Connecting Student Attitudes and Sustainability Competencies in Pharmaceutical Science Education

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Abstract

Environmental and social sustainability is an increasingly significant factor for the pharmaceutical industry. Higher education programs need to equip future pharmaceutical professionals with the knowledge, skills and attitudes to effectively address sustainability problems and seize emerging opportunities. Sustainability competency (SC) frameworks may offer guidance for developing sustainability curricula, but there is little precedence for their integration into programs that do not specialise in sustainability or the environment. This study explores the application of SC frameworks for designing learning and assessment activities, and gauges student attitudes towards sustainability in a module of the Monash University Master of Pharmaceutical Science degree. A mixed methods approach involving a student attitude survey and a reflective assessment task was undertaken (11% response rate). Students discussed insights and experiences that mapped onto each of the systems thinking, problem-solving, strategic thinking, collaboration/interpersonal futures-thinking, and values thinking competencies. Of note, most students considered sustainability as being relevant for their future pharmaceutical science careers. The SC framework provided insight into student perceptions of their learning and gaps, as well as pedagogical design.

Introduction

Environmental and social sustainability is an increasingly significant factor for the pharmaceutical industry (Koenig and Dillon, 2017; Milanesi and Guercini, 2020), and therefore for education in the science disciplines that underpin the industry. Important environmental and social sustainability considerations for the pharmaceutical sector include high energy consumption, environmental pollution from the production and consumption of pharmaceutical products, packaging waste, and the high cost of many drugs (Nour, Asim, Tasneem, S., Wadha, M. M., & Bhagavathula, 2017; van der Gronde, Uyl-de Groot, & Pieters, 2017; Belkhir and Elmeligi, 2019; Bartolo, Azzopardi, & Serracino-Inglott, 2021). Failure to address these challenges will contribute to inequity in access to medicines alongside environmental impacts that will disproportionately affect some communities and regions around the world (Levy & Patz, 2015; Urias, 2017; Nguyen & Ngyuen, 2025).

Sustainable development challenges are complex and interconnected. Addressing these challenges requires professionals, including those working in the pharmaceutical industry, to have the requisite skills and knowledge around environmental and social responsibility (Bartolo *et al.*, 2021).

There is broad agreement in the literature about sustainability competencies (SCs) that professionals need to develop to effectively address sustainability challenges (Wiek and Redman, 2022). These competencies include (Wiek Withycombe, & Redman, 2011; Wiek et al., 2016):

- Systems thinking competency:
  The ability to collectively analyse complex systems across different domains and scales, considering connections, feedback loops, inertia and cascading effects (Wiek *et al.*, 2011: 207).
- Futures thinking (or anticipatory) competency:
  The ability to analyse, evaluate and develop detailed, compelling pictures or visions of the future related to sustainability issues (Wiek *et al.*, 2011: 207).
- Values thinking (or normative) competency:
  The ability to map, specify, apply, reconcile and negotiate sustainability values, principles, goals and targets (Wiek *et al.*, 2011: 209).
- Strategic thinking (or action-oriented) competency:
  The ability to design and implement interventions, transitions and transformative governance strategies toward sustainability (Wiek *et al.*, 2011: 210).
- Integrated problem-solving competency:
  The ability to apply different problem-solving frameworks to complex sustainability problems and develop viable solution options (Wiek *et al.*, 2016: 251)
  and
- Collaboration (or interpersonal) competency:
  The ability to motivate, enable and facilitate collaborative and participatory sustainability research and problem solving (Wiek *et al.*, 2011: 210).

SC frameworks (Wiek *et al.*, 2011; Wiek *et al.*, 2016) serve as organising principles for a curriculum. The competencies are designed to support students to address sustainability challenges and are considered an addition to disciplinary knowledge and basic academic competency (Brundiers *et al.*, 2021). While there is general agreement about the SCs in the literature, there are challenges with how they are being implemented (Wiek and Redman, 2022) and identifying a clear relationship between the SCs and disciplinary knowledge (Brundiers *et al.*, 2021). Furthermore, it is not yet clear how they can be applied to discipline-based education programs, such as a pharmaceutical science degree (Huth *et al.*, 2023). Therefore, this paper investigates the suitability of using the SC framework to evaluate students' sustainability competencies.

This study aims to:

(a) Explore the applicability of SCs to the design of learning and assessment activities in the Monash University Master of Pharmaceutical Science degree, and
(b) Gauge student attitudes on the relevance of sustainability to their career aspirations.

Survey data and reflective assessment submissions from eleven students underwent analysis against a SC framework (Wiek *et al.* 2016). We examine the benefits and limitations of applying current SC frameworks for pedagogical design and highlight opportunities for future research.

Learning Activities

This study focuses on a four-week Sustainability in Pharmaceutical Science module, delivered as part of the second year Career Tools unit of the Monash University Master of Pharmaceutical Science degree. Student teams were assigned either 'for' or 'against' a topic of sustainability controversy. The teams researched the issue and conducted a debate and negotiation with the opposing team. Workshops and written assessments supported the teams in preparing for the debate and negotiation tasks (Figure 1).

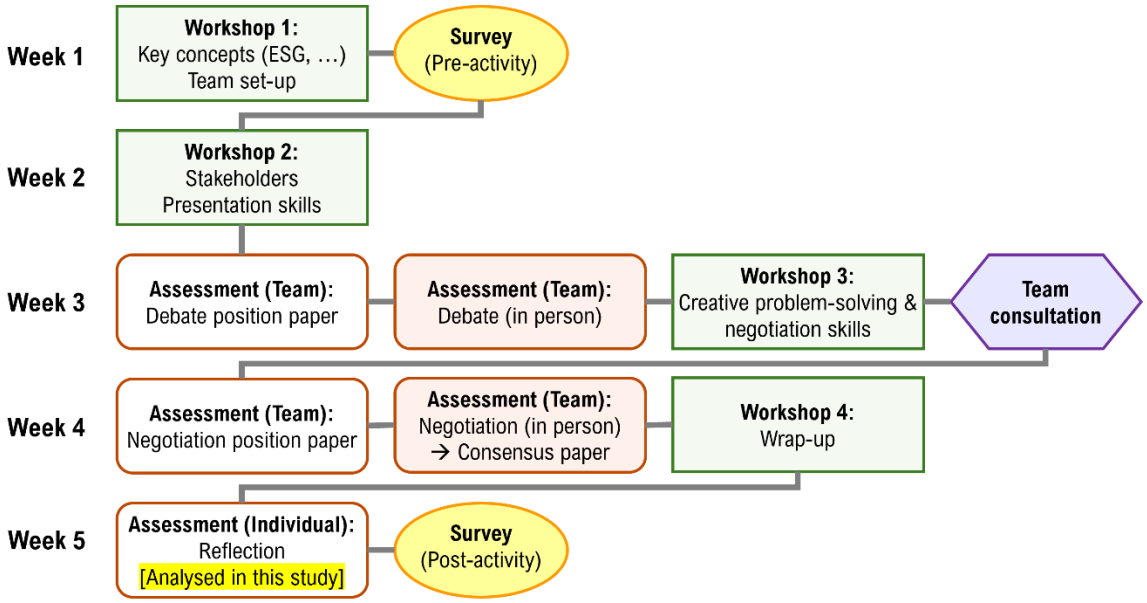

Fig. 1: Structure of the sustainability module, including learning activities and assessments.

Examples of controversy topics used in the module are:

- Should pharmaceutical companies outsource clinical trials to less developed countries?
- Should pharmaceutical companies be responsible for the impacts of production discharges?

After completing the module, the students were required to write an individual reflection of their learning (750 words), using the following prompts:

- What was one key insight you gained from the sustainability debate and negotiation?
- Why is this insight important to you as a professional pharmaceutical scientist?
- How do you plan to use this new insight in future employment and/or academic studies?

Students were asked to include specific examples and descriptions of the situation that sparked their insight (e.g., who was speaking, what point did they make, what evidence did they use, etc?).

Method

A mixed methods approach using multiple data sources was used to explore students' views of sustainability in pharmaceutical science and their learning through the lens of sustainability LOs. The data sources were a pre- and post-activity survey of student attitudes towards

sustainability, and a written reflective assessment task. Written reflective tasks are considered to be a starting point in analysing students' learning and development (Verheijen, 2022) and have been evaluated in the context of employability skills (Hiscox et al, 2022). They align with the content of this unit and the exploratory nature of this study. Descriptive statistics were obtained from the survey. The reflective assessment task data was analysed in three steps described below.

Data Collection

All students enrolled in MPS5303 Career Tools (a core unit within the Master of Pharmaceutical Science that deals broadly with career development) in Semester 1, 2024 were invited to participate in the research. Ethics approval was granted by Monash University Human Research Ethics Committee (Project ID 41926).

Students submitted their assessment tasks before consent to participate was sought. This two-step process ensured that assessment and research participation were separated. The pre-activity and post-activity surveys were conducted during the first and last workshops of the Sustainability module.

Out of 126 enrolled students, 14 (11 %) consented to participate in the research. Eleven of those 14 students (9 %) completed both the pre- and post- survey.

Data Analysis

Step 1 - Develop an analytical framework

A 'concept driven' (Gibbs, 2018) coding framework was used, developing the analytical framework by taking the novice level learning outcomes (LOs) from Wiek *et al.* (2016) and applying three filters to select the final LOs to be coded.

The novice level LOs were chosen because the student cohort was unlikely to have studied sustainability previously and the sustainability module in the unit was short and not designed to provide a comprehensive introduction.

The three filters were:

1. Exclude LOs that were not relevant for the content of the pharmaceutical science unit (e.g. "*Conduct stakeholder interviews to build understanding of different perspectives and values*" was not relevant for the unit);
2. Exclude LOs that were not covered due to the short duration of the sustainability module. For example, from Wiek *et al.* (2016) "*Understand basic theories of change (e.g. behaviour change, social transformations)*" was excluded as it was very technical and detailed and unlikely to be relevant for these students;
3. Exclude codes that overlapped with each other.

Eleven LOs from five of the six sustainability competencies were selected. The values thinking competency was excluded under filter 2.

The LO text from Wiek *et al.* (2016) was then modified to fit the sustainability learning activities and assessment tasks to aid data coding and analysis.

Step 2 - Code reflective assessment task
The 750-word reflective assessment task submissions were downloaded from the Monash University learning management system and anonymised using a numerical code (1, 2, 3 etc). The submissions were imported into the Nvivo qualitative data analysis program. The coding staff (AM) familiarised themselves with the reflections and systematically coded each reflection.

The deductive codes developed from the analytical framework were clearly defined (Step 1) and did not need revision during coding. Where the reflective submission clearly discussed two concepts, the data was double-coded.

Step 3 - Analysing student context
The coding process was discussed with other team members not involved with the coding (SH, SVDM) who undertook further analysis to identify which common concepts from the reflection texts were associated with each LO of the framework. E.g. for the code "*Identifies professionals who may contribute to or hinder the sustainability problem*", it was observed that students identified stakeholders, connected the issue to specific stakeholders and identified that similar stakeholders may have different interests/approaches. This additional analysis was used to develop a summary of the findings, including indicator words for each LO (Table 2).

Results

Survey results
The survey included three questions addressing students' confidence in their sustainability knowledge, their understanding of sustainability, and their views on the relevance of sustainability to their career (Table 1). The same questions were administered at the start and end of the module to provide a snapshot of the students' views.

Confidence (Question 1): Most respondents described themselves as "somewhat confident" about their sustainability knowledge both before and after the sustainability module. Four of the eleven students felt more ("completely") confident after the learning activity.

Knowledge (Question 2): The majority of students were able to select the most appropriate definition of sustainability both before and after the sustainability module. The response distribution remained essentially unchanged after the module.

Career relevance (Question 3): Both before and after the module, most students agreed or strongly agreed with the statement that understanding sustainability will be useful for their career. Two students initially strongly disagreed in the pre-survey and no longer disagreed after the sustainability module. Due to the small response rate, it is not possible to confidently explain why the responses changed.

Table 1: Responses to survey questions. Only students who responded to both surveys (before and after the activity) were included in the count.

Question text	Response option	Before activity		After activity	
		n	%	n	%
1. How confident are you about your knowledge in	Not confident at all	0	0.0	0	0.0
	Somewhat confident	11	100.0	7	63.6

sustainability in the pharmaceutical science sector today?					
	Completely confident	0	0.0	4	36.4
2. Based on your current knowledge, what is the best definition of sustainability?	Meeting the needs of the present without compromising the ability of future generations to meet their own needs	9	81.8	8	72.7
	Creating a government welfare system that ensures universal access to education, health care, and social services	1	9.1	1	9.1
	Building a neighbourhood that is both socio-demographically and economically diverse	1	9.1	2	18.2
3. Rate your agreement/ disagreement with the following statement: "Understanding sustainability will be useful in my career"	Strongly agree	7	63.6	4	36.4
	Agree	2	18.2	7	63.6
	Neither agree/disagree	0	0.0	0	0.0
	Disagree	0	0.0	0	0.0
	Strongly disagree	2	18.2	0	0.0

Reflection Data

In their individual reflections, most students participating in the study reflected on several ideas that were coded to SC learning outcomes, although the SCs were not evenly represented (Fig. 2). When not reflecting on SCs, students recounted their actions, future personal goals, or information about their topic. Taken together, all of the sustainability LOs in the analytical framework were addressed, but to varying levels of detail and sophistication.

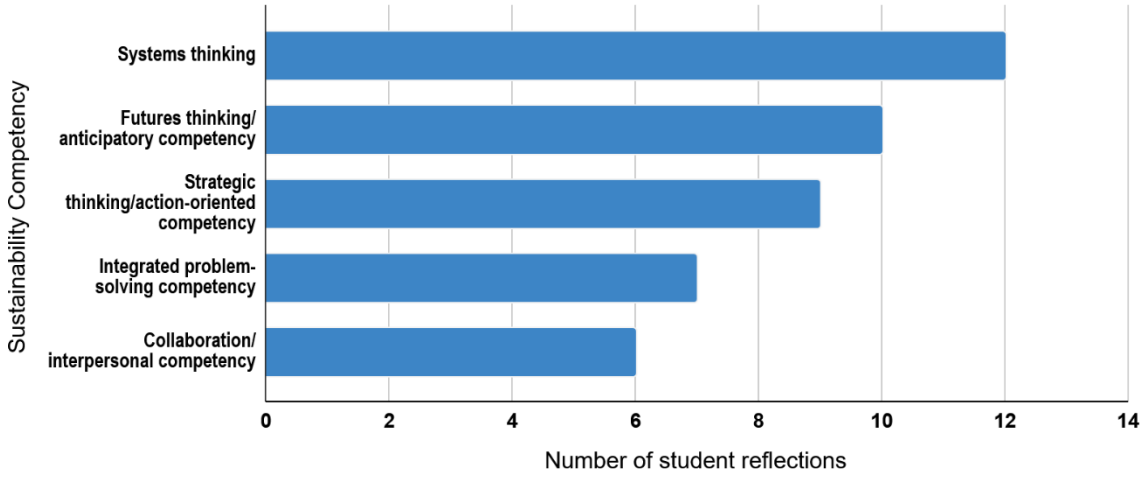

Fig. 2: Number of student reflections coded to LOs corresponding to each SC (out of n=14).

At the basic level, students would identify the general significance of key aspects of a LO. For example, the LO "*describe some functions of systems thinking in sustainability problem-solving*" might be addressed by a student highlighting the general benefit of considering stakeholder perspectives. Other students would demonstrate a more sophisticated understanding by discussing how certain stakeholders are relevant to a particular problem, or how actions at different scales (e.g. local, national, global) are interdependent.

Students frequently reflected on ideas that were coded to two or more LOs. For example, a student would describe a problem-solving approach (problem-solving competency) that also involved communication strategies (interpersonal competency) and demonstrate insight into how stakeholders are related to the problem at hand (systems thinking competency). The interconnection between SCs has been discussed in the literature (Wiek *et al*., 2011; Brundiers *et al.*, 2021) and our results reflect these interconnections. Table 2 provides an overview of the competencies, the LOs proposed by Wiek *et al.* (2016), the adapted codes for this project, and keywords and selected quotes indicating how the LOs were addressed. The results for each of the LOs are further discussed in the following sections.

Table 2: Thematic analysis of student reflections using the sustainability competency LOs proposed by Wiek *et al.* (2016).

Sustainability Competency	**Wiek *et al.* LO**	**Code (Agreed codes column)**	**Indicators (key words or concepts) and Representative Quote**
Systems thinking	Describe some functions of systems thinking in sustainability problem-solving	Demonstrates the benefits of understanding the system (i.e. connections between different parts)	▫ Balance social, environmental and economic factors ▫ Consider (factors, issues, impact) ▫ Perspectives ▫ Interactions, interdependent ▫ ESG *"[...] we must consider the perspectives of all stakeholders and balance the medical needs and environmental impacts to [...] meet regulatory requirements, address clinical needs gaps, and minimize environmental impact"* (Student 14)
	Describe in principle how different professional activities contribute to, or solve/mitigate sustainability problems	Identifies professionals who may contribute to or hinder the sustainability problem	▫ Stakeholders (identify, differentiate) ▫ Connect stakeholders and issues "*Pharmaceutical companies are significant generators of production waste, but other organisations that contribute to the larger production disposal ecosystem include regulating bodies, local governments, and healthcare providers.*" (Student 6)
Strategic thinking/action -oriented competency	Identify factors that affect the success or failure of transitions and interventions	Identify factors (stakeholders, external factors) that affect the success or failure of change strategies	▫ Plan, achieve, advance (a goal) ▫ Balance ▫ ESG, regulation, global ▫ Collaboration *"[...] if we want to support further the localisation of the production of medical cannabis in Australia, a less restrictive regulation [...] is necessary"* (Student 5)
	Explore strategies how to position one's job activities in a way that it contributes to sustainability transitions	Identify potential professional roles that could contribute to sustainability change	▫ Shared responsibility ▫ Contribute ▫ Stakeholders *"We also emphasised how government and business might work together to innovate and create more sustainable solutions."* (Student 7)
Futures thinking/ anticipatory competency	Describe some functions of futures thinking in sustainability problem-solving	Discusses the importance of planning for the future to address	▫ Plan ▫ Consider ▫ Long-term, future (effects) "*Considering waste management before constructing manufacturing sites can*

		sustainability problems	*significantly affect sustainability of the products.*" (Student 1)
	Anticipate in principle how one's job might evolve over time (career trajectory) and how one's professional activities might contribute to, or mitigate future sustainability problems	Discuss how their future profession may contribute to or mitigate future sustainability problems	▫ Future (career, pharmaceutical scientist) ▫ I, me, my ▫ Benefits, contribution "*My responsibilities will entail advocating for expedited regulatory processes, fostering collaboration among different economic sectors, and integrating environmental considerations into drug formulations."* (Student 6)
Integrated problem-solving competency	Understand how sustainability problem-solving competency is critical in professional jobs	Discusses how problem-solving may be relevant to their future profession	▫ Future (career, pharmaceutical scientist) ▫ Problem-solving ▫ Describing process/strategy *"[...] I can explore solutions to problems by embracing a multidimensional approach to thinking. Should one approach prove ineffective, alternative avenues can be pursued."* (Student 10)
Collaboration/ interpersonal competency	Understand general concepts critical to interpersonal interactions, including listening, communication, negotiation, conflict resolution, teamwork, stakeholder engagement, etc.	Understands effective teamwork includes: communication, conflict resolution, negotiation, listening	▫ Insight, benefit, inspiration ▫ Stakeholder perspectives ▫ Skills ▫ Debate, negotiate, collaborate *"[...] When taken into consideration the perspectives of other stakeholders, the solutions to the initial disagreements became clear which helped in the negotiation process"* (Student 2)
	Describe the basic types, phases and techniques of teamwork and stakeholder engagement in sustainability projects	Identifies different strategies of effective teamwork (e.g. coordination, planning, contributing, time management, accountability etc)	▫ Learned ▫ Viewpoints, perspectives ▫ Describes strategy *"Rather than focusing on persuading the other party, she suggested that our objective should be to reach an agreement with them."* (Student 10)
	Understand the basic benefits of listening, communication, teamwork, stakeholder engagement, and other interpersonal skills for one's professional job	Identifies that interpersonal skills are relevant for their professional work	▫ (Future) career, scientist ▫ Debate, negotiate ▫ Manage time/project ▫ Collaboration, teamwork *"[...] Understanding others' perspectives [...] give a person the ability to responds with compassion and empathy which could help turn the tide in a negotiation process by reaching the listeners' hearts influencing them. I plan to use this insight during future employment in a private pharmaceutical company where there are frequent discussions and negotiations."* (Student 2)

Systems thinking competency

The focus of systems thinking in sustainability is for professionals to analyse sustainability problems that cross different sectors and scales (Wiek *et al.*, 2016). The corresponding LOs include the ability to see the need for systems thinking and identifying intervention points and critical actors.

Many student reflections identified the need to balance environmental, social and economic factors to achieve sustainable outcomes in pharmaceutical science. Students associated these factors with sustainability goals or actions (e.g., "advancing medicine", "minimising pollution") or stakeholders representative of these goals ("pharmaceutical companies", "patients", "regulatory bodies"). Other concepts related to systems thinking included the consideration of scale (local/national/global) and the full lifecycle of a product (from manufacture to disposal).

Some students connected stakeholders to specific sustainability problems and solutions, explaining that stakeholder actions are interdependent in achieving sustainability outcomes. It should be noted that students rarely distinguished between professional roles and stakeholders (e.g., workers vs middle management vs CEO, or manufacturing vs marketing within a company).

Strategic thinking competency

Wiek *et al.* (2016) describe strategic thinking competency as the ability to plan and take actions that result in systemic change. In his unit, two strategic thinking LOs were included in the analysis: success and failure factors, and professional roles.

A wide range of circumstances influencing the success or failure of sustainability change were identified in the reflections, including economic, global, regulatory, environmental and social factors, as well as approaches involving innovation, collaboration and stakeholder engagement. These were usually related to a particular goal (e.g., establishing a waste management plan) rather than to a clearly articulated strategy.

The professional roles LO was operationalised as a student's ability to identify roles that could contribute to addressing sustainability problems. Students typically reflected on stakeholders and sometimes explained how they could make positive contributions, such as in the following quote:

> *"[...] TerraCycle, a leader in recycling difficult-to-recycle items, collaborates with businesses to encourage customers to pick up and return goods. [...] We also emphasised how government and business might work together to innovate and create more sustainable solutions."* (Student 7)

However, professional roles were only addressed in general terms ("pharmaceutical scientist"). This may be because a large proportion of the students in this Master's degree have not yet gained the professional experience to more specifically reflect upon different pharmaceutical science roles.

Futures thinking competency

Futures thinking (or anticipatory) competency involves professionals being able to anticipate how sustainability problems may develop over time (Wiek *et al.*, 2016). Two futures thinking LOs were included in the analysis: students recognising the need of planning for the future to

address sustainability problems, and students considering how they may be able to contribute to sustainability solutions in their future professional roles.

Some students identified the need for long-term planning, such as considering environmental impacts before product manufacturing:

> *"Considering waste management before constructing manufacturing sites can significantly affect sustainability of the products."* (Student 1).

The reflections revealed a wide range of thoughts on how students' future roles may enable them to make positive contributions to sustainability. While some students discussed what their future job might require them to do, others took a more active perspective, elaborating on how they plan to use their role to effect positive change:

> *"As a rule maker working for government departments or other similar departments, I need to consider multiple factors including environmental factors, and social factors when developing new regulations for a new medication."* (Student 5)

> *"I have committed myself to pushing for corporate responsibility and supporting programmes that put social responsibility and the environment first. This could be researching environmentally friendly medicine formulations, working with industry partners to implement sustainable practices, or lobbying legislators for laws that support sustainable innovation."* (Student 7)

Integrated problem-solving competency

This competency focuses on applying problem-solving strategies and tools to develop solutions for sustainable development (Wiek *et al.*, 2016). The corresponding LO in this study was recognising the relevance of sustainability problem-solving to one's profession, which clearly aligned with the learning activities and broader context for the postgraduate unit.

Several students stated that they considered problem-solving to be relevant to their future career. Some of them identified specific aspects of problem-solving strategies, such as working with multidisciplinary teams or pivoting to an alternate plan if the first attempt is unsuccessful. Statements that were categorised as problem-solving often contained ideas that were double coded to systems thinking LOs.

Collaboration/interpersonal competency

The collaboration/interpersonal competency relates to professionals being able to identify the need for teamwork and stakeholder engagement, and the interpersonal skills required to undertake these different types of collaboration (Wiek *et al.*, 2016). The foundational LO for this competency is demonstrating an understanding of various interpersonal skills for effective teamwork. Two further LOs were included, which relate to identifying specific teamwork strategies and recognising the relevance of interpersonal skills to one's professional work.

Common ideas from the reflections included the benefits of understanding stakeholder perspectives, and applying communication and negotiation strategies to sustainability and general professional purposes:

> *"I learned from this experience how important it is to listen to different points of view and collaborate with others to achieve shared objectives."* (Student 7)

> *"In case of disagreement or need to coordinate, I can use the skills I learned to find and present the evidence and try to collaborate with others to achieve win-win goals, [...]."* (Student 14)

Other themes: values thinking and personal motivation

While most sentiments from the reflections could be coded using the analytical framework selected for this study, some statements did not match the LOs and SCs described above. These often contained notions of fairness or ethical behaviour (beyond merely balancing stakeholder interests), as well as statements of personal motivation or commitment.

Several students reflected on how sustainability considerations may guide their own future professional practice. Often they would do so from a position of personal engagement or 'activism', using phrases like "I plan to...", "I am committed to...", "we must ...", etc.:

> *"In future employment and academic studies, I plan to utilise the knowledge by actively engaging in sustainability and accessibility into pharmaceutical industries. Approaching projects with ESG framework as a foundation to improve success...."* (Student 13)

Such statements can be related to the values thinking SC, which is the ability to understand the values that motivate stakeholders as well as oneself, and general ethical principles based on fairness, justice and responsibility, and to apply them to solving sustainability problems (Wiek *et al.*, 2016). Values thinking LOs were not formally coded in this study since they were not the focus of the sustainability module. However, the statements above suggest that values thinking LOs should be considered in future studies.

Discussion

The results presented above indicate that the Sustainability in Pharmaceutical Science module had an impact on student learning: in their reflections, students discussed a wide range of themes that could be mapped onto the SC LOs selected for this study.

This study is exploratory, seeking to test the suitability of the SC LO framework (Wiek *et al.*, 2016) for analysing and understanding students' self-reported learning. The small number of participants (survey: 11; reflections: 14 students) means that the findings cannot be generalised to the whole student cohort or beyond this project. However, the study provides insights into student perceptions of sustainability in a pharmaceutical science context, and opportunities for improving pedagogical design.

This discussion focuses on three questions based on the survey and reflective assessment task analysis:

1. What were student attitudes towards sustainability and their careers?
2. What were student perceptions of their learning?
3. How useful is the LO framework of Wiek *et al.* (2016) as an analytical and pedagogical design tool?

Student attitudes towards sustainability and their careers

Both the survey and reflective task data indicate that the pharmaceutical science students who participated in this study considered sustainability to be an important issue and relevant for their future careers. Many of the reflections identified improving human health outcomes (through pharmaceutical product development and improvements in the healthcare system) not only as a key stakeholder interest, but also as a personal motivator, and recognised this as a critical sustainability objective.

The sustainability module was part of a broader, career development unit and several participants noted the relevance of the general skills developed during this module - such as teamwork, communication, interpersonal skills, presentation skills, and time management - to their future career. Some of these skills are part of the collaboration/interpersonal competency (Wiek *et al.*, 2016), while others would be defined as general professional skills. In the literature, the SCs are viewed as closely connected to discipline and academic knowledge (Brundiers *et al.*, 2021), and there are also overlaps between the SCs and other professional skills. Our study supports these observations.

Some students expressed strong motivations to make sustainability part of their future career and noted professional activities they might undertake to improve sustainability (e.g., using renewable energy sources, work with stakeholders towards sustainable practices, etc.). However, these activities were not directly associated with a specific job role, other than the generic 'pharmaceutical scientist'. This lack of specificity may be due to students' limited understanding of what roles exist and what activities they would typically entail. Learning activities that model the application of sustainability principles in a professional context - for example, undertaking life cycle analyses in curricular education or being involved in co-curricular activities such as the My Green Lab program - may help fill this gap.

Student Perceptions of their Learning

This study explores students' self-reported reflections on a sustainability module. The coding revealed that students discussed concepts and insights that could be mapped onto each of the LOs in the analytical framework. In addition, students also reflected on ideas that were not part of the LO analytical framework developed for this project (e.g. values thinking).

Certain themes, including career, stakeholders and transferrable skills, featured particularly strongly in the student reflections. While this is undoubtedly a consequence of the nature of the debate and negotiation activity, the open-ended prompts for the reflection assessment allowed students to explore any aspect of the learning activity that resonated with them. It is noteworthy that students discussed these themes from a range of perspectives, which resulted in them being coded to different SCs.

This is illustrated in Figure 3 for the concept of stakeholder engagement. Discussions of this concept ranged from a basic level (identifying stakeholders in general; recognising the benefit of collaboration) to more detailed and/or applied statements that connected the idea of stakeholders or collaboration to specific sustainability problems or their career, respectively. The corresponding codes extended across four SCs (systems thinking, interpersonal competencies, strategic thinking and values thinking).

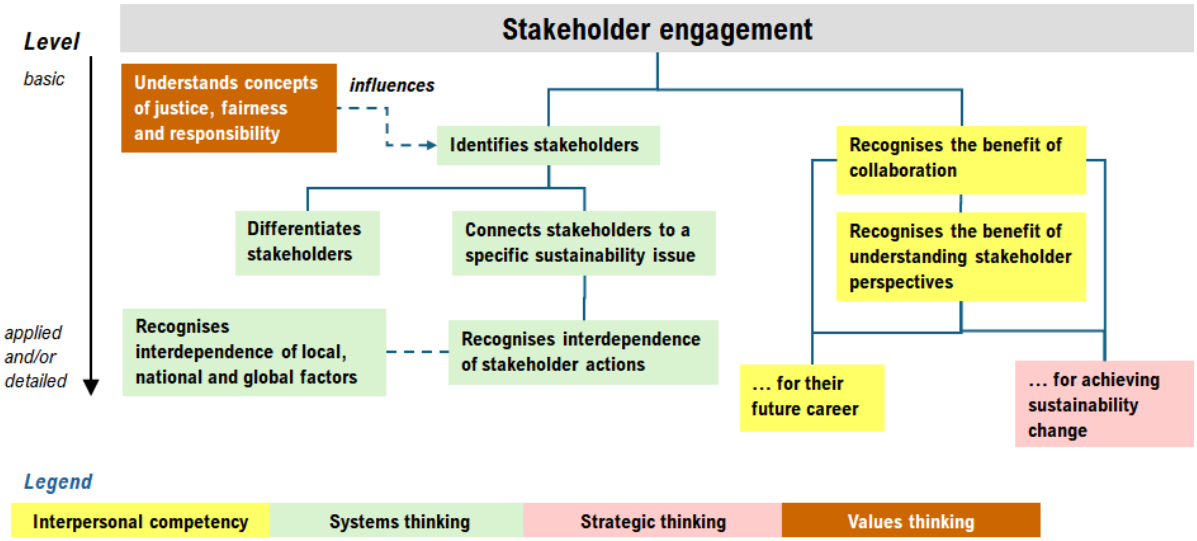

Fig. 3: Concept map for the key concept "stakeholder engagement" based on analysis of student reflections. The colours denote corresponding SCs.

Using the Wiek *et al.* (2016) LO framework

The third point for discussion is understanding how effective the framework is as an analytical and design tool. In this project, the SC framework and the LOs (Wiek *et al.*, 2016) proved useful for organising and categorising student reflections of this sustainability module. The reflections generally aligned well with the LOs, particularly those of the systems thinking and interpersonal SCs. As the learning activities in the module were designed independently of the analytical framework (Figure 1), the ability to assess the LOs in depth is limited. For example, the activity and assessment design did not focus on the skills and tools required for developing some SCs such as forecasting or visioning skills, which can be used to develop strategic thinking and future planning SCs.

We found the framework helped us analyse the pedagogical design of our learning activities and assessment tasks, as we could identify strengths and weaknesses of the existing design and suggest improvements. For instance, the framework could be used to identify activities for developing specific SCs (e.g. futures thinking using visual tools, day-in-the-life narratives and modelling software, such as STELLA). Potentially, the framework could be used to map SCs across different units and a course and for scaffolding learning activities across levels (i.e. using novice, intermediate and advanced LOs).

The framework provided insights into pedagogical design and was effectively applied in practice, but it was complex to use to analyse student reflections of learning activities. The LOs needed to be carefully selected and then applied to the pharmaceutical science context. There are many interconnections between the SCs (Wiek *et al.*, 2011; Brundiers *et al.*, 2021) which take time for researchers to understand and use for analysis. We view this complexity as both a weakness and strength: a weakness as it can make application of the framework complicated and time consuming, and a strength as it captures the interconnectedness of different parts of the sustainability problem solving context.

Conclusion

This project investigated student perceptions of their learning in a 4-week sustainability module in a core unit within the Master of Pharmaceutical Science at Monash University. The data indicated that the module helped students develop their skills and understanding across the coded SCs, although this is based on a small sample size. Students emphasised concepts related to the systems thinking and interpersonal/collaboration competencies.

As a case study, this project demonstrated the utility of the SC framework as an evaluation and design tool in a science course that is not focused on sustainability or the environment. However, the complex and interconnected nature of the SC framework can make it onerous to apply to a learning activity.

As this is an ongoing project, results from subsequent student cohorts with larger participant numbers and additional data sources for triangulation, may shed further light on student learning in the module, including the effect of modifications to the learning activities on the distribution of LOs in the analysis. While the SC framework is a promising educational tool, future research exploring its use in a variety of disciplines and settings could broaden its application. Comparison with other sustainability frameworks, such as the UN sustainable development goals (United Nations, 2015), would help clarify the strengths and shortcomings of each framework as a step toward a more widely applicable 'toolkit' for the evaluation of sustainability learning design.

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