

A Theoretical Guide to Developing Learner Agency in Chemical Engineering Curricula

Zeeshan Qumer*, and Siti Fatimah Ibrahim

School of Chemical and Process Engineering, University of Leeds, Leeds, United Kingdom

ABSTRACT

This investigation was completed to understand the key themes and foundations surrounding learner agency culture for the benefit of student learning. An online literature search was conducted, with 36 selected papers forming the literature matrix that enabled the themes and trends to be spotted in the relevant literature. The key themes were fundamental skills and knowledge, learning environment, learner attitude and self-determination theory congruency. The important message emerging from these themes was the close relationship between environment and attitude for a learner, along with students using their past skills and knowledge in an environment to develop new skills and expertise, with fulfilling self-determination theory criteria enabling this to be repeated through the development of intrinsic motivation. These themes enabled the development of a theoretical framework, including a cycle and an interlinking process route that shows how learner agency could be nurtured in this scenario. To complete the aims of this investigation, this framework will be tested against first-year chemical engineering students and modified if any issues arise.

Keywords: Chemical Engineering, Framework Development, Learner Agency, Pedagogy, Self-Determination Theory

1. INTRODUCTION

1.1 Learner Agency in Context

This paper focuses on researching learner agency literature and collating the emerging themes to provide a theoretical framework and guide for the development of agentic learning in Chemical Engineering curricula. The study will draw upon the BEng/MEng curriculum as of July 2025, that is used within the School of Chemical and Process Engineering (SCAPE) at the University of Leeds.

Learner agency and its wide range of surrounding topics are becoming increasingly important in modern education, with its impact able to unlock more productive and responsible learning in and out of the classroom for students of all ages. Its concepts closely interlink with the psychological and social behaviours exhibited by humans, as becoming an 'agent of your own learning' requires a basis of understanding of complex human behaviour traits [1] [2]. Agency refers to a human's "power to originate action" and their impact to influence the outcomes of one's actions [3]. From this, there is development in their behaviours and beliefs. In this instance, agency with context to learning forecasts that an individual can take control of their learning outcomes through the development of ownership and responsibility from their behaviours and attitudes they construct towards education [4]. Conflicts within learner agency emerge in the 'correct' approach taken when it is presented to a cohort. Rather than being a set idea that is implemented within a classroom, it needs to be developed to meet the needs and challenges that arise from that specific classroom setting [5]. For example, the range of agency that can be displayed by students in a classroom in Western Europe would vary from a similar setting in Eastern Asia [6].

*pm22zq@leeds.ac.uk

There has been a recent shift in how students are taught, with the COVID-19 pandemic shifting a large quantities of learning materials and classroom activities online [7]. Whilst this shift may have been inevitable, it is clear to see that the uncertainty and widespread change brought about by the pandemic has impacted students. Although a host of cultural and societal factors undoubtedly play a large part, individual traits such as motivations and values will play a crucial role in the development of learner agency in all students [8]. The guide and framework developed in this context is open to expansion and improvement to assure the benefits gained from its usage are as widespread as possible.

1.2 Research Questions and Aims

This study will aim to provide a theoretical guide and framework that can be fostered in a Chemical Engineering classroom with an IChemE verified curriculum [9]. The findings and emerging themes will aid the construction of the theoretical framework, which will be developed and examined within a classroom setting in due course. The use of this framework will highlight the strengths and weaknesses of the research and highlight any improvements for the model. The aim of this investigation can be reduced to 3 research questions:

1. What approaches are used in literature to develop learner agency from a chemical engineering perspective?
2. How can learner agency be developed in chemical engineering curricula through the usage of a theoretical framework?
3. Can the learner agency that is developed from this framework influence students' academic success?

2. CONTEXT AND METHODOLOGY

2.1. Context of Study

The University of Leeds offers BEng and MEng Chemical Engineering programmes, with the length lasting from 3-5 years. Each year is weighted by 120 credits, with modules being in the range of 10-40 credits. This degree, awarded by the University of Leeds, is fully accredited by IChemE, which provides criteria of which the curriculum must fulfil [9]. The first year of the programme focuses on developing a students' skills required for higher education, whilst introducing them to some key engineering concepts. The second year of the programme develops these engineering concepts further, with the introduction of more technical knowledge and further refinement of skills. Third year is centred around the BEng Design Project, which combines with learning of key separation and reaction modules. Fourth year includes the masters design project, along with other modules for topic specialization.

The learning of students at the University of Leeds is bounded by the criteria of the curriculum. An investigation will be completed on learner agency literature, to determine the core designs and proposals used. These findings will then construct the method of learner agency development in the classroom and within current curricula, whilst highlighting any improvements that are needed to aid students. The findings from the investigation will be to improve the methods of a first-year module that looks to develop the required basic engineering skills, understanding and competencies for a chemical engineering student.

2.2. Literature Search

The literature search for this subject of study was completed to deduce the key findings and understandings of learner agency. The primary research engines used for the literature search were Scopus and Web of Science. The list of keywords used in this literature search were Learner, Agency, Chemical, Engineering, Student, Learning, Higher, Education, Curricula/Curriculum, Environment, Constructivism (used with learning and education) and Longitudinal. Whilst conducting the literature search, the most successful word selection for finding literature was a combination of 'agency, autonomy and student. The words 'curricula, learning, chemical and engineering' provided satisfactory results, with their intention to provide a more specific focus on the literature in addition to the core search.

There has been a lot of research into language learning, particularly for Efl (English as foreign language) students. Most of the research found had also been conducted within English-speaking countries, presenting that the subject of learner agency may only be applicable to a setting where the infrastructure surrounding education is more developed. Whether learner agency could be developed in other cultures has yet to be seen but provides another opportunity to develop this concept. A simplified flowchart of the literature search process is displayed in Figure 1.

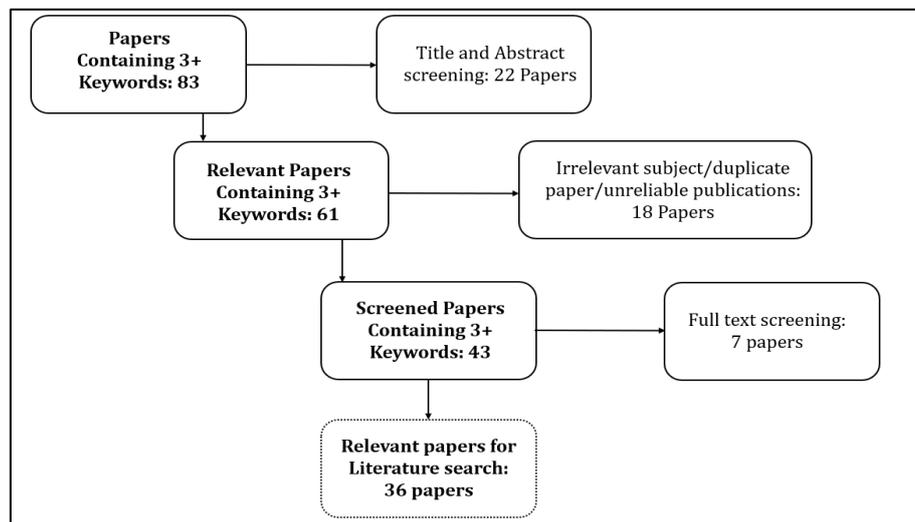


Figure 1. Flowchart of literature search process.

2.3. Literature Review Findings and Matrix Construction

From the conducted literature search, 83 research papers were collected and reviewed for their relevance in providing information to answer the research questions and meet the research aims. Out of the 83 papers collected, 36 were chosen for further study and review. These 36 literature papers relating to learner agency made up the literature matrix that was constructed to determine the emerging themes from all papers, in addition to other helpful information such as research method, country of origin and limitations.

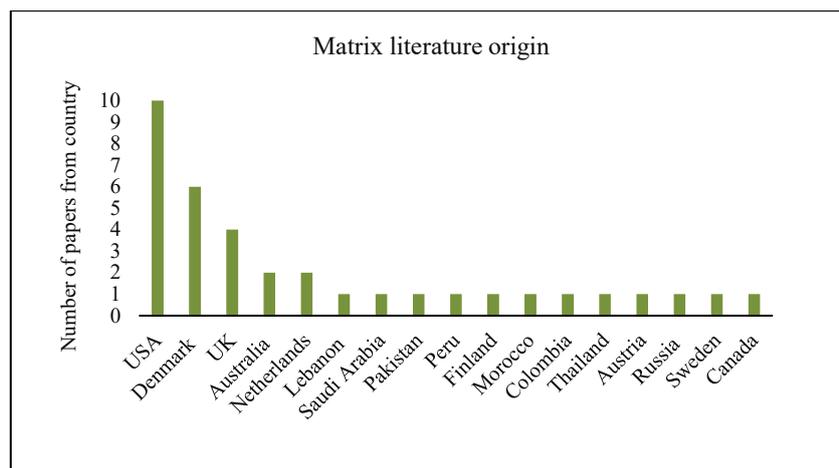


Figure 2. Country of origin for literature matrix papers.

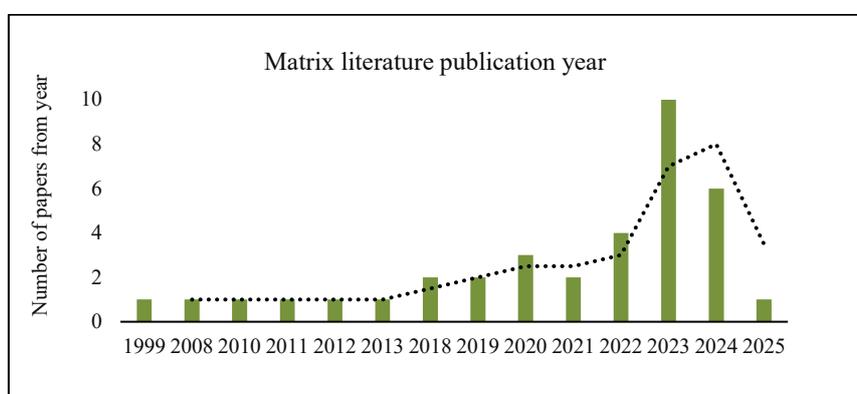


Figure 3. Publication year of literature matrix papers.

Figure 2 shows how the literature published on learner agency is predominantly in westernised society, such as USA, UK and Denmark. Figure 3 also shows an increase overtime of papers published that are linked to learner agency and its surrounding themes, supporting the emerging pattern of increasing post COVID-19 publications. There are already thousands of publications available that link to learner agency, so the results of 36 carefully selected papers cannot be generalised to an overall conclusion on the literature.

Due to the various keywords used in the literature search, the aims of the literature varied. The literature aims did stay consistent with the pattern of exploring how different classroom experiences and settings impacted a student’s academic success or perceived engagement with learning. The methods of testing varied between quantitative and qualitative with Q-methodology being used in one instance [10]. The quantity of study subjects in the literature spanned from 8 to 1230. Personalised learning strategies, such as tailored instruction along with the correct teacher training and resources were crucial for the development of learner agency [11]. Self-directed learning with communication and reflection processes supported by teachers enhanced learner and social agency [5]. The impact of autonomy on motivation for learning was vital, especially when providing skills such as resourcefulness and persistence [12]. This highlights the psychological basis of learning patterns in students, especially with the close link between autonomous, intrinsic motivation and learning [13]. The key factors affecting learning agency can be distilled to interest, motivation, self-efficacy, team dynamics and external support across a cohort [14].

Pisani and Haw [2023] provided insights into the chemical engineering curriculum at the University of Strathclyde, stating that classes fostering agency have high dispositional, positional and motivational ratings by students, with project-orientated modules providing higher agency through the development of critical thinking skills such as reflection, intrinsic goal motivation and independent thinking. Research from similar disciplines such as software engineering identify gaps in students reflective and interpersonal abilities [16], with a transition towards self-regulation and ethical agency recognised in Engineering Education for Sustainability [17]. Graham [2018] has reported that engineering institutions are reshaping their curricula to active learning designs and principles. This comes under the Education 5.0 vision that aims to advance emotional intelligence, adaptability and lifelong learning [19].

The main implications from the literature were that the development of learner agency requires careful consideration over the social, environmental and cultural factors, alongside the teacher training and support structures for agency and autonomy. Papers by Evenhouse and Lee [2023], Cawkwell and Paul [2024] and Jiang and Dahl [2022] all convey a message of problem-based environments promoting self-determination and agency in students. There is also an inherent need for further research to explore the effectiveness of learner agency development strategies in different contexts, so that teaching practices can adapt to support an agentic learning environment [23]. The literature analysed introduced some general limitations into research revolving around learner agency. Eidenskog and Leisler [2023] highlight the contextual and cultural constraints that must be handles to ensure transferable agency-supportive learning experiences. Likewise, digital learning designs and in-person learning environments fostered to develop student's agency can vary in their effectiveness at developing key agency traits [25].

3. THEMATIC ANALYSIS FINDINGS

The examined literature highlighted 4 key emerging themes that will form the main basis of learner agency understanding in this study. These themes will be discussed into how they would aid learner agency development and will be presented in the form of the theoretical framework.

3.1. Fundamental Skills and Knowledge

The skills and knowledge held by a student will impact their performance, confidence and ability within the classroom. The skills and knowledge that a student holds comes from previous learning experiences, both inside and outside the classroom [26]. These previous acquirements along with their interactions within the classroom will allow students to have a perspective over how to complete the desired behaviours when learning, along with using the behaviours for further learning as a student develops academically [27]. Rather than focusing on the knowledge required, a student-centred curriculum would develop the skills and values they require to excel in their subject [4]. The curriculum provided to students must develop on the technical content to enable the growth of soft skills [28]. This can be seen to promote behaviours such as high engagement, ownership and team autonomy in real-world scenarios, showing an alignment in the learning and deployment of agency [29]. The nature of the classes they complete will directly impact the attentiveness and motivation shown towards the module they complete in chemical engineering curricula, which is vital for agentic learning [15]. This would focus on the processes to meet outcomes of this learning, to empower students with the skills and knowledge they require whilst enabling learner choice and individual development [30].

Alongside this, learners need the opportunity to develop the skills and knowledge they attempt to acquire. An effective way to do this could be using formative assessment or a PBL approach used within the classroom [31]. This would entail a student being subject to using their past skills and knowledge to learn a new concept or theory. This approach will increase their motivation,

along with more engagement and better self-regulation skills, as they develop from this learning experience [31].

3.2. Learning Environment

The environment a student learns in is crucial to their academic outcomes and experience of learning. This environment is controlled by many variables, such as teaching approach, teacher-student relationships, student dynamics in the classroom and the resources present for students to develop. This presents the social learning theory basis behind students' learning behaviours as they learn to repeat the actions observed in their surroundings [32]. Therefore, students being placed in the correct learning environment will go on to benefit them in the long-term [12]. As the student needs the opportunity to collaborate with the environment around them, they must be able to communicate with others to develop their positive learning patterns and therefore develop learner agency [11]. As there is a social learning theory basis behind this approach, the interactions that students have with one and other are important for developing learner behaviours and therefore learner agency [10]. In chemical engineering curricula, there are many opportunities to work in group projects and work towards goals with your peers. This allows students to learn from one another and develop the and behaviours that align with the working dynamic [10].

The environment that the students learn in should be beneficial to every single student and allow them to meet the objectives and personal goals. One crucial action the teacher must complete is to relinquish some authority in the classroom to allow the teacher-student dynamic to be less imbalanced and authoritarian [33]. Teachers should see their role as a chance to provide support and guidance, as students take ownership of their learning with increased academic engagement [34]. This support structure should allow students to know what educational outcomes they are working towards in the classroom, along with providing the opportunity for students to develop.

Teachers need to be provided with the correct training to understand what actions need to be taken for learner agency development in their cohort [11]. This displays that responsibility to develop learner agency for the benefit of students and society also falls upon administrators and institutions [10]. This aligns with other literature that suggests that digital environments designed with social-focused principles can foster agency [25]. Looking ahead, the cohesion of this occurring within an institute is important, as a synchronisation of teaching methods and practices within an institution will make it easier for students to develop traits of learner agency [33]. Although the content of curricula and classes may change, a drive to nurture this culture that is supported by all teachers in the institution will assist its development [33].

3.3. Learner Attitude

Learner attitude has a close relationship with the learning environment due to the social learning theory foundations of classroom learning. The environment a student is placed within will determine their beliefs and behaviours towards learning, therefore impacting their attitude [32]. However, it would be difficult to control such traits as cultural beliefs, personality traits, societal factors and students' initial interest in a topic. From the literature matrix, the attitudes that should be developed in the classroom should foster beliefs around setting and meeting individual goals, being driven by some external motivation and gaining positive values within their learning habits [35]. Ideally, fostering the idea that hard work and meeting goals leads to superior results, along with time for reflection, growth and development in this process will assist the learner's development [5]. Presenting some external motivation, such as informal competition between peers, or completion of a task within a period, can encourage students to engage with their work [27].

However, no environment that a student experiences will be the same, each presenting varying levels of dynamics such as autonomy, active participation and the opportunity to develop at a steady pace. A student will become familiar with different classroom environments and the autonomy they perceive in each one. Therefore, as much as the responsibility is on teachers for learner agency to be provided and encouraged for students, they should be able to develop some agentic attitudes in different teaching settings [15]. The learning environment and the attitudes that it develops in students have a dynamic relationship. In this instance, it is thought that the environment will affect the attitude of the learner as past experiences would have also done [14]. As a student experiences an environment more, their engagement with education increases as they start to develop further [36]. This engagement can be seen on a behavioural, emotional, cognitive, and most importantly on an agentic level. This engagement will have long-term educational impacts and even be able to influence future teaching practices and beliefs[36].

3.4. Self-Determination Theory Congruency

Self-determination theory explains how individuals gain intrinsic motivation and become engaged through their personalities by fulfilling the criteria of three innate needs: autonomy, competence and relatedness [37]. Along with social learning theory, self-determination theory (SDT) forms the psychological grounds of modern-day education. Fulfilling these three criteria in education will lead to genuine satisfaction, enjoyment and interest in a subject, which provides a congruence with one's ideal self that verifies the idea of self-efficacy [37].

The most common topic observed in this process was the aspect of autonomy. In this context, this means to give learners freedom and choice over their learning path and outcomes [38]. Medical students with autonomous motivation were found to have long-term engagement and meet learning outcomes effectively, which was increased by autonomous supportive behaviours [13]. The engagement the student develops from the coalescence of their learnt attitudes from their classroom environment will provide the student with the autonomy and freedom they require. The other two components of SDT, relatedness and competence, are also important. This could be fostered through interaction with students through group projects or problem-solving activities [14]. Competence allows a student to know they are correctly completing learning actions. This can be provided through a PBL environment, where students learn from assessment feedback [10].

As a student learns from their mistakes in this assessment method, they will be able to apply their knowledge in other situations as they get closer to succeeding in their learning goals [31]. Teachers can work towards ensuring a student eventually develops the intuition to achieve this success independently [5]. Faculty awareness of student agency is limited, with engineering educators unaware of how to apply self-determination theory within their teaching environment [39]. SDT-aligned support structures can increase retention of information for underrepresented students [40]. Therefore, agency can be seen through an equality lens, requiring an empathy-driven and inclusive teaching structure to be useful for all categories and levels of students [40]. This should lead to its importance being apparent in future curricula construction, for the benefit of learners in both the short and long term [13]. Fulfilling the three parameters will allow for the repetition of this learning process and these learnt behaviours, as they develop the intrinsic motivation to do so [37]. The positive reinforcement a student experiences from meeting their academic goals [32].

4. FRAMEWORK DEVELOPMENT

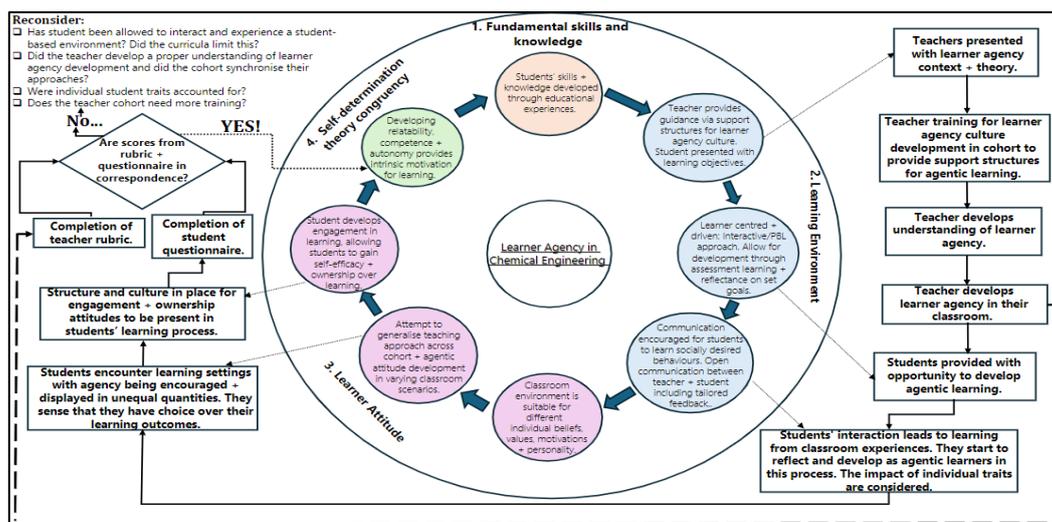


Figure 4. Learner Agency Framework for Chemical Engineering curricula.

Figure 4 displays the theoretical framework constructed from the literature findings in this investigation. It consists of a cycle (inner circle with blue arrows) and a surrounding process (outer structure with black arrows). The framework in Figure 4 works based on the four key findings in this study and develops them in an order that would produce the best long-term outcomes for the learner. The outer process route adds to the cycle by showing how the process of learner agency development is completed. This process would be easier to measure against when testing the framework and includes methods which it can be tested against in a classroom.

The cycle starts off by showing that there are fundamental skills and knowledge needed to become a chemical engineer, with the aim of this learner agency framework is to aid their development. A learner will possess some of the knowledge and skills but will have to continue to develop them as a chemical engineer [15]. The learning environment should be tailored in a way where the teacher can provide support as learners look to achieve academic success, whilst reflecting on their progress. Students encounter a PBL environment where they learn from their experiences and the interactions that occur around them (provides relatedness) [11]. As the student has encountered the support structure provided by the teacher, their attitudes can start to develop. The longer a student interacts in this environment, their attitude turns to agentic engagement, which could lead to them having a sense of autonomy in this process [36].

The surrounding process route works from the main cycle to display the procedure of learner agency development. It is presented in two different parts: the teaching development and the student experience. Once again, the notion of the environment determining attitudes takes hold here as the teaching impacts the student experience as the process develops. The success of the framework comes from the suggested development of a teacher rubric and student questionnaire in the process route, which come at the end of the teaching development and student experience routes. The themes that the testing methods present are linked to the learner agency themes: Autonomy, Self-efficacy, Ownership, Motivation, Resourcefulness, Interaction with environment and Application of feedback.

These assessment methods are developed to quantitatively display the success of the model. The teaching rubric should include grading students' attributes towards learner agency, whilst the student will answer questions closely related to the rubric using a similar scoring system. These scoring systems are subjective to the individual, but there should be a close correlation between the rubric and questionnaire. If the model does not show a close relationship between the teacher

rubric and student questionnaire, there is some reflection that the teacher figure can do to inspect if the model was tested correctly. These are limiting factors to the success of this framework, with the curricula content and institutional approach to learner agency being the main factors that could bound this framework [4]. Time and attentiveness are needed for testing this framework against a cohort, as much as it would be when developing students into more active and agentic learners.

5. CONCLUSIONS

This investigation was successful in its aim to construct a theoretical framework and guide to developing learner agency in chemical engineering curricula. The literature search conducted provided insights and highlighted the key themes that coincide with learner agency. From the literature review and literature matrix construction, fundamental skills and knowledge, learning environment, learner attitude and self-determination theory congruency are the themes that should be carefully manipulated within a classroom in an attempt to develop learner agency. This allowed the framework to be developed, which included the learner agency cycle and process development along with testing methods to determine the success of this model in a chemical engineering classroom. These may be bounded factors such as specific curricula content and the institutional approach to developing learner agency. Therefore, patience and further understanding may be required for the widespread development of learner agency culture in classrooms.

5.1. Limitations and Future Work

In the literature search, some of the findings could not be generalised to other settings or students, along with limited findings on the long-term impact of learner agency. The literature collated in this instance is a small sample size compared to the vast array of literature available on learner agency and its surrounding topics. As this research focuses on four main themes, it could exclude or marginalise findings that do not fall into these topics, for example: learner attitudes, application of feedback, learning difficulties or a different way to measure learning development e.g. learning analytics. In addition, the testing methods used in this instance are not statistically validated.

Above all, this guide is theoretical due to its large reliance on subjectivity, self-reported data and perceptions held within education. Further research should be completed across different cultural settings, student age and intelligence to confirm or modify the framework in this study. To answer question 3 (*Can the learner agency that is developed from this framework influence students' academic success?*), this model shall be against chemical engineering students at the University of Leeds. This will verify the findings of this investigation and allow for modifications to be made to the framework if any issues are highlighted, which will then allow students to develop academically with agency.

REFERENCES

- [1] Bandura, A., 2000. Current Directions in Psychological Science 9(3), 75–78.
- [2] Bandura, A., 2001. Annual Review of Psychology 52(1), 1–26.
- [3] Manyukhina, Y., Wyse, D., 2019. The Curriculum Journal 30(3), 223–243.
- [4] Goodman, J. F., Eren, N. S., 2013. Ethics and Education 8(2), 123–139.
- [5] Mairitsch, A., Sulis, G., Mercer, S., Bauer, D., 2023. International Journal of Educational Research 120, 102214.
- [6] Pérez, M. A., Tiemann, P., Urrejola-Contreras, G. P., 2023. Educación Médica 24(3), 100–108.
- [7] Crowhurst, P., Cornish, L., 2020. Australian Journal of Teacher Education 45(9), 24–41.

- [8] Lyngdorf, N. E. R., Du, X., Lundberg, A., 2023. *European Journal of Engineering Education* 48(6), 1130–1147.
- [9] Alenezi, A., 2023. *TEM Journal* 12(4), 2023–2037.
- [10] Jehanghir, M., Ishaq, K., Akbar, R. A., 2023. *Education and Information Technologies* 29(4), 4159–4196.
- [11] Williams, G. C., Saizow, R. B., Ryan, R. M., 1999. *Academic Medicine* 74(9), 992–995.
- [12] Jiang, D., Dahl, B., Chen, J., Du, X., 2023. *IEEE Transactions on Education* 66(6), 591–601.
- [13] Pisani, S., Haw, M. D., 2023. *Education for Chemical Engineers* 44(1), 200–215.
- [14] Groeneveld, W., Vennekens, J., Aerts, K., 2023. *Software Engineering Education Beyond the Technical: A Systematic Literature Review*.
- [15] Narong, D. K., Hallinger, P., 2024. *Sustainability* 16(2), 641.
- [16] Pacher, C., Woschank, M., Zunk, B. M., Gruber, E., 2024. *Production & Manufacturing Research* 12(1).
- [17] Evenhouse, D., Lee, Y., Berger, E., Rhoads, J. F., DeBoer, J., 2023. *International Journal of STEM Education* 10(1).
- [18] Jiang, D., Dahl, B., Du, X., 2022. *European Journal of Engineering Education* 47(6), 1103–1121.
- [19] Boyle, R. C., 2022. *Education 3–13* 50(4), 471–482.
- [20] Eidenskog, M., Leifler, O., Sefyrin, J., Johnson, E., Asplund, M., 2023. *International Journal of Sustainability in Higher Education* 24(9), 70–84.
- [21] Salikhova, N. R., Lynch, M. F., Salikhova, A.B., 2020. *Contemporary Educational Technology* 12(2), 1–13.
- [22] Tang, K.-S., McLure, F., Williams, J., Donnelly, C., 2024. *The Australian Educational Researcher* 42(2).
- [23] Fornós, S., Udeozor, C., Glassey, J., Cermak-Sassenrath, D., 2022. *The CHEM Jam – how to integrate a game creation event in curriculum-based engineering education*.
- [24] Litzinger, T., Lattuca, L. R., Hadgraft, R., Newstetter, W., 2011. *Journal of Engineering Education* 100(1), 123–150.
- [25] Mitchell, J., Tilley, E., 2024. *Journal of Problem Based Learning in Higher Education* 12(1), 1–17.
- [26] Littlewood, W., 2009. *ELT Journal* 63(3), 246–254.
- [27] Nieminen, J. H., Tuohilampi, L., 2020. *Assessment & Evaluation in Higher Education* 45(7), 1–15.
- [28] Bahou, L., 2012. *Educational Action Research* 20(2), 233–250.
- [29] Patall, E. A., Pituch, K. A., Steingut, R. R., Vasquez, A. C., Yates, N., Kennedy, A. A. U., 2019. *Journal of Applied Developmental Psychology* 62, 77–92.
- [30] Oussou, S., Kerouad, S., Hdi, S., 2024. *Studies in English Language and Education* 11(1), 116–132.
- [31] Matos, L., Reeve, J., Herrera, D., Claux, M., 2018. *The Journal of Experimental Education* 86(4), 579–596.
- [32] Ryan, R. M., Deci, E. L., 2000. *American Psychologist* 55(1), 68–78.
- [33] Moses, L., Rylak, D., Reader, T., Hertz, C., Ogden, M., 2020. *Theory Into Practice* 59(2), 213–222.
- [34] Dell, E. M., Verhoeven, Y., Christman, J. W., Garrick, R. D., 2017. *European Journal of Engineering Education* 43(3), 344–359.