	6	8	21	6
Anticipatory (renamed Futures-Thinking in Redman and Wiek, 2021)	1	4	13	6

Normative (renamed Values-Thinking in Redman and Wiek, 2021)	0	3	7	1
Strategic	0	2	4	1
Interpersonal	6	5	13	2

Overestimations. In their reflective writing, students most commonly identified systems thinking and interpersonal as the competencies they had overestimated. Within systems thinking, students realized how much they still had to learn. Some example statements include the following:

- "I must have thought I was a master at systems thinking. While doing this project, I realized that thinking in systems is difficult" (Participant 1).
- "I don't know why I answered neutrally the first time, I guess I was having a good day" (ranked themselves as lower in the post-self-assessment) (Participant 4).
- "Looking back, I can say that at that point in time, I had not learned a lot about systems thinking yet and was not actually thinking in patterns and relationships" (Participant 13).
- "When it came to the question about systems thinking and whether I can think in that way, I overestimated myself a little bit. I definitely learned when I first did the first draft of my systems map that I was looking at it in the wrong way" (Participant 27). The reference to the "first draft" of the systems map is related to specifications grading. This student received feedback on their first submission and had to complete revisions.

Students who reflected that they had overestimated their interpersonal competence described how they frequently assumed leadership roles in group settings in other classes but reported that they found themselves sitting back and working more collaboratively within the interdisciplinary groups in the sustainability course. Example statements include the following:

- "Thankfully, I did not have to be the leader, but hearing from my group this project was not taxing on anyone and we all contributed and communicated very well" (Participant 4).
- "I felt like I took more of the role of the organizer (in this instance), as I was very good at making sure everyone was contributing during discussions and delegating

> tasks. I was also great at creating meeting agendas and scheduling meeting times. Still, I had difficulty keeping all the assignment deadlines organized and would often need help understanding what came next or where our priorities should lie. I also realize that being a leader can look very different for very different projects, as my current leadership role at my job looks quite different from this leadership role" (Participant 1).

Other students changed their perspectives on what was involved in leadership. Sample statements include the following:

- "I have also had to reevaluate what being a strong leader looks like. It is more than just guiding a group to success and is mainly dependent on personal interactions, which proved to be an area where I overestimated my abilities" (Participant 7).
- "At the beginning of the course I had an inflated view on how easy communication was going to be… This transferring of information back and forth as well as having my group members be timely in their communication was much more difficult than I thought" (Participant 16).

Underestimations. Overall, more students indicated that they had underestimated, rather than overestimated, their competence in the pre-self-assessment. Systems thinking was identified as the most underestimated, followed by interpersonal, anticipatory, normative, and strategic. The students often framed this as a lack of confidence in their abilities when completing the pre-self-assessment. Sample statements regarding each of these include the following:

- Systems thinking and anticipatory thinking: "I was lacking confidence in my ability to [think in systems, analyze future situations, and create and craft sustainability visions for a project] because although I had had practice with the theory after taking SUST 201, it was very difficult for me to envision and understand my ability to apply these concepts to a real situation" (Participant 2).
- Anticipatory thinking: "I had no experience in thinking in different geographical scales… I believe I lacked confidence in my thinking and knowledge" (Participant 7).
- Interpersonal communication: "my confidence in contributing to team success was definitely lower" (Participant 24).

In addition to the above, three students indicated that they had generally been inaccurate in their estimates of their competencies, and eight students indicated that they had been accurate in their initial assessments.

Most improved. Students were asked to identify three areas of competence that were most improved during the course. The summary data are presented in Table III. As students had self-assessed themselves for multiple statements for each competency, they often indicated that they had improved on multiple areas within a single area of competency. For example, Participant 18 indicated that they had improved their ability to consistently consider the stakeholders involved in a project and to consider the societal, environmental, economical, and cultural aspects of an issue. Both are part of systems thinking competence. Although students discussed multiple areas within a competency, they are only counted once in the summary data shown in Table III.

As Table III shows, several students indicated that systems thinking was their most improved competency (21). Anticipatory thinking and interpersonal competence were both identified by 13 students as areas where they had improved. The community-engaged learning project, interdisciplinary context, and working with students from different disciplines were all cited as key to developing these competencies.

There are discrepancies when looking at the areas the students identified in their written reflections as being most improved with the ones that were most statistically significant from the pre- and post-self-assessments. This comparison is included in Table IV.

Table IV. Comparison of statistical significance and student reflection of competency improvement over semester

	P-value and significance cutoff	Number of students who identified in final reflection
Systems-thinking	0.00550 ($p<0.01$)	21
Anticipatory (renamed Futures-Thinking in Redman and Wiek, 2021)	0.00171 ($p<0.01$)	13
Normative (renamed Values-Thinking in Redman and Wiek, 2021)	0.00015 ($p<0.001$)	7
Strategic	0.01561 ($p<0.05$)	4
Interpersonal	0.00050 ($p<0.001$)	13

While all the competencies showed significant improvement in the self-assessment, interpersonal competence and normative thinking had the highest significance level. Interpersonal was mentioned by 13 students; normative was mentioned by seven students in their final reflections. Meanwhile, systems thinking, which was most identified in the reflective writing (21 students), had one of the lowest significance levels ($p=0.00550$). Strategic competence was the least significant ($p=0.01561$), and only four students mentioned it in their reflective writing.

Future goals. Students were asked to identify which competencies they were most interested in developing further. Systems thinking and anticipatory thinking were the most common.

Discussion

To become expert learners, students need to develop their informed judgment and apply it to their own work and abilities. Assessment, framed by sustainable assessment, is a key part of this development. Unfortunately, many competence assessments have been treated more as an afterthought rather than being intentionally designed to support learner development (Redman et al., 2021). The current study aims to begin to address this concern.

According to Tan (2007), "future-driven self-assessment looks beyond the notion of reliability within formal programmes of study to embrace a more critical and reflexive view of student assessment and self-assessment" (p. 121). Therefore, our concern was not on the validity of individual self-ratings but on how students understood their own competency development within the course and their ability to identify future learning goals. To this end, we found three major themes.

1. Students are often unaware of the full scope of competence within an area and, therefore, have difficulty identifying what they do not know.
2. What learning has occurred is challenging for students to recognize; they assume that it was instead something they had all along but were not confident in.
3. Experience with self-assessment, supported by reflection, has the potential to support lifelong learning through the development of metacognition.

You don't know what you don't know

Overestimation has been perceived as more common among novices (Dunkel et al., 2020). This has been referred to as the Dunning-Kruger effect (Kruger & Dunning, 1999). However, recent research has revealed that this association may not hold (Dunkel et al., 2020; Gignac & Zajenkowski, 2020), particularly in populations that are considered to have higher levels of intelligence, such as undergraduate students (Dunkel et al., 2020). Therefore, what has been classified as an overestimation by students may be that they weren't aware of the full scope of the competence.

The students' interpretation of their interpersonal competence provides an example of this. Students often mistook interpersonal competence for taking on the duties of a formal leader in the group. The students defined this as setting schedules and ensuring everyone stayed on task. However, the interdisciplinary nature of the groups and the real-world context provided by PPBL exposed students to new interpersonal contexts and challenges, which are key to developing interpersonal competence (Aboytes & Barth, 2020; Konrad et al., 2021). They discovered aspects of interpersonal competence that were previously unfamiliar to them such as communication and setting priorities, as illustrated by some of the quotations in the Results section. This resulted in students overestimating their competence on their pre-self-assessment and adjusting their understanding before completing the post-self-assessment.

The lack of awareness regarding what is involved in a competency highlights the importance of supporting students in understanding each competence for self-assessments to be accurate. For example, the coursework addressed effective teams, leadership, and collaboration. As a result, students began identifying ways they contributed to the group's leadership without being the formal leader.

Similarly, students who indicated that they had overestimated their systems thinking competence discovered throughout the course that there was more involved in systems thinking than they initially understood. Therefore, they revised their original self-assessment of competence. The students required guidance in investigating and responding to unknown or unanticipated skills, knowledge, and competence. As lifelong learners, they will not always have guidance from an expert on what they are missing. Therefore, an important step in developing lifelong learners is to help them identify gaps in their own experience. This can occur through activities such as working on projects.

An interesting point is that students often identified the same competency for future development as they did for their most improved competency. This is important because it shows that these students still recognized the need to develop their competence further in these areas despite having already improved. In many cases, students identified improvement on specific parts of the competency, represented by the individual statements, but recognized that they still had improvements to make in other areas. For example, Participant 11 indicated that they can understand the potential repercussions of decisions but struggle to envision those decisions within the bigger picture, which are both parts of anticipatory competency. In other cases, students acknowledged that while they had improved, they generally had further to go. As Participant 13 said, "Even though I feel like I now have more tools to validate my assumptions and I am able to think more holistically, I still struggle with creating and crafting sustainability visions for a project." While additional research is needed to support this finding, this does indicate that once a student begins to understand the complexity of the skills, knowledge, and competencies that they have or need, they can see future learning needs. This indicates that they are beginning to recognize that learning is an active process (Boud & Falchikov, 2007a).

Learning is hard to recognize

A common theme, particularly within the discussion of underestimation, was students realizing they had more competence in a particular area than they had previously thought. While this can arise from not having a comprehensive understanding of how different skills might be connected when integrating the instructor's analysis of their work and progress throughout the semester, it seems more likely that students had difficulty recognizing when learning had occurred. For example, Participant 7 indicated that "I had no experience in thinking in different geographical scales… I believe I lacked confidence in my thinking and knowledge" (Participant 7). In this statement, they illustrated that they had underestimated their ability, rather than recognizing that they had developed skills in this area during the course.

This was a common framing: students would indicate that they had underestimated their abilities at the start of the semester, implying that improvements were a result of having a more accurate understanding of their existing abilities, while at the same time, indicating that the same competency had improved. This reflects the difficulty of metacognition, that is, the process of thinking about, being aware of, and understanding one's own thinking and learning. Many students struggle with metacognitive processes (Stanton et al., 2021). However, reflective processes with prompting questions can potentially support student metacognitive development (Alt & Raichel, 2020). This encourages monitoring and control of learning (Stanton et al., 2021) that are essential to the development of metacognitive processes. Therefore, a future avenue to pursue is how the development of metacognition may influence students' perceptions of what they are learning versus what they already know. This development will then support the students in identifying future learning needs and addressing them.

One question is how the novelty of the learning environment may contribute to what stands out to students as their key learning. The data for strategic competence supports the importance of novelty. The two statements for strategic competence were: "I am able to learn new skills and connect them to my professional goals/plans" and "I am able to see real-world situations and relationships." Of the two statements, the four students who indicated that strategic thinking was one of their most improved areas all referenced the latter item. The first statement is a large part of many people's undergraduate experience and may be familiar to the students before the course and, therefore, not as notable. In relation to the other competencies, students regularly identified areas of systems thinking, anticipatory thinking, and interpersonal competence as being unique experiences due to the focus on PPBL and the interdisciplinary context. This supports the idea that novelty may play into the students' perceptions of learning; however, more research is required to investigate this.

Reflection supports metacognition

There is evidence that the pre-tests could have primed the students to pay attention to specific elements in the course (Soderstrom & Bjork, 2023). However, the pre-self-assessment, on its own, is likely insufficient to contribute to the development of informed judgment (Tai et al., 2018). Tai et al. (2018) recommend using self-assessments over multiple periods to identify

future learning needs and engage in feedback on improving self-assessment. The former was addressed by the pre- and post-self-assessment conditions used in the current study. Reflective writing contributed to the latter two requirements. The reflective writing asked students to critically consider their self-assessments to highlight gaps in understanding between the two time periods. This supports metacognition as the students thought about why they had self-assessed as they had in each period (Daniar et al., 2023). In this way, they had to explore evidence for their conclusions. This is supported by Yan et al.'s (2023) findings that qualitative self-assessment through written comments and reflective notes is identified as more valuable for learning by students than quantitative assessment.

The context of PPBL is also important to these findings. Nieminen and Boud (2024) found that authenticity was key to self-assessment: students engaged with the self-assessment more meaningfully if it was authentic to professional practice. By basing the self-assessment around the PPBL, students could associate their experiences and skills with real-world contexts. Several students identified this as meaningful in their reflective writing. Thus, the self-assessment and the reflection contributed to metacognition, at least in part, because students were assessing themselves on authentic tasks rather than as an instrumental task conducted only for the purposes of the course (Nieminen & Boud, 2024; Sokhanvar et al., 2021). This has further implications for addressing employers' concerns regarding students' ability to apply skills and knowledge in workplace settings (Sokhanvar et al., 2021).

Conclusion

Sustainable assessment is intended to support the development of learners who can identify learning needs, set goals, and plan appropriate learning paths beyond the scope of formal education (Boud & Falchikov, 2007b; Boud & Soler, 2016). This development can be supported through intentional pedagogical strategies, including how assessment is used in formal education settings (Tai et al., 2018). The current study aimed to explore how pre- and post-self-assessments, referred to as self-assessments in the paper, support the development of student self-assessment abilities. In addition, we explored how reflection contributes to self-assessment. Our findings indicate that reflection adds a valuable tool for students to use in developing their self-assessment abilities through the process of metacognition. It was the reflective writing that supported students in unpacking their initial evaluative judgments, as well as their learning over the course.

At the same time, we found that two challenges made it difficult for students to self-assess at this stage: novice understanding of what a competency involves and difficulty in recognizing learning. These findings provide important groundwork for future research. First, as Tai et al. (2018) suggest, and as supported by the UDL principles (Novak & Rodriguez, 2018), teachers can engage students in co-creating self-assessment and rubric development criteria. This helps students learn how to better understand what is involved in a particular skill or competency. Second, learning itself must be reframed as an active process so that students can better see themselves as active learners. This second point is already in progress in many sustainability classrooms through the use of active learning pedagogies such as PPBL. Thus, a

next step may be to investigate whether students experiencing these pedagogies are in fact identifying as active learners. Building on this could be the co-creation of assessment criteria for the learning achieved through PPBL and other pedagogies. We know that this is already exists in the field; thus, we call for research to explore the impact on the development of lifelong learners.

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