Teaching and Educational Methods

Student Reflections on Problem-Based Learning: The Use of Open Research Calls in Problem Design

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Abstract
While assessment is a necessary part of teaching and learning, how we assess is more flexible. This article demonstrates how using open research calls to design group-based assessment, implemented using the Problem-Based Learning (PBL) approach, enhances the student experience and learning. Data were captured through feedback surveys from final-year undergraduate agricultural science students taking a Food and Agribusiness Strategy module. Student reflections focused on ranking their preferences and perceived learning benefits of various assessment types along with brief justifications for rankings. The overall experience with PBL was captured qualitatively.

Findings indicate that the PBL improved engagement and peer-to-peer learning; students were motivated to learn and develop skills they identified as relevant for their future careers. Academics are well positioned to use research calls to design assessments and implement active learning strategies, such as PBL, to structure learning. This approach presents an opportunity for academics to challenge students to engage with real-life problems in a supported environment. Students described the approach as empowering and insightful. The positive sentiment and meaningful engagement experienced by the students were reflected in greater perceived learning benefits and a clear preference for PBL compared to other approaches.

1 Introduction

The agrifood sector faces multiple complex problems, from climate change, biosecurity and disease, economic uncertainty and price volatility to ethical and moral issues. These problems are compounded by wider societal and geopolitical challenges that impact the global food system. If we are to challenge ourselves and our students to consider these complex agricultural relevant problems in the classroom, we must begin with appropriate pedagogies that integrate thinking across disciplines and develop skills beyond technical knowledge in the curriculum. Students who will become future leaders need the skills to tackle real-life, complex problems and understand how to work in interdisciplinary teams. The integration of diverse students and the use of pedagogies that support iterative learning, such as problem-based learning (PBL), ensure that they experience the challenge of evaluating unstructured problems in a structured and safe way. PBL supports the development of professionals who are ready to tackle the real-world challenges (Lucena et al. 2025). The exploratory nature of PBL allows students to recognize the limitations of their knowledge and helps them explore problems from another perspective. This article suggests that group work, designed using research calls and implemented through the PBL approach, enables more effective learning experiences and contributes to the development of future leaders who are well equipped for interdisciplinary conversations.

Preparing the next generation of leaders to deal with problems which require diverse skillsets and knowledge, is a challenge for educators. In agriculture, for example, specialist education often limits

student exposure to other relevant fields. Similarly, in industry, interdependent actors are often not necessarily closely linked. Many upstream operators, such as input suppliers or farmers, may never interact in a meaningful way with downstream operators such as retailers. Such links across the supply chain from farm to fork are often weak and largely based on essential transactional relations (Leat and Revoredo-Giha 2008). This typically reflects suppliers (farmers) as price takers in commodity markets. While market power can be dissolved somewhat through alternative business models, such as farmer cooperatives, it is a challenge to successfully sustain a comparative advantage against conventional global supply chains (Kelly et al. 2024). It is useful for students to consider these contextual factors when looking at strategies for food and agribusinesses. Weak links across supply chains and the interdependent nature of problems in agriculture require us to open the minds of students to understand actions and reactions from multiple perspectives. Positioning students at the core of such problems and asking them to consider challenges (e.g., the inequality of below-cost selling or sustained low profit margins on farms) while simultaneously bearing in mind consumer demand, food availability, nutritional value, and upstream pressures in the wider context of our food system broadens students' thinking. It is for these reasons that research calls and industry consultations are relevant for student assessment.

Research calls, which require interdisciplinary approaches, are useful resources when designing problems for PBL. Interdisciplinary skills are important for future employability. PBL approaches enhance students' interdisciplinary competence (Brassler and Dettmers 2017). The PBL approach also aligns with the well-accepted principle that not only is teaching enriched by research but also that research can be enriched by teaching. The importance of the research-teaching nexus is identified as mutually enhancing (Brennan et al. 2019). University support to enhance the research-teaching nexus is crucial (e.g., supporting teaching staff to train and develop innovative teaching strategies). Approaches to assessment and learning that inspire future leaders to engage with societal problems and understand multiple perspectives within a food system prepare students for the workplace because they develop life-long learning skills alongside technical knowledge. This article demonstrates that presenting students with an assignment based on a real-life "live" problem (research calls such as Horizon Europe or The Wellcome Trust) acts as a catalyst to develop interdisciplinary skills and can promote broader systems thinking in students as they develop holistic solutions. The problem itself needs to create interest to encourage self-directed learning. The PBL approach provides scaffolding to structure a group assignment, which is very different from traditional group-based assignments. Structure supporting group development outlined by Tuckman (1965) as the forming, storming, and norming approach is key, as is providing structured processes of problem-solving, such as structured meetings around learning tasks. The structure of problem, meeting, research, feedback, and response, applied by Forsythe (2010), helps students establish a protocol for achieving their self-directed learning goals. Learning tasks ensure that all students have a research job and present their findings to the group. Furthermore, providing iterative feedback in class emboldens students to develop or alter proposals.

2. What Is Problem-Based Learning?

The concept of PBL emerged from the Canadian McMaster University School of Medicine in the 1960s (Barrows 1983; Sherbino et al. 2022). The school's introductory article is a useful guide for academics considering PBL, outlining core principles of PBL, the facilitation role and management process (McMaster University, School of Rehabilitation Science 2022). More generally, PBL is described as part of the broader suite of learning approaches "enquiry-based learning" (Kahn and O'Rourke 2005; Barrett and Cashman 2010). PBL is a pedagogical approach in which the role of the teacher changes to a student-centered approach (Trullás et al. 2022) and is a well-established teaching approach for supporting experience-based learning (Hmelo-Silver 2004). PBL is becoming a widely used pedagogical approach used across the globe in various disciplines and professions (Barrett and Moore 2011). While there is a

strong focus on the use of PBL in the health science disciplines, there is increasing recognition of its value in the applied and agricultural science spaces (Abbey at al. 2017; Liangyu et al. 2024; Xiang 2024; Lucena et al. 2025). The principles of PBL ensure that learning is constructive, contextual, collaborative, and self-directed (EDLAB 2023) and that it activates prior learning in the creation of new knowledge (Norman and Schmidt 1992). In a similar way to the evolutionary nature of organizational learning (Nonaka et al. 2006), students build on accumulated stocks of knowledge with a core aim of engaging them in their learning process.

Classic models of PBL are built on the premise of using authentic, complex, ill-structured, open-ended challenges that are not too narrow. While they can be hypothetical, they are generally grounded in a real-life context (Barrows 1983). The method is based on social constructivism, where learning activities are highly dialogic in nature (Bridges et al. 2015), derived from constructive learning theory. The approach does not allow students to meander; rather, it provides a clearly structured opportunity to think, reflect, and apply knowledge in developing solutions to problems. Many useful resources exist to support PBL design. The establishment of clear learning objectives and sufficient scaffolding is fundamental in guiding and supporting students in achieving their learning outcomes (Woods 2005). Many models have been developed to support implementation (Hung 2006), and multiple general PBL guides on design and implementation are available for tutors (Barrett and Cashman 2010; Bessant et al. 2013), including resources from institutions such as Maastricht University (NL), University College Dublin (UCD), and Manchester University (UK), which have extensive resources in this area. The principles of PBL outlined by Barrows (1983, 1996), which emerged from the approach set out by McMaster University, remain the core guide to implementing PBL. Barrows (1983) also highlighted that the traditional lecture method may not be the most cost-effective way of learning, emphasizing that the information provided will be lost and what is retained will become dated; however, encouraging skills of problem-solving and self-directed learning will place graduates in a good position in their future careers. Clarifying this further, Barrows (1983, p. 3078, emphasis original) states when looking at learning objectives, PBL is "concerned not only with *what* knowledge is acquired, but *how* it is acquired." This feeds into how the student experiences learning and recall.

PBL allows students to apply theory to real-life situations (Almulhem and Almulhem 2022), developing skills beyond knowledge, including critical thinking, effective communication, learning to work in interdisciplinary teams, and understanding social context as well as longer-term knowledge retention and application of knowledge (Schmidt et al. 2011; Thistlethwaite et al. 2012; Yew 2016; Bendowska and Baum 2023; Alexander et al. 2024). PBL is particularly useful in developing key attributes in students, including teamwork, writing ability, time management, problem-solving and leadership (Tan 2016). While PBL is not new, it was identified as the most researched pedagogical approach in education and one that improves skills required for innovation (Hoidn and Karkkainen 2014), but in our discipline it is still not widely viewed as part of a standard teaching and assessment strategy in the same way that the delivery of traditional lectures and exam-based assessment are. The benefits of PBL outlined above present an opportunity for educators to augment the standard delivery of lectures to consider the use of enquiry-based learning, such as PBL, and to consider the incorporation of research calls into teaching and learning strategies, given the complexity of problems we face in the sector. The need to consider teaching methods and performance remains important, as highlighted by Roehe et al. (2024), who also emphasized the need to move away from one-size-fits-all approaches to teaching to exploring deep strategic learning and surface learning approaches. There are practical challenges associated with the application of PBL, such as tutor and student skills (Henderson et al. 2021). As part of the completion of a professional certificate in Teaching and Learning offered in UCD, the authors of this article completed a PBL course before implementing changes to modules. This gave authors a deeper understanding of the concepts of PBL and confidence to change existing approaches. While support is available in the development of PBL skills, time constraints, resourcing, and problem

design can also be challenging. While resourcing is often outside of our control, problem design is not. This article demonstrates that using real problems, such as open research calls and public consultations, can provide academics with a template for problem design and provide for mutual learning for academic and students. While this supports the research-teaching nexus (Brennan et al. 2019), it also generates student interest in topics from the outset as they embark on solving a "real" problem.

3. Application of PBL for Students in Agriculture

The challenges facing agriculture are vast and underpin many of the UN Sustainable Development Goals. Students of agriculture must be prepared to engage with these problems and challenges. This article suggests that incorporating research calls and structured PBL provides a good basis for developing the interdisciplinary skills required to address them. This rationale underpinned the change from a teacher-centered, lecture-based delivery to a hybrid PBL approach. Initially a hybrid approach was taken due to the inexperience of the lecturer in using PBL and to ensure the basic economic principles of strategy (economies of scale and scope, etc.) were covered in the first weeks of term. The second rationale was to encourage students to work with students from another area of study and to improve peer-to-peer learning between diverse groups. In previous years, traditional lectures combined with in-class activities encouraged transactional interactions focused on task completion. To address this and to promote more meaningful engagement, PBL was incorporated to develop a new assessment strategy, replacing a traditional group-based assignment previously implemented. Survey results outline how students experienced this change.

With respect to application, lecturer guidance and formative assessment throughout the teaching term provide students with a sense of direction. Guidance can come from the academic instructor but also from the peer-to-peer task setting. Task setting is an important part of progressing and developing student ideas. PBL empowers students to take ownership of their own learning (Nicol and Macfarlane-Dick 2006). Giving students a choice on what is assessed, through selecting what aspect of the problem they will solve and how. This allows students to be involved in the process of their learning experience. The first step in PBL is to design the problem. Using active research calls as a basis for problem design ensures the problem is novel and emerging and that there is no single predefined solution. It allows input from diverse groups to creatively discover the value of collaborating with others outside their own direct area of study. In doing so, it simulates the experience of researchers writing proposals for interdisciplinary research calls. Working through the problem with students also challenges the academic to consider questions from a nonacademic audience. This presents nuanced views of a research problem.

The PBL approach provides structure (scaffolding) for discussion and debate, requiring students to set tasks, conduct research and reflect on proposed solutions, thereby developing their critical thinking. The findings of this study support much of the existing literature on student learning experiences, while also demonstrating that PBL can be purposely utilized to foster engagement among students from different but aligned disciplines. This is particularly relevant for faculty teaching students across diverse specialisms within agriculture (Figure 1). The aim of this article is to demonstrate that open research calls can be used to design assessments and that PBL provides a well-established structure to achieve learning outcomes related to understanding complex problems and increasing engagement between different cohorts of students. This approach enhances the skills future leaders need to innovatively solve the problems facing agriculture while also enhancing the research-teaching nexus promoted in universities. Creativity is recognized as a competitive advantage in leaders (Brown 2016) and hence creative problem-solving is a key skill for graduates (Brown et al. 2024). It provides students with the confidence to understand and embrace different perspectives and to negotiate and guide a group decision in the discovery and development of a solution.

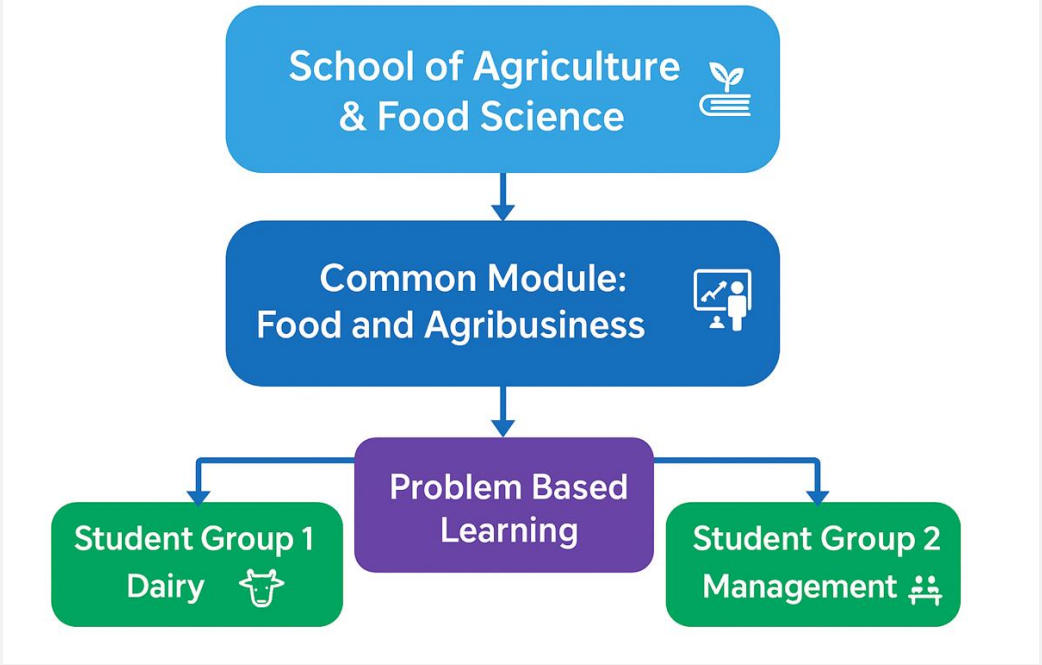

Figure 1. Use of PBL with two groups of final-year agricultural students

The relative importance of creativity and innovation in solving complex global issues is reflected in what Rittel and Webber (1973) termed "wicked problems" or "super wicked problems" (Levin et al. 2012). Wicked problems are particularly pertinent in the agrifood sector as they involve multiple interacting systems with social and institutional uncertainties, which are met with imperfect knowledge about their nature and solutions. The key characteristics underpinning these wicked problems are a lack of or a weak central authority on the issue. Frequently, those tasked with solving such problems are also part of the cause of those problems. The agrifood context is ripe for designing and applying problem-based challenges for students, who will contribute to such solutions in the future. Problems such as improving water quality, mitigating climate change, reducing obesity levels, or eliminating hunger are global, dynamic, and evolving challenges. Such problems are multifactorial, with economic, social, and biological ecosystem conditions that are all part of a wider complex interdependent food system. PBL is based on the premise of co-creation and co-decision, it creates co-ownership of the project outcomes, and it provides teachers with a structure to engage students to think about these types of wicked problems.

In the innovation literature, "problem-oriented innovation systems" (Ghazinoory et al. 2020) are identified as frameworks to solve global problems such as global warming, a key wicked problem for the global agricultural sector. This reflects the movement toward tailored responses to addressing local barriers and enablers to change. Other perspectives focus on levers and lock-in frameworks within the wider enabling environment, which support or hinder new transitions in the agrifood sector (Williams et al. 2024). What is clear is that the inclusion of wider systems thinking provides a strong basis for solving the global challenges facing agriculture. Consequently, it is important to prepare the next generation of farmers, food business operatives, and representatives to understand comprehensively this new and evolving innovation system and the problems that exist within it.

Designing innovative educational programs that allow students to learn in an explorative and creative but loosely prescribed way is essential for future leaders to learn how to learn, how to listen to other perspectives, and how to come to an agreement on solving a given problem. PBL meets the need to

encourage more creative thinking in the classroom by moving away from more instructive methods of teaching to a more student-centered explorative learning experience. Students are exposed to learning collaboratively, developing hypotheses to identify solutions, and conducting data searches to pursue an agreed solution (Ram et al. 2007). In agriculture, these are essential skills for our future leaders. The approach mimics applications in real-world settings used by governments (Andrews et al. 2012) and industry (Dillon et al. 2023).

The benefits of a hybrid approach to PBL include the delivery of both traditional lectures and self-directed learning. Amendments in PBL delivery have been made based on student feedback; for example, the first application took a split-term approach, delivering a block of traditional lectures in the first eight weeks, followed by a four-week block of in-class PBL facilitated learning sessions (see supplementary material). In recent years, a more iterative approach was used with traditional lectures and PBL tasks integrated throughout the teaching term; for example, a two-hour time slot was delivered as a one-hour traditional lecture followed by an hour of facilitated group work (examples of scheduling and tasks in supplementary material). During scheduled facilitated learning hours, all groups got the opportunity to set tasks and seek feedback on progress; as the weeks progressed, they refined ideas and focused on the development of an agreed set of solutions. The well-established structure supporting the PBL process of problem, meeting, research, feedback, and response (Forsythe 2010) and Tuckman's group development guide was provided to students along with guidance on identifying group roles and ground rules. These structures provide clarity and assist in governing their activities. PBL tasks can be flexible and integrated more systematically or in smaller units (Barrett and Moore 2011), with varied options in terms of the practice and methods used (Virtue and Hinnant-Crawford 2019).

4. Methodology

At the end of the term, students were asked to provide feedback on the PBL assessment through an anonymous in-class survey. The results provided insights into the student experience with PBL and how it compared to other methods of assessment. The purpose was to understand students' preferences and perceived learning benefits. Over the course of two years, survey results from 72 students were collected, and participation was voluntary. The survey design employed a combination of ranking and open-ended questions to gauge students' preferences and experiences with PBL. Feedback was sought based on assessment approaches used previously in the module, and students were asked to rank preferred assessment type, including PBL group work, traditional group work, multiple choice examination, or individual reports.

4.1 Application of PBL

The students registered for this module are from two different agricultural science programs, Dairy Business (hereinafter dairy) and Food and Agribusiness Management (hereinafter management), in the final year of their degree programs. The learning outcomes of both degree programs overlap in terms of fundamental concepts such as innovation and sustainability, they take discipline specific modules as they progress to stage 4 (Table 1), and the module mix is tailored to meet degree program learning outcomes.

Management students specialize in business-specific topics, such as Applied Economic Analysis and International Food Marketing, while dairy students specialize in topics such as Animal Nutrition I & II and Applied Dairy Breeding and Fertility (Figure 2). The two student groups have unique bundles of complementary skills from farm to fork. In their final year (stage 4) both dairy and management students take AERD40040: Food and Agribusiness Strategy (Figure 1). This module—which is concerned with the study of the economic principles of business firm growth and development—was the testbed for PBL. Theoretical economic principes of strategy and case studies from the food and agribusiness sector

Table 1. Discipline specific (SP) and general (GE) learning outcomes

Undergrad degree programs: learning outcomes	
Dairy Business (DB)	**Food and Agri-Business Management (FAM)**
Specific learning outcomes (degree relevant)	
1. Demonstrate strong business and leadership skills, and an in-depth knowledge of core issues related to dairy production	1. Describe the core principles of economics, business and financial management, and how these apply to farming, food production and marketing
2. Analyze systems of production both from the biological/technical and financial perspectives, identify their strengths and weaknesses, and make recommendations for remedial action as appropriate	2. Apply economic, business and financial analysis to support decision making in the agri-food industry, and effectively communicate the results
3. Understand the dairy industry in Ireland, the context in which it operates and its relationship to dairy industries internationally	3. Analyze and evaluate food supply chains and agricultural markets
4. Implement knowledge to offer well-founded advice on sustainable dairy systems, incorporating knowledge of current and future policy constraints	4. Develop agribusiness strategies and prepare business and marketing plans
5. Use their knowledge of the scientific method to devise, analyze, interpret and report on scientific investigations	5. Interface between the technical, scientific and commercial aspects of production, processing and marketing within the agri-food sector
General learning outcomes	
6. Demonstrate an ability to think critically and creatively to solve problems	6. Develop and apply skills in quantitative analysis
7. Use strong communication skills, both written and oral	7. Explain key agricultural, food and environmental policies, and analyze their effects on the food system, the wider rural economy and the natural environment
8. Develop and utilize a wide range of generic skills useful in further career development through specific class exercises and PWE	8. Understand core animal and crop production sciences, and evaluate their role in efficient farm management and achieving environmental objectives
	9. Describe basic food sciences including food quality and safety assurance, and assess their role in production and processing systems
	10. Demonstrate research, critical thinking and problem-solving skills as they apply to the food and agribusiness sector
	11. Develop and utilize a wide range of generic skills useful in further career development through specific class exercises, professional work experience and project work

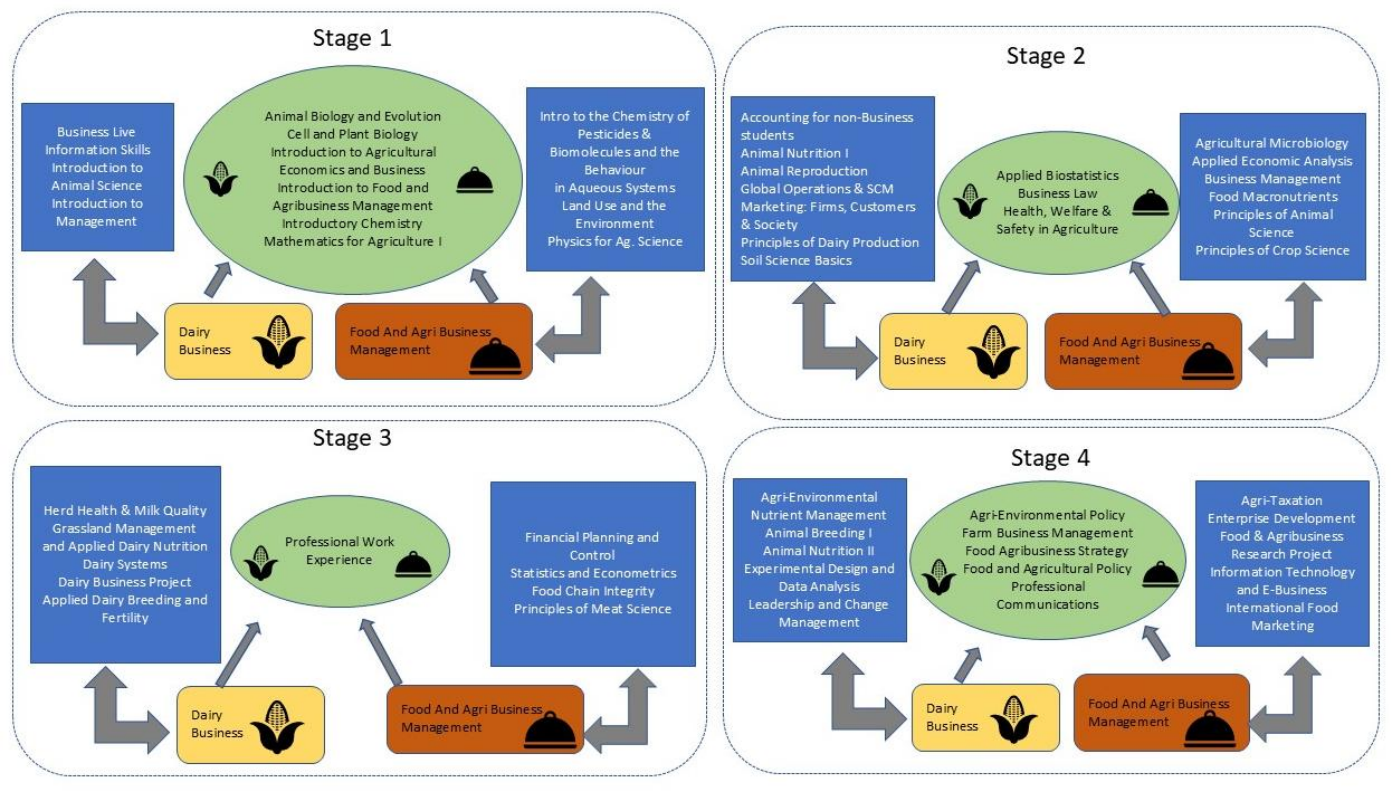

Figure 2. Modules studied over four-year degree program

underpin the course content. The course explores strategic decision making in agribusinesses operating from inputs, such as feed and fertilizer companies, to retail and food service operators.

The role of regulation and culture is considered when examining globalization strategies and the influence of wider systemic institutions and organizations supporting business activities. This provides the class with a broad range of skills and knowledge, apparent in discussion and debate, relevant for solving the complex problems facing the agrifood sector. This study was carried out over two years; PBL groups were purposively selected to ensure a mix of dairy and management students.

In-class observations showed that students sit with their relevant program groups, with dairy students seated on one side and management students seated on the other, despite being part of the same faculty for years. PBL was used as a catalyst to increase interactions, knowledge exchange, mutual respect and create an enjoyable learning energy between the groups. Communication of ideas and theories reinforces concepts for students, the McMasters introductory PBL guide outlines such in the context of cognitive and social benefits of the approach, which formed part of the rationale for introducing PBL. This article demonstrates how agricultural science students experienced PBL using research calls as a guide to problem design. Through a survey instrument, the students qualitatively described their experience and quantitatively ranked various assessment strategies, in terms of their personal preference and perceived learning benefits. The first step of PBL was problem design.

4.2 Problem Design and Assessment

The problems selected for this module were based on a Horizon 2020 Research and Innovation Action call announced in 2018: "Towards Healthier and Sustainable Food" (SFS-16-2018) (European Commission n.d.) and a EU Commission industry consultation, depicted in Figure 3. Research calls

Figure 3. Adapted problem presented

present a rich resource for designing problems. They are broad enough to allow for student's to creatively find and present a solution with a given direction and scope. The direction, in terms of learning tasks and the parameters set such as timeframe and budget, acts as scaffolding in guiding students. Implementation plans for the EU Commission industry consultation problem, including a four-step guide for problem selection, are available in supplementary materials. Students grapple with the loose nature of problems in much the same way that researchers and industry leaders do as there are potentially multiple valid solutions. Students were assessed in two ways: formatively and summatively. Formative tasks were designed to encourage students to incrementally share ideas for feedback, demonstrating the

evolution of their thought process as ideas emerged. Tasks included a recorded five-minute video of initial ideas and an in-class presentation of more developed ideas for feedback. This assists the groups in the early stages of group ideation as Tuckman (1965) refers to the process of forming, storming, and norming, as they progress to the final step of performing. In the early stages, the students are more reliant on the academic. Formative assessment facilitates these early stages of the PBL learning and team development processes also. The summative assessment included a group action plan, peer-evaluations, and individual reflective diaries.

5. Data

From a teaching perspective, the PBL approach involved three broad steps, problem selection and design, implementation, and student reflection. While problem selection, design, and implementation are outlined above and in supplementary materials, the research objective is to identify the student experience in order to elicit their preferences and perceived learning benefits of the PBL approach. Specifically, to evaluate how agricultural science students experience the use of research calls, which address wicked problems in the agrifood sector, to design and actively develop their understanding of authentic, real-world agrifood problems.

Survey responses were collected over two years, Year 1 (Y1) and Year 2 (Y2). From a total of 121 students registered (Y1=56 and Y2=65), a 60% response rate (N=72) was achieved. Students were asked to respond to the following questions:

1. Describe how you experienced the problem-based group assignment in this module?
    a) Open qualitative response
2. If you were to compare the following assignments[1] which, would you prefer?
    a) Rank listed assessments [1–4]
    b) Why? Justify with an open qualitative response
3. In terms of learning, which of the following assignments[3] would you benefit most from?
    a) Rank listed assessments [1–4]
    b) Why? Justify with an open qualitative response

5.1 Data Analysis

The qualitative data were transcribed and imported into NVivo for coding and data management purposes. The student experience data reflected nodes on connectedness (student learning, being part of their learning) and interrelations in the wider agrifood sector (professional skills). Thematic sentiment analysis was used to identify themes and overall sentiment. Sentiment analysis can be done using machine learning or a lexicon-based approach. This study uses a lexicon-based approach, which is the sum of the sentiment based on a word or phrase, semantic orientation (Turney 2002). Student feedback was evaluated in terms of positive and negative lexicon. Each negative phrase was weighted -1 and positive phrase weighted as +1. This summative weighting based on semantic orientation provided an overall sentiment for each student reflecting their experience (example in Table 2).

An iterative inductive approach was used to help support the development of themes from the data through reading the text, further enhanced with deductive analysis informed by the PBL literature. This was supported with a dictionary of statements, which were color-coded and categorized using Excel, reflecting the student sentiment of their experience with PBL. In the second part of the survey students ranked four types of commonly used assessments, first in terms of their general preference and then in terms of their perceived learning benefits. The assessment scored as 1 being most preferred/greatest

[1] Traditional group work, problem-based learning group work, individual assignment (e.g., essay/project), multiple choice questions (MCQ), or other (specify).

Table 2. Sentiment score: weight and example

Overall Sentiment	Weighted Score	Example
Extremely positive	+3 or +4	New group project experience. Relevant to future career as it required good organisation and a hierarchy of responsibility (Y2_23)
Positive	+1 or +2	Good way of learning (Y2_8)
Neutral	0	I liked trying to solve the problem, I found it difficult to work and get the work done in a large group (Y1_12)
Negative	-1	4-6 group members may have been enough (Y2_42)
Extremely negative	-2	Difficult to understand. Not realistic. (Y1_19)

learning and 4 being least preferred/ least learning. These were reverse weighted and cumulatively scored.

6. Results

Overall, students expressed a positive sentiment toward PBL, preferring it to other forms of assessment, and perceiving it to provide greater learning benefits. Having completed Professional Work Experience (PWE) in the third year, students had the confidence to grapple with a real-life industry problem. Students referred and reflected upon their PWE experience, activating prior knowledge when discussing topics. The diversity of skills and knowledge resulted in the presentation of more holistic solutions in both formative and summative submissions. These factors contributed to the positive experience and greater learning benefits as their ideas improved and became more refined with in-class support and feedback provided early and often. The data, reflecting students experience of PBL, included qualitative reflections, based on open-ended questions, and quantitative responses, based on ranking of preferences and learning benefits. Qualitative reflections are first presented, followed by the quantitative findings.

6.1 Qualitative Student Experience (Overall)

The qualitative reflections are captured using simple sentiment analysis, which demonstrates the overall student experience. The sentiment funnel (Figure 4), and the scatter graph (Figure 5) show that 72% of students express an overall positive PBL sentiment, 18% had a neutral view and 10% had an overall negative view. Sentiment scores were based on language, ranging from -2, meaning the student provided two negative references, to +4, indicating a student made four positive references to PBL. Statements scoring +3 or higher were categorized as extremely positive, for examples, see Table 2.

Three themes were developed from the sentiment analysis, prominent from the positive sentiments were engagement; student ownership; and future career skills. The negative themes revolved around group size and guidance. The positive themes are discussed first, followed by the negative.

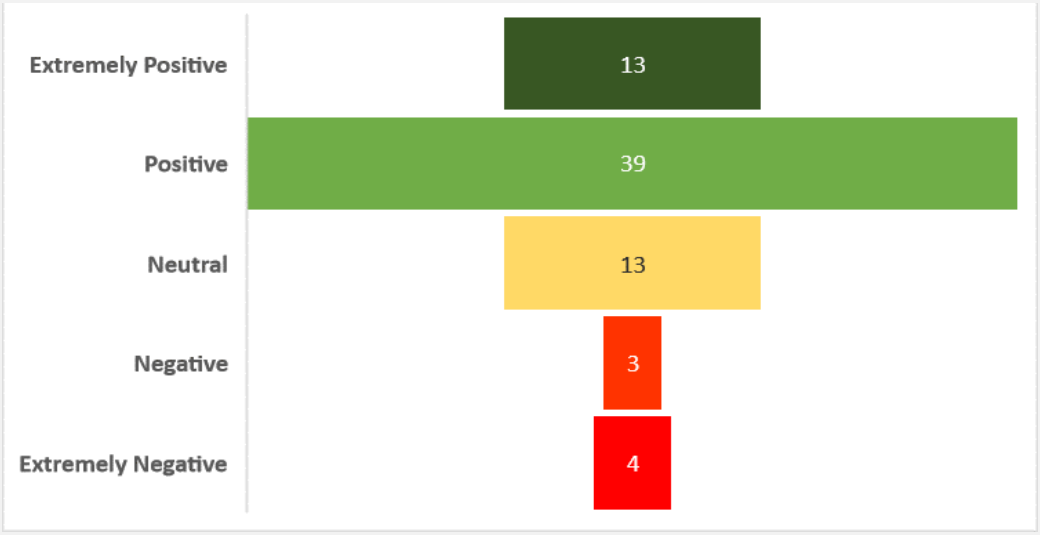

Figure 4. Sentiment analysis: overall student sentiment (count)

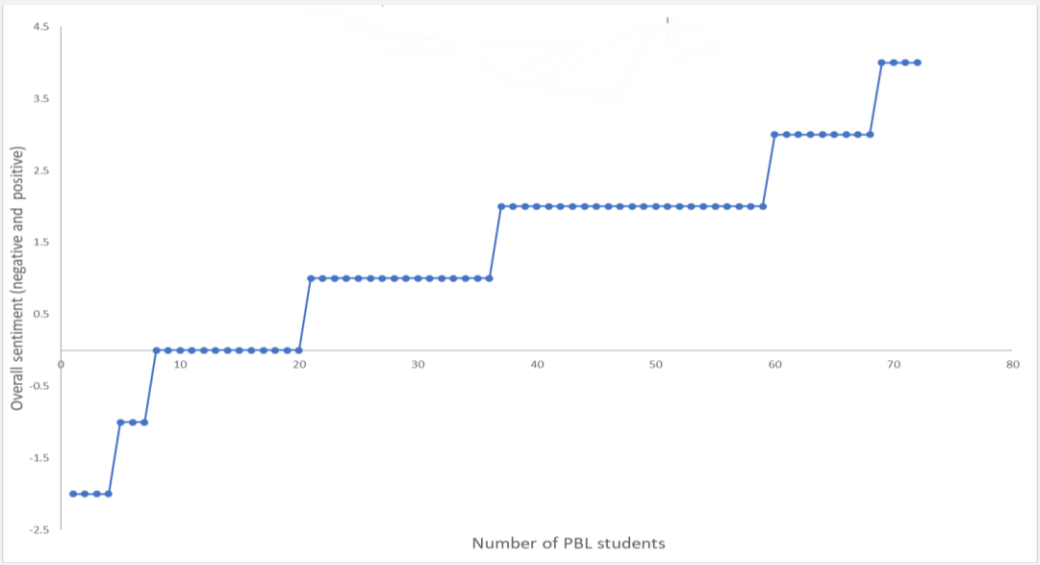

Figure 5. Sentiment analysis

6.1.2 Engagement and Learning

This theme reflected the positive student perspectives on the diversity of skills in groups, peer learning and meeting new people. Peer learning was a prominent element in this theme "interesting to see how peers thought about a topic and how ideas spurred from this" (Y2_35). Their exposure to how diversity in groups can be positive was also clearly evidenced, "each member had a different level of knowledge about this module and helped teach others in the group" (Y1_7), "we learned off each other as everyone had different skills and qualities" (Y2_25). The selection of groups was specifically referenced by students, "Good to mix groups" (Y1_18) "great to get to mix with others in the class from different courses" (Y1_23), which shows the lack of prior meaningful engagement. The engagement sentiment was well referenced "Engaging both with topic and with others." (Y2_46), also referring to the appreciation of

a diversity of perspectives when solving an agricultural problem, "Different points of view on topics is beneficial" (Y2_46), and the importance of "Good group-based approach of open discussion" (Y2_6). The purposive selection of the mixed groups was viewed as a positive, as well as the academic benefits it was also an enjoyable part of the group work "Liked how groups were assigned" (Y2_34), "Very enjoyable. Made friends." (Y2_13).

The engagement theme was the most densely coded set of statements with references to peer learning, diversity of skills and knowledge in the groups. Comprehensive discussion on the problem presented was a clear factor underpinning the overwhelmingly positive sentiment toward PBL. In total, over 1/3 of the comments related specifically to the diversity of knowledge and engagement in group work. Engagement also overlapped with other themes below, as the students felt empowered with diverse knowledge and confident in their ability to provide real-life solutions.

6.1.3 Student Ownership

There was an overarching sense that groups worked well with the structure provided by the PBL approach, "Everyone worked, contributed and communicated well, everyone took responsibility for the project" (Y1_8), the burden of "work was split evenly" (Y1_4), and individuals in the group took responsibility for tasks assigned. This sense of ownership in the project and a genuine interest in making contributions were evidenced in the level of in-class student engagement but also in the quality of their projects.

The concept of co-creation was also outlined in the student reference to having the freedom and flexibility to develop ideas into solutions, "Really enjoyed it as it made us think for ourselves to create a concept." (Y1_22). This suggests students embraced the opportunity to shape their learning. The PBL structure provides them time to think creatively about topics, rather than provide responses to a prescribed set of questions about a topic. The co-decision and co-ownership associated with PBL was clearly evidenced in their input into their projects "The broadness of the question allowed us to choose what we were interested in" (Y2_13). The approach allowed students to think about the problem holistically, building on group skills and knowledge "The Project was challenging and allowed us to look at an issue in a comprehensive manner." (Y2_39). Students embraced the novel approach and found the concept stimulating "I found it challenging and enjoyable" (Y2_10), "I loved it - really enjoyed the title and flexibility to develop our own solution." (Y2_28). The freedom associated with choosing the topic was embraced within the PBL approach "Good freedom on topic." (Y2_1). This loose structure was a crucial part of the process.

Within this theme, the flexibility in designing a self-driven solution was the dominant student view, which was supported by features around timing, feedback and workload. The timing, specifically working on the project in class was heavily referenced in this theme, "It was very beneficial that the meetings could take place in class" (Y1_13). The benefits of working on the PBL in class reflected the availability of individuals and opportunities to receive feedback.

With one student mentioning peer evaluation as a motivating factor "once peer evaluation was mentioned everyone started to have a bigger input" (Y2_14). As the PBL project progressed, the facilitator requested different members to perform various tasks, to ensure all members engaged in the process. Findings indicate the process of learning, negotiating and developing solutions enhanced the student experience.

6.1.4 Professional and Research Skills

The third theme which students referenced as part of their experience with PBL was the real-life nature of the problem presented. Students perceived this to be beneficial for their future careers. It was relatable. The students relished the experience of building on their knowledge in self-selected areas. Students developed a range of skills, during the PBL process, strong references to deeper learning and

increased understanding of the module content as well as development of research skills. Students built on their unique sets of resources and knowledge to create valuable solutions.

The learning for future careers theme spanned a variety of workplace skills, such as "how to work with people" (Y2_31) and "delegate" (Y1_23). These are skills which the students recognized as valuable "Relevant to future career as it required good organization and a hierarchy of responsibility" (Y2_23). The challenge was evident, but students demonstrated their willingness to embrace the challenge, recognizing the value in terms of their learning, "challenging working with so many people but good experience for future career" (Y2_33), "it made us think hard about a solution in a short time just like you would do in a workplace." (Y1_21).

Deeper understanding of the module content and the development of problem-solving skills were key areas of learning identified by the students. This was underpinned by self-directed learning and research. It was seen as an enjoyable challenge but one they enjoyed "I liked trying to solve the problem" (Y1_12), it demanded "research to solve an issue" (Y2_6).

The approach encouraged students to engage with class material during the semester "I thought the PBL was very helpful in understanding the module more." (Y1_14), akin to learning on the job, building incremental knowledge through the term. The PBL approach required a deeper understanding "helpful and gave me a better understanding" (Y2_24) as students needed to apply knowledge to complete tasks assigned. This self-directed learning was also acknowledged "It was good to encourage us to learn for ourselves" (Y2_9), "Aided putting what we learned in lectures into practice." (Y1_5). This was a freedom they enjoyed as part of the PBL structure. The students engaged in the process and recognized the benefits of the approach as Y2_26 explained in their statement "Great experience and really developed my knowledge and researching ability." Their ability to reflect and recognize that PBL developed skills which would equip them for careers in the agrifood sector was welcome as these were stage 4 students. The real-life nature of the problem is key to this as they were forced to think as an industry actor and not as a student, "Very enjoyable, different, real-world problems" (Y2_38) and recognizing its relevance and application "looking at real current problems - study of current Irish food sector market" (Y2_37).

The use of research calls to design the problem-based group work mimics applications in real-world research settings, including policymakers, industry and wider society who are also grappling with solving these problems. The consensus was that students found it to be a positive experience "It was interesting, and I learned a lot from it." (Y2_30), "It was enjoyable and helped me learn." (Y2_44). The following student summed up the positive responses commenting, "Thought provoking, engaging, interesting" (Y2_16).

6.1.5 Group Size and Guidance

The negative sentiments reflected group size, a need for more guidance and structure. The group size and guidance could be addressed through more teaching support however, the loose structure reflects the nature of the learning, but evidently not embraced by all students. The overall sentiments are reflected in a comment from Y1_11: "not having a lecturer there at all times to help and guide us was hard as the objectives were unclear at the start." In addition, Y2_27 "found it interesting but the group was too big to be productive and the assignment gave little direction." Students who referenced structure as being a challenge, viewed it as a short-term or an initial downside of PBL. These short-term challenges are reflected in "felt it was unclear what we had to do at first but it became clearer as it went on" (Y1_1). Groups struggled to grasp it initially "we found it difficult to grasp the idea of problem-based learning but once we understood it fully we found it easier to complete" (Y1_3). This may also reflect their lack of experience with PBL, this was a novel approach to assessment and their first experience with PBL. The loose structure which lacked a correct answer removed the safety of a prescribed assignment which students found daunting initially.

6.2 Assessment Preference

Students were asked to rank four types of assignments (Table 3), the quantitative ranked preferences corresponded with the qualitative findings, indicating that PBL is the preferred option in terms of assessment (Table 3) and learning (Table 4). When looking at the overall ranking, it is clear there is a division between group and individual work, this indicates a varied assessment strategy should be considered. While there was an overwhelmingly positive response to PBL as a method of assessment, students also indicated that individual submissions such as MCQ assignments were important. PBL received 39 first preference votes while MCQ received 20 (Table 3).

Table 3. Student preferences

Assignment	Total Weighted Rank Score	First Preference (freq.)
PBL	224	39
MCQ	181	20
Traditional group work	120	3
Individual assignment	115	10

Notes: Reverse weighting[2] of ranks allows for responses to be comparative scaled to reflect importance. Applying cumulative scoring[3] produce a total score for each item from all students.

Students had the opportunity to justify their ranking through an additional open question asking them to explain the rank order. These comments are grouped into student preferences for group work (PBL and traditional group work) (N = 42) and individual work (MCQ and assignment) (N = 30). Responses are discussed below.

6.2.1 Preferences for Group Work: Why?

Students who selected group assignments as their first preference primarily made note of their preferred personal learning style. Themes evolved around discussion, engagement, and peer learning. These responses reflect a personal preference: "Personally working in groups is more suited to me as you have more of an opportunity to discuss and reflect ideas versus the pressure of MCQ" (Y1_3). Peer learning and engagement were a prominent rationale for choosing PBL as the most preferred option, as it "allows for interactive learning from other students, knowledge from student to student" (Y1_8) and is more interactive: "I preferred the PBL group work as we had a group discussion" (Y1_16). Students also expressed their ability to be creative: "PBL was more immersive and creative" (Y2_21) and to express themselves in the discovery of a solution: "PBL gives you a chance to interpret a problem in your own way and hence find a suitable solution" (Y2_28). These comments again reflect student ownership, while active learning through PBL, compared to other approaches, was also acknowledged: "I think PBL is the most active way to learn" (Y1_25). Students presented clear rationale for selecting group work over individual work.

6.2.2 Preferences for Individual Assignments: Why?

The students who selected the individual based assignments (42%) cited being more familiar with the approach as a preferred learning experience. Themes such as control, independence, and avoiding the

[2] Where weight is $w_{ij}=n - r_{ij} + 1$; n= total items ranked (n =4), r_{ij} = rank given by each student for each item.

[3] The sum of weights for each item is $\sum w_{ij} = n - r_{ij} + 1$. For example, if student A ranks PBL as 1 and student B ranks PBL as 3, the reverse weighting applied is 4 and 2 respectively. The cumulative weighted score for PBL for these two students is a total of 6.

free-rider problem are generally associated with group work summarize the rationale for selecting individual assignments. Individual preference was a strong sentiment in the comments: "I learn more with MCQs and generally prefer essays or exams over group work" (Y1_6). These were linked to control: "Your success can be achieved yourself. If you want to do well in group, usually need to take on more than you should" (Y2_19); independence: "Not dependent on the work of others for individual assignment or MCQ" (Y2_23); and risk factors associated again with the free-rider problem: "Often it can be difficult to work in groups, risk of someone not carrying their weight" (Y2_22). This is understandable given that these students are in their final year with pressure to attain higher grades as they work toward the final degree outcome. Preferences for learning where students working individually believe they "learn better. Less politics" (Y2_44), and generally "prefer to study individually" (Y1_17).

Overall, the general preference for group work presented by students reflects more engaged and active learning preferences, with more opportunity for discussion on the topics as opposed to more pressurized individual-based assignments such as multiple choice or individual reports. The experience of shared ideas where their voices were heard was also important in their preference for this approach. Preferences for individual work reflects an individual style of learning more aligned with control and an individual mindset. These findings highlight the need for varied assessment strategies to support learning styles.

6.3 Quantitative Ranking and Rationale: Perceived Learning Benefits

Student perceptions on learning benefits indicate 61% of students chose PBL as having the greatest learning benefits, despite 27% of this group previously indicating they prefer the individual based work, they recognize that PBL provides the greatest learning benefits: "Group allows new ideas to be generated and challenged" (Y2_39). Another student, despite their preference for individual work, found "PBL more challenging, requiring more research and thought" (Y2_25), showing their ability to reflect on how their learning developed. In terms of learning benefits, students felt this approach reflected more of a real-life setting and, therefore, felt this provided for greater educational experience.

Table 4. Student perceived learning benefits

Assessment	Total Weighted Rank Score	Perceived Learning (freq.)
Problem-based learning	232	44
Individual assignment	163	9
Multiple-choice questions	146	14
Traditional group work	115	3

Students who recognize the clear learning benefits of PBL over other assessment strategies again reflects the sentiments from their overall experience and the themes identified in this article. Themes of engagement, future skills, and student ownership are dominant throughout the quantitative ranking and qualitative responses.

6. Discussion and Conclusions

The overarching finding from the student survey indicates that PBL approaches, which are designed based on research calls, constitute a positive learning experience for agricultural science students compared to other more traditional assessment strategies such as essays, assignments or multiple choice exams. The main reasons cited reflect the engagement they experienced and the satisfaction they got from working with a diverse group of people based on a real-life problem. Findings indicate that PBL works well for those who wish to enhance the learning experience of students through using real-life

problems and to develop skills useful for future careers in research and industry, where problem-solving is a key competency. The structure supporting PBL is an important part of implementation, and it is an approach that requires clear planning for students. Findings indicate that the provision of support (scaffolding and feedback) is key. While some students will always prefer individual assignments, where the guidance and support are highly structured and submission is their sole responsibility, the advantages of PBL in terms of learning benefits and student experience are positively supported in our findings. To counter the negative sentiments of PBL, such as group size and guidance, additional resources are something which needs to be considered for future iterations in this module. While implementation can be daunting for academic authors, they are encouraged to experiment and find what works for their subject area. This was the approach taken in this example, and the hybrid PBL approach is still used in this module.

The co-creation of solutions was a key overall finding in this study. Students felt they had something to contribute due to their diverse skillset and industry experience. This is important in terms of application beyond the classroom in their future careers. This article strongly supports the use of PBL as part of a varied assessment strategy. It is particularly relevant for the agricultural sector: The problems we face are complex and require engaged interdisciplinary research. University is an appropriate place for this type of learning as it provides a safe place for students to explore their creative side of problem-solving skills in a supported environment. Students build confidence in their ability to communicate, develop proposals to solve real-life agrifood challenges, to counter and challenge ideas, and to support arguments with solid academic research.

This approach reflects transformative learning as students reflect critically on their experiences and engage with others who put forward complementary ideas to develop more holistic and creative solutions. The level of independent thinking and research skills improved over the course of the module as they learn about presenting strong evidence-based arguments. The respectful dialogue between individuals in the classroom was the most satisfying part of this approach as an academic. This reflects their growing and learning in how to appropriately communicate, not only in how to convey information but in how to respectfully and openly discuss topics of interest.

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