Assessing factors considered in the project design and the perceived value of a research project by the students in a university chemistry course

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ABSTRACT

Project-based learning has received a lot of attention in academia across all education levels as one of the pedagogical approaches with the potential to promote scientific literacy and the development of work-related knowledge, skills, and competencies. Through mixed methods, this descriptive study assessed chemistry students' perceptions about a project design experience in response to the following research questions: What lessons can be drawn from students' perceptions about conceptualising a research project? What are students' perceptions about the inclusion of research projects as part of their learning in chemistry? Likert scale questionnaires and open-ended questionnaires were used to collect data. Quantitative data were analysed through descriptive statistics to establish patterns, while qualitative data were analysed through conventional content analysis. Findings show that most students were able to design their own projects with minimal assistance. Environmental concerns, curiosity and concepts from other courses were primary factors that influenced students' choice of projects. However, the conceptualisation of the research projects by students showed some challenges and lack of coherence, which were attributed, in part, to students' lack of experience in both research and experimentation. Nonetheless, students recommend the inclusion of projects as part of their learning because of the opportunities they experienced. The study concludes that project design stage is critical and exposes students to essential elements of project-based learning, should be introduced early and be supported with resources and adequate supervision. Adoption of project-based learning has the potential to help students acquire and develop skills readily applicable to address real-life problems.

KEYWORDS

Project-based learning, chemistry, university students' perceptions, project design, project value

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INTRODUCTION

Calls for innovative and responsive means for students to access curricular materials have been a cornerstone for many educational reforms. These calls are mainly focused on transforming classroom teaching and learning practices into ways that, to a large extent, connect to real-life issues, respond to the needs of individuals and societies, and assist in developing skills applicable within and beyond classrooms.[1-4] Teaching and learning experiences should contribute to enabling individuals to be better citizens who are productive and well adapted to live in their societies,[1,5] as well as to provide opportunities for students to engage in activities that reasonably approximate the work of scientists.[1,2] Students need to develop a sense of urgency for their learning and be actively engaged in knowledge development to promote their conceptual understanding.[6] In addition to the established body of scientific knowledge which students have to master, they also need to "…understand science as a principled process of inquiry".[6]

One pedagogical approach that can assist students in developing scientific inquiry skills and scientific literacy is project-based learning (PjBL).[4,7] Through inquiry for knowledge acquisition and development, "…students pursue solutions to non-trivial problems by asking and refining questions, debating ideas, making predictions, designing plans and/or experiments, collecting and analysing data, drawing conclusions, communicating their ideas and findings to others, asking new questions, and creating artifacts".[8] Research studies have shown significant improvements in students' academic performance when they are engaged in PjBL. The reported improvements in academic performance can be attributed to several affordances of PjBL, such as its ability to promote motivation, sustained interest in learning,[9] self-regulated learning, collaborative learning, and improved problem-solving skills of authentic problems.[10-12]

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PjBL, like other pedagogical practices, has some challenges for teachers and students that may impede its success. Research literature documents challenges such as the curriculum which is not tailored to accommodate PjBL. Furthermore, teachers are sometimes not adequately equipped to facilitate PjBL, which requires extra effort for teachers to structure teaching and learning objectives and activities in ways that allow students to engage in meaningful learning.[11,13,14] Students also demand more assistance to understand the fundamentals of PjBL.[13] Students' difficulties are more evident in cohorts with little to no experience of PjBL.[15,16] Some of "…these difficulties are those associated with initiating inquiry, directing investigations, managing time, and using technology productively" (p.36).[13] Consequently, there are mixed views about how students perceive PjBL. Some students find PjBL as a viable learning mode, while others find it to have more challenges than the affordances.[14]

Anecdotal evidence and some literature reports have demonstrated that students usually struggle to create their own research projects, which prompts lecturers not only to guide them but to end up simply prescribing the projects to them.[13,17] This practice raises concerns regarding the balance between the amount of support given to students and their autonomy to develop necessary skills in PjBL. Students should have a sense of ownership of projects to realise the benefits of PjBL.[18] Allowing students to engage in PjBL activities fully prepares them for life beyond the classroom situations. Therefore, students must be allowed to identify contextual and relevant problems that can be addressed.[3,11] It is against this background that an argument is made for student-led projects; when lecturers prescribe projects for students, the skills developed through PjBL may not be adequately realised.

Among some of the advantages of offering chemistry courses to students is to help them apply chemistry propositions in solving real-life problems, be better adapted to live in the communities, engage in research, and produce useful physical and intellectual artefacts.[5,17] Chemistry-based knowledge and skills are some of the driving forces

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behind many economic sectors such as agriculture, food industries, pharmaceuticals, cosmetics, transport, construction, textiles, etc.[19] Therefore, students need to be exposed to activities that can help them to develop 21st century skills to be able to critically identify real-life issues that need to be addressed through carefully conceptualised scientific methodologies.[5] In this study, students were expected to identify any problem in their country, Lesotho, that they could address through the application of analytical chemistry concepts and principles as well as knowledge acquired from other courses. Though there is literature on PjBL, the results of its impact and influence on students' learning vary across different international contexts. Therefore, this study was meant to provide insights from a different context, characterised by several issues, such as lack of resources.[20] Furthermore, the study was necessary to address the paucity of local literature on how students who are used to different methods of learning other than PjBL would experience it. The assumption of this study was that informative lessons could be drawn from students' perceptions as they engage in PjBL activities such as identification of a problem, understanding the problem, formulation of purpose, proposal of solutions and how the proposed solutions would be achieved. Therefore, the objective of this study was to establish the perceptions of chemistry students towards the fundamentals of project design and to identify factors or elements which bring challenges to the students. The study responds to the following research questions in order to achieve its purpose:

1. What lessons can be drawn from students' perceptions about conceptualising a research project?
2. What are students' perceptions about the inclusion of research projects as part of their learning in chemistry?

THEORETICAL BACKGROUND AND LITERATURE REVIEW

Project-based learning encompasses pedagogical approaches characterised by crucial attributes such as but not limited to "…1) extended student investigation, 2) in-depth inquiry into a topic, 3) some degree of student self-direction or choice, and 4) presentation by students of their findings, results or conclusions" (p.2).[3] When students are engaged in PjBL, they critically exercise their cognitive abilities to learn rather than focusing on the final product alone. By being actively involved in the design and carrying out of the projects, students engage better in meaningful learning.[21] One essential element of PjBL is the identification of a problem that the proposed project aims to address. Therefore, students must carefully identify a problem or a critical question which anchors their project undertaking.[7] PjBL being student-centred in nature, allows students to further become actively involved in fundamental activities such as "…designing the project-based theme activity, making the project proposal, executing the tasks of projects, and presenting the project report" (p.307).[22] Another essential attribute of PjBL is that students draw ideas from multiple sources and disciplines to apply innovatively in establishing the solutions to real-world problems. For this study, perceptions of students were limited to conceptualisation stages, where students selected topics for their research projects and wrote proposals.

Literature has documented some perceptions of students about PjBL. Some research studies noted that PjBL has the potential to assist students to develop "… enthusiasm, confidence, critical thinking, creativity, collaborative learning and self-directed ability" (p.118)[23] which some scholars refer to as "cross-curricular competencies" (p.13).[24] Moreover, the experiences of PjBL assist students to develop other necessary skills, like problem-solving, innovation, and the ability to respond to life challenges, ultimately fostering their productivity as citizens.[5,25] Other research studies provide insights indicating that students assert their motivation to engage in meaningful learning increases when they solve real-life problems in their immediate surroundings .[12] In addition, literature documents instances where students acknowledge the autonomy and acquisition of soft skills. These skills include working with others in various situations, communicating productively and constructively, searching for information (developing research skills) to guide their projects, developing project management skills,[26] and practically experiencing real professional work.[20,27] Moreover, cross-cutting interpersonal skills are also improved when students engage in PjBL[22] due to interaction with other people and various sources of information.[26] Students who embrace and have experienced the benefits of PjBL have advocated for its inclusion in the curricular activities.[26] Generally, when students are actively immersed in PjBL activities, their knowledge of content, in line with their context and applicability in the real world, improves significantly.[5,26]

Notwithstanding its potential to promote meaningful learning, PjBL is prone to some practical hurdles, such as students' lack of working knowledge to frame and initiate projects[28] and critical skills to decide and manage their own projects.[3] These are some of the consequences of limited to no experience with PjBL activities.[15,16] For instance, in some recent studies, students perceived PjBL as challenging during the initial stages.[22,28] More specifically, participants in a study by Matilainen et al.[28] identified the "…design phase, experimental work and data acquisition as the most difficult parts." (p236). Another challenge of PjBL for students emerging from their limited experience, is struggling to make sense of published literature to inform their ideas and proposed project designs.[29] It is not only during the initial stages where challenges have been reported but also during execution, though their impact is low. For instance, since in PjBL students take more responsibility for their learning tasks and experience a lot of new things on their own,[30] they sometimes feel overwhelmed, confused and uncertain of what to do.[15] Furthermore, students encounter challenges with new methodologies, which are sometimes explained in complicated technical language in the literature,[29] overwhelming time demands of tasks and how to deal with unanticipated results from unfamiliar experiments.[28]

Some research studies show that students perceive PjBL as susceptible to challenges related to supervision, institutional support and the collective will of those involved.[31] Therefore, it may be essential to spend more time in the enculturation of students into the practices of PjBL in order to realise most of its benefits.[15] On the contrary, some students draw motivation from the experience of new adventures and challenges such as more time and effort demands associated with PjBL than other learning traditions.[30] From these contrasting views, it may be argued that the effects and/or influence of PjBL differ from context to context, and therefore, its success depends on how students perceive it based on actual experience. This study aimed to assess how a cohort of students who were more accustomed to traditional teaching and learning approaches and guided experimentation perceived PjBL, particularly the conceptualisation and proposal writing stages of the projects.

METHODOLOGY

This study was framed as a descriptive study employing both qualitative and quantitative approaches. It is framed as a descriptive study because it seeks answers to 'what' type of research questions[32] concerning chemistry students' perceptions about conceptualisation and proposal writing of their research projects. Descriptive studies are economical and can be carried out to provide quick results that are readily applicable in addressing problems. Moreover, descriptive studies can provide important insights for further research studies. However, results from descriptive studies have some limitations of not answering questions on causal relationships.[33] The use of both qualitative and quantitative methods allows researchers to better understand phenomena by taking advantage of the collective strengths of the two approaches.[34] This study used quantitative data to illustrate patterns in students' perceptions through descriptive statistics. The subsequent analysis and interpretation of qualitative data were done to gain more insights and to discover any divergence or convergence with the patterns established through quantitative data analysis.

Sample profile

A purposively selected sample for this study was a cohort of fourth-year students (n=35) registered for the analytical chemistry course in the Bachelor of Science (B.Sc.) degree program. The students were given a chance to organise themselves in groups of two or three to start conceptualising and writing proposals for their own research projects. These students take laboratory-based practical modules within different classical chemistry courses such as physical, analytical, organic, and inorganic chemistry. In addition, as part of their coursework, they are expected to embark on an independent research project in analytical chemistry that aligns with the course content. Among the activities expected, students need to identify a research project title, formulate a problem, research questions and/or objectives, design and propose an experimental approach and then proceed with the project upon approval by the course instructor or supervisor. The cohort was purposively selected because of the virtue of having enrolled in the course, which demands that they engage in some practical project work, and most importantly, the course was offered by one of the authors. Purposive sampling allows researchers to identify and include cases with desired characteristics suitable for the purpose of the study.[32] Ethical considerations were observed throughout the study. Invitations to participate in the study were made through email to the students. The objectives of the study were explicitly stated in the email, and that students' participation was voluntary. Students were also made aware that their views would be reported without revealing their identities and would not affect their assessment in the course as the study was a separate exercise. Students were given pseudonyms for reference when the questionnaires were received for reference (e.g. ST-1 for student 1). Two students returned incomplete questionnaires which were not included in the analysis of data.

Instrumentation and data collection

The instrument for data collection was a self-designed questionnaire with closed and open-ended questions. The questions were framed in line with the objectives of the study, which were to determine the perceptions of individual students concerning:
1. The factors that influenced students' choice of their research projects and which they considered key during the conceptualization stage,
2. Students' initial stages of conceptualisation of the projects in order to assess challenges and opportunities, and
3. Overall perceptions of students about the inclusion of projects in a chemistry courses.

The first author designed the data collection instrument and then shared it with the second author to comment and make inputs on the content of the questionnaires. After that, meetings were held to collaboratively discuss and agree on content validity [34] and the scope of the instrument with regard to research questions. After the discussions, a final copy of the questionnaire was produced, which had six open-ended questions and six closed-ended Likert scale questions. For each Likert scale question, students were also required to justify their responses. For instance, if they had rated the educational value of projects at 1 (strongly disagree), an explanation related to the perception was sought. The final, edited questionnaires were circulated to students as soft copies for completion with a request to return them via email.

Data analysis

The data set was comprised of a Likert scale questionnaires and open-ended questionnaires. The quantitative data from the Likert scale questions were analysed to generate descriptive statistics so that patterns could be identified. The qualitative data from open-ended questions were subjected to conventional content analysis[35] to provide an in-depth and rich understanding without much influence caused by preconceived ideas. Codes and categories are derived from interaction with the data.[35,36] Therefore, in line with the aim of this study, conventional content analysis of the qualitative part of the data became helpful in providing a better understanding of how science students experienced conceptualisation of research projects**.** First, the authors immersed themselves in the data by reading it several times to understand the students' general perspectives. Secondly, a meeting was held where an agreement was reached on formulation of initial codes. Drawing some guidelines from Graneheim et al.,[36] about methodological challenges in qualitative content analysis, the authors undertook coding and analysis independently by engaging in the following steps:
1. An initial coding scheme was drawn based on codes identified from reading the data several times. Authors did the initial coding independently, then convened to discuss the codes and agree on the final ones to use.
2. The codes were then categorised, and thereafter the frequencies of categories were established[37] through simple descriptive statistics to demonstrate any patterns which could be compared to quantitative data from the Likert scale questions.

In order to guard against bias and ensure some level of validity,[34] several meetings were held after each stage of the analysis to identify contradictions, which were discussed until a consensus was reached. After that, a final version of the analysis and presentation of findings was prepared. Sections of data presentation are supplemented with "rich, thick description" (p.251)[31] of students' experiences of selection of topics and writing of proposals for their research projects which are some of the fundamentals of PjBL.

FINDINGS

This section presents the findings in relation to students' perceptions gathered to provide insights to the following questions derived from main research questions:
- What influenced students' choice of their research projects?
- Which factors do students consider when they conceptualise their research projects?
- What are students' overall perspectives about including projects as part of their learning in chemistry?

The presentation of the findings includes descriptive statistics representations and essential meanings of vignettes from students' narrations.

Assessing the factors which influenced students' choice of their research projects or titles

The project title provides a snapshot of what needs to be achieved. It is the first and most important step in research design as it contextualises the problem and serves as an essential reference guide for the rest of the project design and execution. The responses for this part were based on a group work, but each student had to provide what they individually perceived as influential factor for the choice of their projects. Care was taken to compare responses from a given group so that similar responses were recorded only once to avoid duplication (i.e. if analysis of the questionnaires from a pair of students (who worked together) both had 'environmental pollution' then environment was given one tally and recorded once).

The analysis of the students' responses to the question about factors which influenced the choice of their research projects revealed four main categories of factors. Namely, environment, curiosity, other subjects and lastly, whether the lecturer/supervisor had a significant say in the topic proposal. Figure 1 presents these four main categories of factors.

Figure 1 shows that the environment was the most influential factor with the highest frequency of occurrence (15) followed by curiosity (7), then other subjects (6) such as parasitology. The input of the lecture/supervisor was the least cited factor (5) which contributed to the choice of research project in cases where students struggled to come up with their own topics.

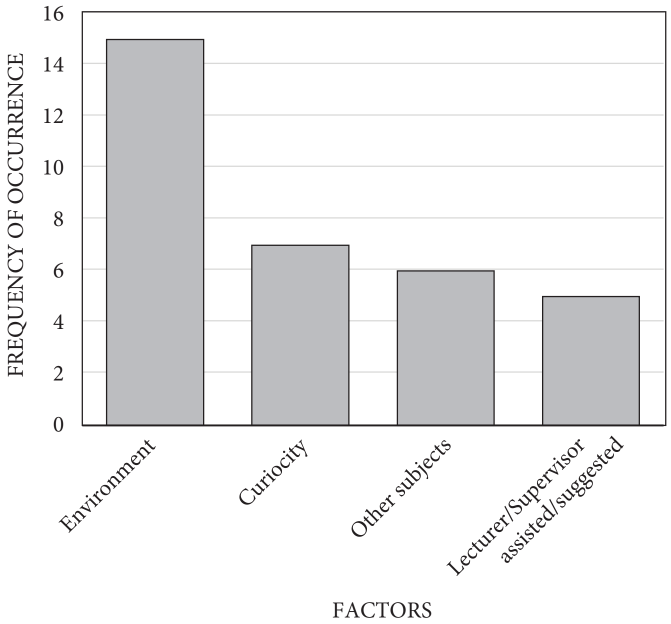

Figure 1: The factors which influenced the choice of topics for students' research projects.

The role of a lecturer or supervisor in students' choice of projects was probed, and it emerged that where and when there were challenges, the lecturer assisted in providing students with clues to identify problems they could solve thus narrowing down the scope of the topic to something that could be achievable. The students were free to frame their projects, whether the project was aimed at providing a solution, product or new process largely following analytical chemistry techniques and concepts. The lecturer also assisted in contextualising the problems. This is demonstrated by the response below:

> *Initially, we wanted to test the amount of acid content in the rain, but we were made aware that there has not been a lot of rain recently and there are not many industries in Lesotho such that acid rain could be formed.* ST-2.

The interpretation linked to the above extract is that if the lecturer had not intervened, the students would have wasted their effort, as the context would not be appropriate for the type of solution they were thinking about.

Of all the students who were assisted, only one student stated that s/he was 'clueless', and the lecturer suggested the topic which they adopted. However, through their struggles to come up with a topic, it became apparent that their inclination was more towards techniques mainly employed in other subjects (e.g., organic chemistry and biology) than analytical chemistry. Could this be that interdisciplinary projects should also be allowed? This is the question that the lecturer could consider in future to provide a holistic approach to learning instead of focusing on a specific content area as though the students are learning in an isolated environment.

Quote from one response:

> *In choosing the topic, we were assisted by Prof… (name withheld) since we have tried so many times to try to bring about an analytically based topic. Many of the topics we have thought about were still analytically based topics, however, they were also seemed to have more Biology and or Organic chemistry techniques employed. Having assisted to design our topic, me and other members of the group have tried to combine thoughts in generating the problem statement of the topic and have come up with one.* ST-7.

From the quote above, it becomes evident that students found it easier to adopt methodologies prominent in biology and organic chemistry than in analytical chemistry.

Which factors do students consider to be key when choosing a research project topic?

The analysis of the responses to the question above led to identification of multiple factors, namely, equipment, chemicals, budget, accessibility of samples, ability to execute procedures, time frame, significance, methodological considerations, and relevance to the course. These factors were then categorised under resources, time, human capacity, and others. Figure 2 shows frequencies of coded categories derived from students' responses. The frequencies of categories do not show a direct relationship to the number of respondents because each student was free to state as many factors as possible. Therefore, the frequencies represent the number of occurrences for each coded category.

As shown in Figure 2, equipment and chemicals (9) and time frame (12) were the most cited factors, followed by availability of budget (5) and human capacity (5). Methodological approaches (4), relevance to the course (4), accessibility of samples (3) and significance of the projects (3) were indicated to a lesser degree by students as shown by their frequencies of occurrence.

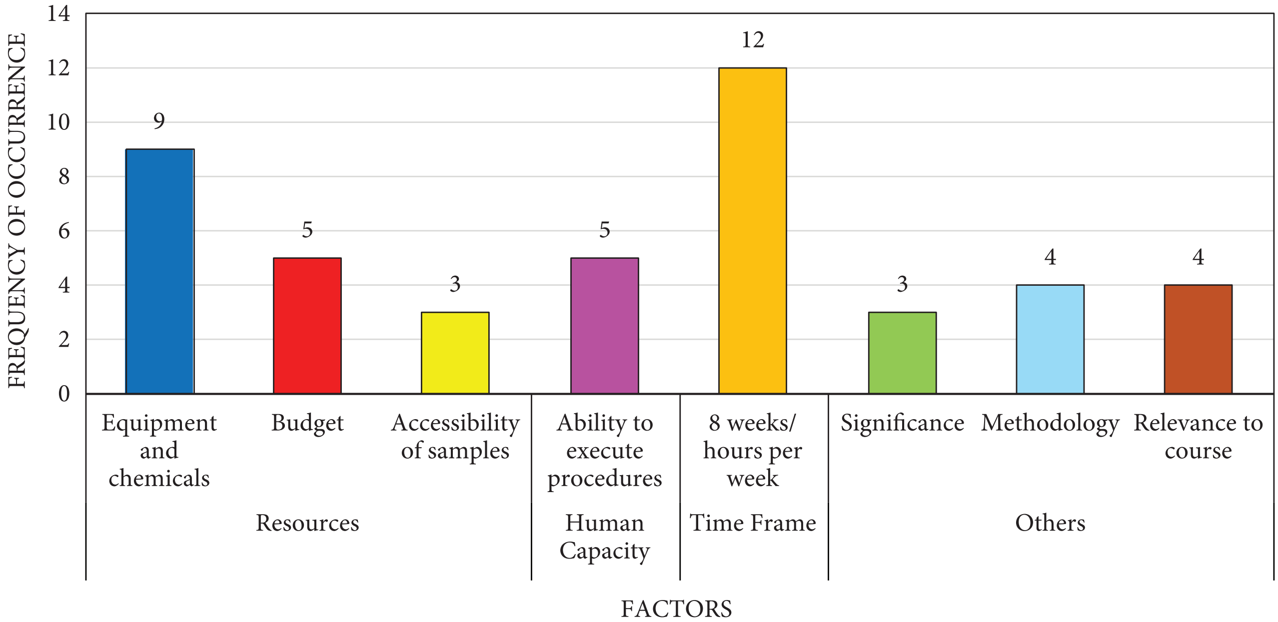

Figure 2: The factors which students considered when choosing a research project.

Further refinement of the data relating to the factors gave rise to three categories of students' orientations, namely, process, product and combined process and product orientation. A response was recorded under process-oriented if the student had mentioned resources and how they would be used. The responses placed under product-oriented were those where the students only mentioned what their projects would achieve without details such as resources and procedural considerations. The last category was process and product orientation where the resources were mentioned and how the project would be carried out with clearly specified intended outcome. Figure 3 presents these orientations and their frequencies.

Figure 3 shows product-oriented students at a lower frequency (n=9) followed by process orientation (n=11), and a higher frequency for process and product-oriented students (n=13).

The product-oriented students (n=9) focused more on coming up with a solution without thoroughly considering elements such as resources, budget, time, and their expertise capacity, which would have impact on their progress. Excerpts below illustrate this orientation:

> *To try to come up with a new means of measuring acidity or alkalinity in substances.* ST-3.

> *The topic must be versatile to be of the significance both in present and the future, they must solve the observed problem above all.* ST-19.

Evidence of some level of critical and strategic thinking was noted for both process-oriented and product-oriented students. However, notable differences were also observed in their conceptualisation narratives in terms of their main areas of focus.

Process-oriented students (n=11) primarily based their choice of research projects on consideration of methodological feasibility in terms of time and availability of resources. Little emphasis was made on the targeted outcome as a determinant of their choice of project. Lack of consideration of the envisaged outcomes made it difficult for students to justify the significance of their projects. Consideration of the significance had a very low frequency as shown earlier in Figure 2. The response from one student is quoted below:

> *The factors considered in choosing the research topic include the time to conduct the study to completion as we only had 8 weeks to conduct it. Also, we considered the narrowing down of the topic, we had to design it in such a way that it is confined to Analytical Chemistry, and also that the procedure for it, all the materials needed are either readily available from the school's laboratories or affordable as the study is not funded but self-funded.* ST- 33.

The process and product-oriented students (n=13) category shows that students had broad consideration of the entire project's feasibility. Specifically, process and product-oriented students considered purpose, methodology, resources, and anticipated outcome. These show most elements of project design and provide some reasonable evidence for the extent of critical thinking employed by students. However, the omission of essential elements such as safety was evident, just like in the process-oriented students' category. The extracts below provide details:

> *Factors considered when we chose the topic project were the amount of time it would require to finish it since we were only given 8 weeks. If the project will be solving a problem. And if the project won't be expensive that is if reagent and sample would not be expensive to obtain. And if they would be easily accessible.* ST-6.

> *Will it be easy to do the necessary steps to reach our end goals? Will our project contribute anything to society? Will our project be affordable to do and hopefully finish?* ST-21.

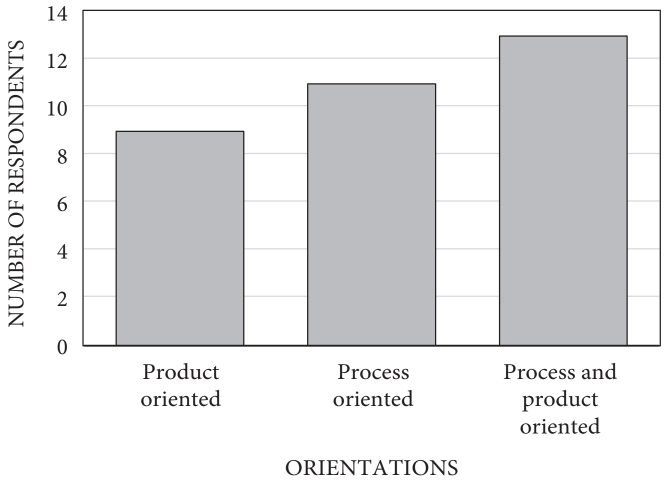

Figure 3: Students' orientations when conceptualising their research projects.

Students' perceptions about some elements of project-based learning

Following their experience of the initial stages (project conceptualisation and proposal writing) of PjBL, students were asked to share their views on whether the inclusion of the projects as part of analytical chemistry course was educational, exciting, easy, time-wasting, or difficult.

On educational value, students asserted that they had to engage in research, critical thinking, assessing the feasibility of various research methodologies, designing time-bound projects, self-regulated learning, collaboration and seeking help, problem-solving and application of analytical skills. The following are excerpts from some students:

> *I learned that different science disciplines intersect more than I had anticipated so coming up with a project demanded a wide perspective. Another lesson learned was to be considerate of the time almost always, so we had to draw up a timeframe for every step of our project and it had to accommodate every member. I also learned that communication is crucial in order to succeed.* ST-1.

> *Self-discipline in a way that I had to do things myself without being pushed Self-confidence in a way that I had to be confident in what I think, so that I can both execute the results and to explain it to the supervisor. And accountability.* ST-8.

> *Doing experiments which are part of the project is very enjoyable and working with other people. Working with different people as a team helps to see things differently and it improves one's ability to think or reason beyond them. Within a group, there could be times when there are disagreements but at the end of the day, a solution is found and that improves our reasoning and learning as more research in made to prove arising problems while carrying out the project… A research project is very crucial as it helps with so many skills; teamwork, improves analytical skills and helps to generate ideas and make findings. Research helps to give a feel of what happens in the real world outside of school and classrooms. It helps one to engage with other people, voice their ideas and reason while also learning and gaining more knowledge.* ST-13.

Some students pointed out that engaging in projects brought some excitement when they had to apply their knowledge in real-life settings to solve problems of their choice.

> *The fun was in the abundant freedom from instruction. For most of academic every assessment is guided, has an instructor. This time I could choose what to be assessed on therefore it lightened the worry burden off when choosing a project topic…Being able to*

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brainstorm, design and conduct a project idea has been very helpful and amazing experience. I got a chance to apply principles and concepts from lectures from previous years, not only in analytical chemistry. Preferably, I would rather have had this kind of projects in other courses as well. ST-15.

When asked about what was difficult or challenging to propose a topic and design action methodology, students highlighted several issues. Namely, being clueless about topic selection, limited laboratory equipment and consumables, time constraints, formulation of problem statement and its justification, the requirement to identify principles of analytical chemistry that would be engaged, coming up with feasible and economical methodology and having to tolerate conflicts of interests among group members. About the time demands of the research projects, some students highlighted that they had to create more time for researching and consultations.

Finding a research topic is very challenging on its own, let alone finding the right topic. Choosing the right methodology and availability of materials, reagents etc. Time management- finding time when everyone is available outside the time allocated for project slot to finish up some parts of the project. ST-4.

It was difficult to identify what problem the proposed topic will be solving. It was hard to think of educational projects that can be done. ST-17.

Selecting a topic that more analytical, that applied analytical methods. Most of the topics that we came up with were biological formulation topics. ST-7.

The extracts above provide further insights into students' perspectives about the challenges they experienced. Despite the external contextual challenges, there were personal challenges related to instances where students had to do a lot of independent learning through research and consultations. The levels of difficulty and challenges were within students' reach because they all produced projects in the end. Therefore, it may be argued that a challenging educational task with some reasonable level of difficulty does not equate to an inaccessible task and can potentially promote independent learning. Figure 4 provides some supporting information for this argument by showing a negative relationship between 'difficult' and 'easy' across five levels of a Likert scale, Strongly disagree, Disagree, Neutral, Agree and Strongly agree.

Figure 4 shows that some students (n=10) rated conceptualisation of projects from agree to strongly agree on the issue of difficulty, which indicates that students agreed that conceptualisation of a research project was difficult. Other students (n=10) decided to remain neutral. The remaining students (n=2) disagreed that the conceptualisation of the research project was difficult. On the contrary, students' perceptions on the easiness of project conceptualisation show that few students (n=5) chose 'agree' and 'strongly agree' to show that conceptualisation of the project was easy for them. Five students were neutral on the easiness of conceptualisation of a research project, while fourteen disagreed with the statement that project conceptualisation was easy.

These findings show some degree of negative relationship between difficult and easy. For instance, if the students agreed that the conceptualisation of a research project was difficult, it would be expected that they would disagree that the conceptualisation of a research project was easy. This observation provides some form of validation in students' assessment of their experience of conceptualising projects. Under the difficult option, 22 responses were recorded, while under easy, 25 responses were recorded and used for calculations of frequencies excluding some missing responses. The missing data was caused by some students who, after responding to difficulty, ignored to rate their perceptions under easy and vice versa.

Comparison of the perceptions of students regarding the educational value versus time-wasting of projects

Ultimately, the students were asked to share their perspectives on sustaining and expanding learning through research projects. Figure 5 shows students' responses about educational value versus time-wasting of projects on a five-point Likert scale with options, Strongly disagree, Disagree, Neutral, Agree and Strongly agree.

Figure 5 shows that a large number of students (n =24) agreed that projects are educational. Three students remained neutral while only one disagreed that projects are educational. It should be noted that data from some students (n=5) were not included as they wrote 'Yes' on the questionnaire without specifying their level of agreement or disagreement on a five-point Likert scale. Concerning time-wasting many students (n=17) chose 'disagree' and 'strongly disagree' for a statement saying that projects waste time. Five students remained neutral, while another five students agreed that projects are time-wasting. Some students (n=6) simply replied 'NO' on time-wasting, while others who rated educational value high did not respond to the question on time-wasting. These show some level of misunderstanding of the instrument.

The results in Figure 5 show that there is some negative relationship between educational value and time-wasting responses. The fact that many students disagreed with the perception that the project was a waste of time demonstrates the value the students attached to the exercise. There seems to have been a bit of misunderstanding of time-

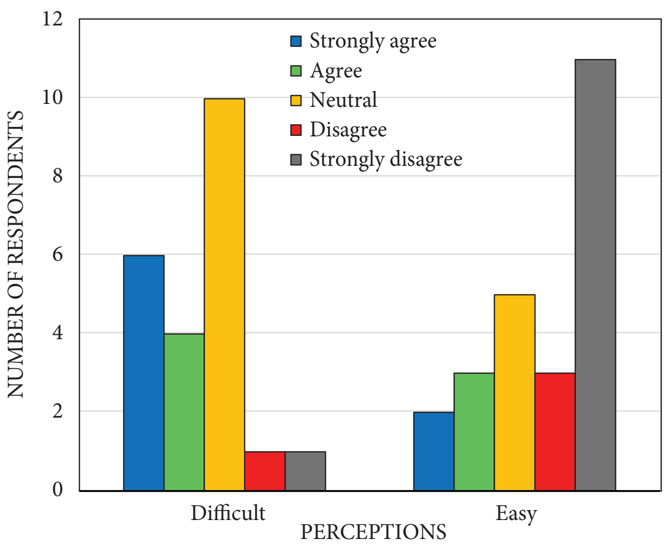

Figure 4: Perceptions of students about difficulty and ease of project conceptualisation.

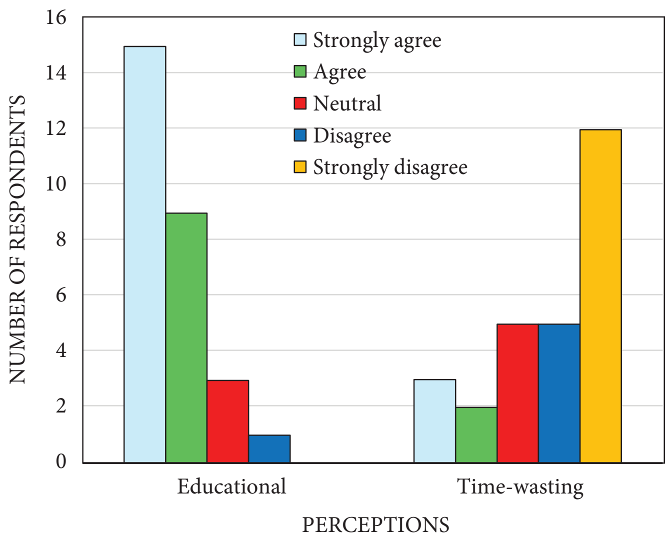

Figure 5: Responses of students on the educational value of research projects versus time-wasting.

wasting, whether it referred to the time taken doing the exercise or being worthless, contributing very little to students' learning. It seems some students may have missed the relevance of project designing to the actual implementation of the project, as well as its contribution to the course. Some issues expressed regarding time were that the project took a lot of students' time when they engaged in researching, thinking, and drafting plans for the experiments.

The analysis of qualitative data on students' perceptions regarding the inclusion of research projects in chemistry courses revealed that though some students had some challenges, they were able to experience positive effects of engaging in PjBL exercise. This finding can be attributed to the fact that when challenging tasks are structured within students' capacity and access to assistance is made available, the challenges allow students to engage in practices that expose them to self-directed learning, application of theoretical knowledge and skills they acquired to solve real-life problems other than being impediments to learning. However, some students still believe that more can be done to enhance learning through research projects. For instance, securing a wide range of analytical equipment and laboratory consumables and considering time frames could ease challenges. The extracts below illustrate these perceptions:

> *I highly recommend that is continued. More than anything, I was able to learn on my own and read the work of other people thus making it easier for me to know and understand exactly what I'm doing. … it is a perfect way to expose us students to what our chemistry degrees can do for us, how there is so much that we can offer with our knowledge and just how easy it can get once everything needed for the success of the project is available. … research project is an eye opener and should maybe considered instead of practical labs in fourth year.* ST-9.

> *A research is a necessity; it really gives … exposure … some get to use some instruments they never did in their life before, so yah it should continue. However, some adjustments or improvements are needed, especially in terms of the chemicals, tools, and instruments … should be available ... That will allow easy flow of project progress.* ST-15.

> *Research projects are very helpful because they could be carried out even outside school. They are very challenging and time consuming, but it is worth it because a lot of knowledge is gained. The frustration and stress are all worth it in the end so I would recommend it to be continued. However, I wish more time would be allocated.* ST-11.

The extracts above illustrate essential aspects of learning. The students were able to develop a bigger picture of the project design even at their novice stage. This observation provides evidence of the extent and relevance of the PjBL approach in promoting deep and meaningful self-directed learning.[11] With adequate supervision, students could go an extra mile in research as they conceptualise their projects. They had more practical experience of the scientific quest for knowledge than in their usual practical work, which is largely confined to pre-determined procedures.

DISCUSSION

The study reported in this paper sought to understand how students enrolled in an analytical chemistry course experienced some fundamentals of PjBL during their final year of undergraduate studies. The exercise involved project conceptualisation, where students were expected to provide working topics, the motivation behind the topics, and the factors they considered during the conceptualisation and proposal writing for their research projects. Ultimately, students were asked to share their perceptions about the inclusion of research projects as part of mainstream teaching and learning activities. Similar to the findings by Zhao and Lei,[12] environmental concerns were the main focus of students' choice of topics. The diversity in the students' projects about the environmental issues demonstrated the prevalence of problems facing the physical environment in Lesotho. This environmental consideration can be attributed to students striving to engage in authentic real-life issues[7,11] by applying knowledge and skills acquired from the classrooms in novel situations outside classrooms.[1,2] Students demonstrated the ability to apply interdisciplinary integration of concepts and knowledge to produce practical scientific artefacts in their choice of projects. Some scholars refer to this set of skills as "cross-curricular competencies" (p.13).[24] In agreement with the notion that PjBL promotes students' autonomy[26] and motivation,[9] some students' choice of projects was of an affective and exploratory nature, where students had some urge to try out new things different from routine laboratory experimental work embedded in various courses.[14] Despite the efforts made for students to collaborate and work on realistic projects, some students still had to be assisted by the supervisor in refining their project ideas so that the projects were within reach and fitting into the context of the course. This finding mirrors that of Matilainen et al.[28] where students pointed out that project design is one of the challenging aspects in PjBL.

Three categories of orientations were identified about the factors which students considered during the conceptualisation and proposal writing stage of their research projects, namely, process-oriented, product-oriented, as well as a combination of process and product-oriented students. This diversity of students' orientations towards project conceptualisation could be attributed to their low level or lack of experience in PjBL,[16] especially those who did not consider both the process and intended product. Planning a research project without extensive consideration of feasibility factors is one of the issues that leads to challenges during actual execution of the project.[28] Nonetheless, some students were able to consider quite a sizable number of elements, showing the extra effort they put in during the conceptualisation stage. For instance, availability of equipment, chemicals, personal budget, accessibility of research site and samples, their capacity to execute envisaged methodological approaches, the significance of the project, relevance to the course, and the time available to complete the project were among the elements students considered.

On the value of projects, students cited various essential elements of PjBL, which corroborate findings from other studies elsewhere. For instance, students emphasised the importance of research projects in the development of self-regulated learning, independent research, meaningful learning, collaboration, problem-solving, critical thinking, as well as motivation. To substantiate their perceptions, students further highlighted that PjBL establishes a connection between the in-classroom experience and the outside world.[28] These hard and soft skills are essential for people to better adapt to life , be relevant and responsive to the challenges of the 21st century.[5] Furthermore, most students suggested that PjBL should be one of the teaching and learning approaches adopted in chemistry as it makes learning more meaningful and relevant. Students also advised that PjBL approaches should be introduced early enough so that when students are in their final years of study, they have adequate experience to deal with the complexity and demands of project conceptualisation, research proposal and processes of carrying out projects.

In addition to the positive contributions of PjBL to students' learning, some challenges were also reported. PjBL is a highly cognitively demanding process from the beginning to the end. Students in this study, like participants in Matilainen et al.[28] had some challenges in the initial stages of coming up with topics for their projects and designing the methodological approaches. Additionally, in agreement with the findings by Abuhmaid,[30] students experienced the need to put in extra time in their reading and planning schedules. They also had to broaden their reading scope, where they faced some challenges related to understanding highly specialised technical language and certain methodological approaches,[29] which they found relevant to their work. These findings provide valuable insights that, indeed, experience in

PjBL plays a crucial role for students to acquire the useful knowledge, skills, and competencies. Equally important is the structuring of the demands of the tasks in PjBL, which must be within students' reach while at the same time leaving room for innovation and expression of an individual's ability to solve problems in real-life situations.

CONCLUSIONS, LIMITATIONS, AND RECOMMENDATIONS

This study has revealed some benefits of project-based learning from students' perspectives. For instance, the influence of different subjects that the students take plays an important role in the project conceptualisation. Consequently, project-based learning should be approached holistically to avoid limiting students to engaging in projects within the perimeters of the specific course content. Among the factors that influence the choice of the projects include the environment that students live in and the content of different courses that they do. While the considerations for successful project implementation such as the availability of resources in terms of materials and time were made by students, some other essential elements were missing. For instance, none of the students considered the impact of their projects on health (i.e., safety aspects) or the generation and disposal of the waste that would be produced. There seem to be almost an equal number of students who considered 'process' and those who considered 'product'. Therefore, this could possibly be attributed to the fact that some students demonstrated mastery of general chemistry principles while others showed mastery of analytical chemistry principles in their choice of research projects. This distribution observation is interesting since chemistry is indeed about materials, while analytical chemistry focuses on processes. This demonstrates that the students understood the concepts and attained a certain level of maturity and readiness to face the real world by applying chemistry principles and techniques.

One identified limitation of this study is related to data collection methods which were only based on closed and open-ended questionnaires. Some important elements might have been missed because students' responses could not be followed up with other methods like interviews. However, efforts were made to gather rich textual narratives with several open-ended questions from students, which provided useful information in relation to the research questions.

The study recommends that lecturers/supervisors should refrain from being too prescriptive about projects to the students so that the maximum benefits can be derived from situating students' learnings within real-world issues. Students need to be introduced to PjBL as early as possible so that they can gradually develop skills, knowledge, and competencies before they reach the final years of their degree programmes. The approach has the potential to bridge the practical and theory gap and equip students with skills readily applicable to the world outside classrooms so that students can identify and solve real-life problems in their communities. Further research studies can be done focusing on how students compare their experience of the project conceptualisation stage and the actual experience of carrying out the projects.

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