

Empowering Self-Determining Biochemistry Learners: The XPLORATE Module for Gen Z with Alpha Features

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ABSTRACT

This study emphasizes the implementation of the XPLORATE module for Biochemistry learning as a transformation based on the principles of heutagogy and project-based learning. This module is designed according to the HEUBRID Model, to strengthen learning ownership among Generation Z who also have the characteristics of Generation Alpha learners, namely digital, flexible, and reflective. A total of 64 Bachelor of Education (Biology) students from a public university in Malaysia implemented learning using this module. This study used a combination of quantitative and qualitative design. The questionnaire instrument was built based on the Technology Acceptance Model (TAM) to measure students' perceptions of the experience of using XPLORATE. Meanwhile, structured interviews were conducted to obtain more in-depth reflective views. Quantitative findings showed high acceptance in terms of Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Behavioural Intention (BI). The interview sessions also found four main themes: learning ownership, research skills, time management, and active engagement. This study proves that the XPLORATE module is able to develop students who are independent, reflective, and skilled in the use of technology. The implication is that the heutagogy-based approach should be expanded in an effort to strengthen the marketability of graduates, improve the quality of teaching, and prepare higher education institutions for the challenges of future generations of learners.

Keywords: Heutagogy, Self-Determined Learning, Biochemistry Education, Generation Z, Project-Based Learning

INTRODUCTION

The challenges of 21st century higher education demand radical transformation in teaching and learning methods, especially in science fields such as Biochemistry which are complex, abstract and require active student involvement. Transformation of teaching and learning in higher education is now an urgent need due to the changing learning landscape and the nature of the new generation. Conventional lecturer-centred teaching methods are becoming less relevant in meeting the needs of Generation Z students, let alone Generation Alpha who will dominate higher education institutions in the coming years (Şahin Sarkin & Güvercin Seçkin, 2023). Students of this generation tend to be digital, fast, flexible and reflective, and demand more authentic and self-based learning experiences (Onjewu, Belal, Anwar, & Abumalloh, 2024).

In the context of this study, the operational definition of “Generation Alpha Characteristics” refers to the characteristics and digital learning behaviours of the alpha generation, which exist among Generation Z students. In this study, based on the age of the respondents, they belong to Generation Z. However, they have a tendency towards technology, flexible learning needs and are self-sufficient. These characteristics show similarities with the characteristics of the alpha generation. Therefore, the application of heutagogy-based learning modules such as XPLORATE is not only relevant to their current learning experiences, but also serves as early training to form an understanding of future pedagogical approaches (Şahin Sarkin & Güvercin Seçkin, 2023; Blaschke, 2021).

Furthermore, these students are future educators who will teach Generation Alpha students in schools. Generation Z in higher education institutions have shown a high level of technology acceptance, as they grew up in the era of the internet, social media, and mobile systems (Onjewu et al., 2024). It is a challenging task to attract students’ interest and build their understanding in a field such as Biochemistry that is abstract and complex. A study by Ratulani Juwita, Muhamad Syafiq, and Norliza (2023) reported that teaching Biochemistry often fails to spark active engagement when still relying on conventional approaches.

The heutagogy approach, which is self-determined learning that emphasizes learner agency, reflection, and flexibility, has proven to be a relevant approach (Blaschke, 2021). Heutagogy provides space for students to explore their own learning styles, actively build understanding, and take responsibility for their learning achievements. This approach is in line with the requirements of the Biochemistry curriculum that requires students to not only understand the content, but also be able to apply and relate it in a real-world context (Ryan & Deci, 2022).

In response to this challenge, the author has developed the HEUBRID Model (Desa, n.d.), which is a pedagogical model that integrates heutagogy principles in a hybrid learning context (Figure 1). Heutagogy is identified as an approach that can produce students who are prepared to face the uncertainties of the future through flexible and reflective self-determined learning (Hase & Kenyon, 2000; Blaschke, 2021). Based on this model, an activity module called XPLORATE was designed and implemented in the teaching of Biochemistry at the undergraduate level. This module combines project-based learning, reflective activities, digital technology elements and flexible guidance to enhance teaching effectiveness and empower students' self-determined learning.

This study describes the implementation of the XPLORATE module, the assessment methods used, and its impact on students based on the findings of the study. It is hoped that this study can contribute to academic transformation in higher education institutions and strengthen teaching and learning strategies in meeting the challenges of Generation Alpha.

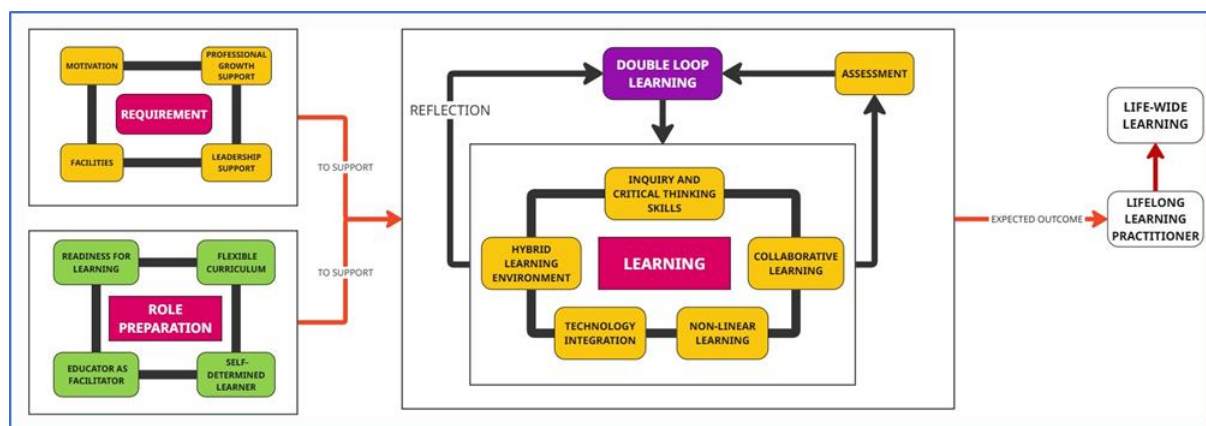


Figure 1: The HEUBRID model combines the concepts of heutagogy and hybrid learning, to create lifelong learning practices for life-wide learning purpose.

METHODOLOGY

This study used a mixed-method design, using both quantitative and qualitative methods. This aimed to assess the effectiveness and acceptance of students towards the XPLORATE module. This approach was chosen to obtain a comprehensive picture, encompassing aspects of students' perceptions towards the use of the module and their actual experiences while implementing project-based learning activities. This study was conducted on the SBK3013 Principles in Biochemistry course at a public university.

Study Context and Respondents

A total of 64 second year students from the Bachelor of Education (Biology) program were involved as respondents in this study. All students were taking the SBK3013 Principles in Biochemistry course which focuses on understanding biochemical concepts such as enzymes, metabolism, regulation and aerobic respiration. The XPLORATE module was used in this course as a transformative approach compared to conventional approaches such as lectures, laboratories and tutorials.

XPLORATE Module Implementation

The XPLORATE module is designed based on the main principles of the HEUBRID Model. The module includes five main learning steps:

- i. Self-goal setting,
- ii. Topic exploration and mini-study,
- iii. Self-reflection and understanding,
- iv. Collaboration and presentation of findings, and
- v. Self-assessment.

The XPLORATE module emphasizes self-learning, technology integration, and critical thinking development through a project-based approach. In this implementation, students are guided to carry out research projects related to the Biochemistry topics studied. Each week, students need to discuss and relate the content of the topic to the project to be implemented. In line with the heutagogy approach, the selection of topics, setting objectives, and planning the implementation of the project are determined entirely by the students themselves.

This process is designed to build critical and creative thinking characteristics, ownership of learning, curiosity, and lifelong learning practices. The module operates in a hybrid learning environment, and integrates non-linear learning activities such as self-exploration and collaborative learning through sharing of results in small groups and learning communities.

Students also develop digital technology and AI skills through the use of applications such as Google Workspace, Canva, Padlet and self-learning video recordings. The module is also supported by the author's own custom GPT, Heuta-X, as a project guide and mentor to address questions outside of formal lecture hours (Figure 2). Students are monitored through the *Feedback Studio*, which allows lecturers to provide formative feedback based on students' progress reflectively.



Figure 2: A customized GPT to assist students in implementing projects independently

As a distinctive feature of the HEUBRID Model, students are given the space to change or restructure their projects when new discoveries are made, or adaptations are needed. This is a feature of double-loop learning implemented in this module. In a heutagogical approach, students undergo double-loop learning, a learning process that corrects actions, but also involves reflection on their values, beliefs, and learning strategies. This is in line with the heutagogical goal of building capabilities, metacognitive thinking, and lifelong learning (Hase & Kenyon, 2000). This approach encourages students to re-evaluate their original objectives, ways of thinking, and decision-making throughout the learning process.

For example, one group that initially chose the topic of lipid metabolism realized that the topic was too general and difficult to relate to daily applications. So, they changed the topic to a more focused one. This change occurred as a result of self-reflection and active formative guidance through Feedback Studio and GPT Heuta-X.

This process encourages students to respond to challenges and reshape their learning strategies and goals. This approach is very much in line with the needs of Generation Alpha who demand adaptive, independent, and reflective learning experiences. The final assessment is carried out through the presentation of results and the construction of students' digital portfolios, as part of the evidence-based and reflective assessment process.

Data Collection

Quantitative data were collected through a questionnaire based on the Technology Acceptance Model (TAM) framework which contains three main constructs: Perceived Usability (PU), Perceived Ease of Use (PEOU) and Behavioural Intention (BI) (Davis, 1989; Said Al-Gahtani, 2001; Napitupulu, Haryono, Maulina, & Arifin, 2018). This questionnaire was distributed online after students completed learning using the XPLORATE module.

For qualitative data, two students were selected to undergo a structured interview session. Participant selection was made using the maximum variation sampling approach, which was based on the variation of their scores in the TAM questionnaire. The interviews were conducted online, recorded, transcribed using the Insight 7 application. Then, the transcript information was re-confirmed by the respondents before further analysis was performed.

Data analysis

Quantitative data were analysed using descriptive statistics such as mean and standard deviation for each TAM construct. For qualitative data, thematic analysis methods were used to identify patterns and main themes from the interview transcripts. The coding process was done manually with reference to the heutagogy theoretical framework and the principles of self-determined learning (Blaschke, 2021; Ryan & Deci, 2022).

FINDINGS

Quantitative Findings: Student Acceptance of the XPLORATE Module

The results of the questionnaire based on the Technology Acceptance Model (TAM) framework showed a high level of acceptance among students towards the XPLORATE module. All three main constructs, namely Perceived Usefulness (PU), Perceived Ease of Use (PEOU) and Intention to Behave (BI), showed high mean scores (Figure 3). This proves the students' confidence and willingness to engage in learning using this approach. Students stated that the use of this module had helped them understand Biochemistry concepts better through real project experiences and self-exploration. In addition, the ease of use of technology integrated into the module also contributed to increased motivation to learn actively and independently (Napitupulu et al., 2018; Said Al-Gahtani, 2001).

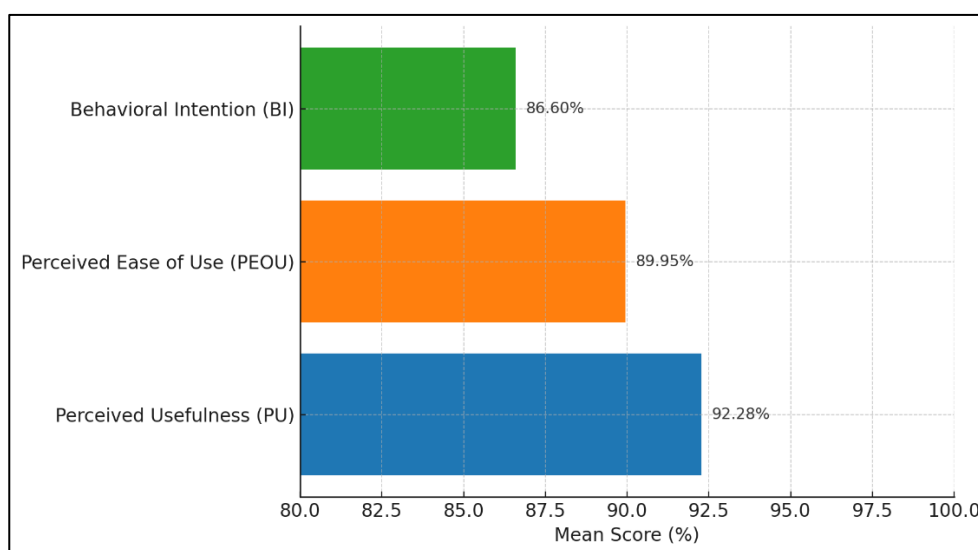


Figure 3: The mean score for the main constructs in the Technology Acceptance Model (TAM) shows the high level of student acceptance of the XPLORATE module in the aspects of Perception of Usability (PU), perception of Ease of Use (PEOU) and Behavioural Desire (BI).

The highest mean score was recorded on the Perceived Usability (PU) construct, which was 92.28%, indicating that students considered the XPLORATE module to truly add value to their learning. This is in line with the findings of Napitupulu et al. (2018) and Said Al-Gahtani (2001) who emphasized that the perception of the effectiveness of a technology is a key indicator of its acceptance. In the context of complex Biochemistry learning, students felt that this module not only accelerated the understanding of concepts, but also helped them build a more authentic connection between theory and application.

Meanwhile, the Perceived Ease of Use (PEOU) construct recorded a mean score of 89.95%, demonstrating a high level of usability of the digital activities and platforms integrated in the module. This is important because Generation Z students are very responsive to intuitive and flexible interfaces.

Module features such as freedom in choosing topics, the use of user-friendly digital tools, and the facilitator role of the lecturer clearly contributed to a smooth and less stressful learning experience.

Behavioural Intention (BI) also recorded a mean score of 86.60%, which although slightly lower than PU and PEOU, still shows a strong commitment to continue using this module in the future. Although students may take time to adjust to self-determined learning, they still show a positive tendency to repeat or recommend this approach, especially when they see the results and its impact on self-understanding and motivation. Overall, Figure 3 proves that all constructs in the TAM complement each other and support student acceptance of XPLORATE. High scores in all three aspects also strengthen the rationale for using the heutagogy approach in higher education, especially among students who are digital-native and willing to take responsibility for their learning.

Reflections on Student Experiences

Structured interviews with two students selected through maximum variation sampling yielded four main themes that describe the impact of the XPLORATE module on their learning experiences.

Theme 1: Autonomy and Learning Ownership

"I feel very satisfied because I can choose my own topic of interest. I feel like this project, is like my own and I am more enthusiastic about learning..." (Respondent 1)

This quote reflects the existence of an element of learning ownership (learner agency) when students are given the space to set their own project title and objectives. This autonomy encourages a deeper enthusiasm for learning and shows active engagement in the learning process. This is in line with the principle of heutagogy which emphasizes responsibility and freedom in learning (Blaschke, 2021). This element also supports the questionnaire findings for the PU construct which show that students see this module as very useful and has a direct impact on their learning.

Theme 2: Improving Research and Communication Skills

"This is the first time I really feel like doing my own research. Find articles, organize information, and present it in a way that people understand. Very challenging, but worth it." (Respondent 2)

This experience shows how students are beginning to hone their skills in finding sources of information, evaluating and organizing it, and confidently presenting results through presentations and digital portfolios. It emphasizes authentic experiential and project-based learning. These characteristics are clearly closely related to perceptions of the ease of use and flexibility of the module, as recorded through high scores in the PEOU construct.

Theme 3: Time Management and Self-Planning

"I have to learn to manage my own time. If I am late, my own project is affected. So, I start planning in advance and organize my assignments properly." (Respondent 1)

The implementation of this module also shapes students' ability to plan and manage time effectively. This is an important skill in lifelong learning. This also reinforces the BI findings that show students' intention to continue using this approach, and recognize its need for future learning.

Theme 4: Active Engagement and Intrinsic Motivation

"This module makes me more involved. I don't wait for the lecturer to teach, but I myself search and understand. I feel like a little scientist." (Respondent 2)

A student will show increased intrinsic motivation when given the trust to explore and create meaning in their own learning. They show high engagement, and strengthen the ability to learn continuously in an authentic and dynamic context (Ryan & Deci, 2022). This feeling clearly reflects the enthusiasm in the BI construct, which is the tendency to repeat experiences. This is because they believe in the positive impact on their own learning.

The combination of quantitative and qualitative findings provides a comprehensive picture that the XPLORATE module based on the HEUBRID model is not only accepted from a technical and practical perspective, but also touches on the dimensions of motivation, self and learning identity of the students themselves.

Implications, Reflections and Transformations

The findings of this study reinforce the potential of the XPLORATE module as a catalyst for the transformation of Biochemistry teaching, especially in the context of empowering self-determined, reflective and student-centred learning. This module has successfully translated the main principles of the heutagogy approach, such as self-goal setting, ownership of learning, and the planned integration of digital technology and AI. It is an approach that is in line with current needs, even beyond future needs (Blaschke, 2021; Ryan & Deci, 2022).

Although students from Generation Z were involved in this study, the results show that their learning characteristics are very much in line with the expectations of Generation Alpha. Among them are the need for active engagement, technological competence, the ability to learn independently and flexibly, and the habit of thinking visually and reflectively. This provides a clear indication that the landscape of higher education is changing no longer towards adapting content, but rather restructuring the learning experience. This creates learning that is more personal, authentic and based on student agency. Therefore, today's lecturers need to be prepared to transcend the boundaries of traditional pedagogy and adopt an approach that is more responsive to the characteristics of post-2025 students (Onjewu et al., 2024).

More significantly, the students in this study are prospective teachers, future educators who will directly deal with Generation Alpha students in the classroom. The implementation of the XPLORATE module is not just a teaching innovation, but a scientific and humanistic exercise, which provides an authentic space for students to build an understanding of future pedagogical needs through their own experiences. They not only learn to master the content, but also learn to become lifelong learners, future facilitators, and agents of educational transformation.

This study provides strong justification that project-based heutagogy approaches such as XPLORATE need to be expanded to other courses. The HEUBRID model that is the basis of this module should be promoted as a major alternative approach in higher education that is transformative. This module has been proven to be able to develop students who are technologically literate, critical thinkers, reflective, independent, and ready to play a role in a learning ecosystem that is no longer one-way. This is the model of the future student we hope for. Students who do not just wait for knowledge from lecturers, but build and choose their own path of knowledge.

This study also shows the clear alignment of the implementation of the XPLORATE module with the main components of the HEUBRID Model. The learning process takes place in a hybrid environment combining self-paced, digital, and direct guidance sessions. Students demonstrate active engagement through non-linear learning, where they are free to explore and structure learning at their own pace, including changing the direction of the project based on new discoveries.

Collaborative learning elements can be seen through sharing results in teams. While self-reflection and formative feedback are strengthened through the use of Feedback Studio. Most significantly, this module encourages double-loop learning. This occurs when students reflect, adjust their actions to challenges, re-evaluate the objectives and purposes of the project. These components prove that the changes that occur are not coincidental, but the result of a learning design planned based on heutagogy principles through the HEUBRID Model.

However, this study is acknowledged to have limitations. The findings were obtained from a cohort of students in a specific course and involved two respondents for in-depth interviews. Therefore, further longitudinal or cross-institutional studies are recommended to strengthen understanding of the effectiveness of the XPLORATE module in various contexts and disciplines. This opens the door for broader research, which evaluates the module's impact and builds a national teaching policy framework and strategy.

The XPLORATE module is an innovation that connects the role of the lecturer with the reality of the students, past thinking with future needs, and makes education a more meaningful, reflective and realistic journey.

CONCLUSION

The implementation of the XPLORATE module in teaching Biochemistry courses has shown a positive and comprehensive impact on students, not only in terms of content mastery, but also self-determination, reflection, time management and ownership of learning skills. This study proves that the heutagogy approach implemented through the HEUBRID Model-based module is able to support the learning needs of Generation Z students who are increasingly showing the characteristics of Generation Alpha, namely digital, fast, flexible and independent (Blaschke, 2021; Ryan & Deci, 2022; Onjewu et al., 2024).

Indirectly, this module has served as a transformative tool that bridges the gap between the teaching approach of traditional lecturers/lecturers and the learning expectations of current and future generations of students. XPLORATE not only supports content learning, but provides a space for students to be architects of their own learning experiences. This is an important aspect in educating prospective teachers who will face Generation Alpha students in schools in the future. In the context of higher education, these findings prove that teaching innovations that combine heutagogy principles and digital technology are a necessity to remain relevant and resilient in the world of education.

RECOMMENDATIONS

Based on the findings of the study and reflection on implementation, four things are suggested to expand the impact of this module. First, expanding the implementation of the module to other courses. The XPLORATE module should be adapted and applied to other courses at the higher education level, especially in the fields of Science, Technology and Education. The flexible and self-contained features of this module make it suitable for various contexts and student needs. Second, developing lecturer capacity in heutagogy and Gen Z/Alpha literacy. Targeted training for lecturers should be carried out so that they can understand, adapt and implement teaching strategies that are responsive to the changing student generation. Modules such as XPLORATE can be used as reference material in university teaching good practice workshops.

The third is the matching of AI, reflection and feedback in the module. In order to strengthen the effectiveness of the module, aspects of AI use, self-reflective activities and continuous feedback need to be systematically arranged. This can further support students' metacognitive skills and improve their technological literacy (Şahin Sarkin & Güvercin Seçkin, 2023). Finally, is the documentation of good practices and dissemination in the academic community. This study proves that small but consistent teaching innovations can have a big impact. Therefore, efforts to document and disseminate the results of modules like this in seminars, journals and communities of practice are important to encourage change on a broader scale.

The XPLORATE module is a starting point for pedagogical transformation based on self-determined, reflective and digital principles. It is a bridge between the way lecturers think, and the way Gen Z and Alpha students learn.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

Shakinaz Desa: Conceptualization, Supervision, Original draft preparation, Reviewing and Editing. **Putri Nuratira Elliya Azizan Shah:** Data collection (survey and interview), Transcribing , Data analysis (statistical and interpretive), Reviewing and Editing.

DECLARATION OF GENERATIVE AI

During the preparation of this work, the authors used *Grammarly* and *QuillBot* to enhance the clarity and readability of the manuscript. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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