Leveraging Transdisciplinary Engineering in a Changing and Connected World
P. Koomsap et al. (Eds.)

doi:10.3233/ATDE230667

Knowing Your Learners to Scaffolding Their Autonomy: The Perspective of Learner Capability and Perception

Duangthida HUSSADINTORN NA AYUTTHAYA[a], Pisut KOOMSAP[a,1], and Cathal de PAOR[b]
[a] *Industrial Systems Engineering, School of Engineering and Technology, Asian Institute of Technology, Pathumthani 12120, Thailand*
[b] *Mary Immaculate College, University of Limerick, Limerick, Ireland*

Abstract. Learner autonomy has been a primary learning outcome for all fields, including engineering since it has been positively connected with successful learning experiences. Autonomy encompasses knowledge and skills, including self-awareness and reflection, independent learning and development, creativity and inventive thinking, and decision-making, all crucial for the modern workplace. Learners with high autonomy demonstrate a higher willingness and more responsibility to finish their tasks, as well as a strong potential to sustain and enhance their competences as they progress through their professional pathways. In the engineering discipline, several strategies that provide opportunities for learners to act autonomously and develop confidence in a real-world context, such as learner-led research and project and community service learning, have been incorporated into academic journeys to foster learner autonomy. Many high-impact teaching and learning strategies and methods (for example, project-, problem-, and inquiry-based learning) have also been adopted in classrooms. However, because students have varying levels of autonomy, it is common that only some of the class can engage in and successfully complete challenging activities. Scaffolding and progressing learner autonomy are linked to developing learner capabilities and enhancing their perceived value in attaining greater autonomy. Therefore, this paper presents a four-quadrant learner autonomy analysis under the perspective of learner capability and value perception to assist instructors in determining the learners' autonomy level before developing appropriate instructional scaffolding to progress their autonomy to the expected level. A case study of engineering students is presented and discussed.

Keywords. Learner autonomy, scaffolding, learner capability, learner perception, engineering education

Introduction

According to the constructivism theory, learning is a process in which individuals construct meaning from experience and connect with prior knowledge to form or advance their new understanding [1]. Furthermore, individuals will learn at their pace and when ready to learn.

[1] Corresponding Author, Mail: pisut@ait.asia.

For successful knowledge construction, instructors must be aware that since the individual students come from diverse backgrounds, their meaning construction at the initial stages when a new topic is introduced is expected to be at different paces and form different understandings. When content-based instruction, placing students in passenger seats, is utilized, all students, regardless of their differences, are shaped unwillingly with the same mold. Some who are passionate about the topic can be self-motivated to listen. Those who have yet to perceive its value will minimize their effort in learning and may focus only on surface learning strategies for passing examinations with low thinking levels of learning, inadequate for them to solve complex problems in practice. In fact, content-based instruction benefits most to the instructors who actively transmit knowledge by repetitively strengthening their respective neural networks.

On the other hand, passive listening whether intentionally or unintentionally creates weak neural networks in the students' brains, prone to decay as time passes. The long lecture has been proven to be inadequate for an individual to have a deeper understanding, strengthen problem-solving skills, and produce creative works [2]. Furthermore, it limits the chance of shared learning, keeps students' understanding heterogeneous, and widens the student gap as the class progresses. As a result, the students are segregated to be performers and non-performers, which is not the objective of education.

According to Biggs [3], a learning gap can be narrowed when teaching and learning methods become more active. Students with a sound background and are passionate about the subject perform well in standard passive lectures and have a much deeper understanding of the subject with active learning. Those without a passion but who need to fulfill the requirements can drastically improve their knowledge of the subject from a surface to a deep understanding by changing teaching and learning methods to active learning. Therefore, the active engagement of students while learning is crucial and necessary for their knowledge construction, and group activities as social engagement stimulate experience sharing, converging their common understanding and supporting more homogeneous class learning and performance. The higher the shared experience the class achieves, the more meaningful the learning will be.

The transformation from instructor-centered content-based learning to student-centered active learning has been noticed in all disciplines, including engineering. A significant change in engineering education can be recognized from the beginning of the 21st century. Students are expected to gain a robust learning experience supporting knowledge construction and competence development [4, 5]. They must possess technical and non-technical knowledge, including transdisciplinary and transversal skills, and active learning has gained popularity [6].

Several leading universities have practically illustrated the effectiveness of technology-enhanced and modern teaching and learning methods in delivering quality engineering education. Several activities and methods, from easy-to-implement ones (e.g., group discussion, jigsaw, Think-Pair-Square-Share, interactive questions, and answers) to complex methods (e.g., X-based learning when X can be a project, problem, cooperative, challenge) have been utilized to replace long lecture hours [7]. They allow students to engage in the content and connect them to more immersive and authentic real-world contexts and collaborative working environments.

Accordingly, utilizing high-impact methods has attained greater attention and will become a norm in delivering engineering education worldwide. However, implementing these methods poses several challenges. Active learning is not magic, and there is no one-size-fits-all in active learning. It is not uncommon to see different reactions from the students to class activities, including being inactive in active learning classes. This is because varying levels of autonomy may exist, playing a vital role in determining student engagement. As a result, only in some classes can they engage in and complete challenging activities.

Scaffolding and progressing learner autonomy become essential. Therefore, this paper presents a learner autonomy analysis from the perspectives of students' capability and perception to assist instructors in determining their autonomy level before developing appropriate instructional scaffolding to progress their autonomy to the expected level.

1. Learner Autonomy

Learner autonomy is the ability to take charge of one's own learning [8]. It is self-governing with a strong interest and commitment to make decisions and take voluntary actions according to one's self-endorsed will [9]. It results from personal belief in one's ability when given an opportunity to successfully complete a given task.

Learner autonomy was initially perceived as learners having the ability to do things on their own, emerging from adult education and self-access learning systems but was later perceived as being interchangeable with independent learning, shifting the focus to doing things for themselves and indeed opting not to do anything at all if they were so inclined [10]. Autonomy was later differentiated from independence. Autonomy is not synonymous with independence [9]. While independence means to do for oneself and not rely on others, autonomy means acting freely but with a sense of volition and choice [11]. In this context, independence is a state that a student is self-directed and explicitly recognized not depending upon others in achieving a task. Autonomy is the quality accepted by others for a student to arrive at that state.

It can also be explained through the lens of principles of delegation in management activities, having three key components: duty, authority, and obligation. Delegates here are students who have a duty to perform an activity. With given authority, students are free to explore but are obligated to deliver outcomes. In this case, autonomy means utilizing authority with an obligation aligned with sovereignty and responsibility roles in student-centered learning. On the one hand, students can take control of their learning, including determining learning goals, decisions, and actions to achieve those goals. On the other hand, they are accountable for their decisions and actions, ensuring the completion of the activity and reaching the goals [9].

Autonomy encompasses skills and abilities, including self-awareness and reflection, independent learning and development, creativity and inventive thinking, and decision-making, all crucial for the modern workplace. Furthermore, autonomy reflects an emotional investment and links with the affective domain from a low level of passive listening (receiving) to the internalization of values at the high level (characterization). Learners with high autonomy feel in control and act with confidence. They demonstrate higher preparedness, feel more responsible about task completion and demonstrate a high potential to sustain and enhance their competencies as they progress through their professional pathways. On the opposite side, when one is uncertain or insecure, he/she is likely to be passive and gives way to others. A transition zone exists in between that can reflect levels of autonomy.

Autonomy is one of the three basic needs that individuals must satisfy to achieve a sense of self-fulfillment besides competence and relatedness [11]. To be autonomous is to be proactive toward personal goals in exploring and responding to a situation. Students have an internal locus of control, perform academically well, and feel autonomous even when engaged in a prescribed activity [9]. More importantly, student autonomy can be developed [12].

In the engineering discipline, several strategies that provide opportunities for students to act autonomously and develop confidence in a real-world context, such as learner-led research and project and community service learning, have been incorporated into academic journeys to foster learner autonomy.

2. Learner Autonomy Measures

In terms of characterizing autonomous learners, researchers have proposed both indirect measurements of associated characteristics, such as motivation to learn and perceived competence [13], and direct measurement. The Self-Directed Learning Readiness Scale developed by Guglielmino was the most widely used measure in the past but its use has been discouraged more recently due to validity concerns [14]. Another Self-Directed Learning Readiness Scale [15] was introduced, but it was long and for a specific group of students only.

Therefore, the Autonomous Learning Scale (ALS), a brief psychometrically sound measure of autonomous learning, was introduced [14]. The five-point Likert scale-based measure has twelve items focusing on independence of learning (e.g., I enjoy new learning experiences or I am open to new ways of doing familiar things) and study habits (my time management is good or I am happy working on my own). ALS is easy to use and suitable for large-scale studies [12]. However, ALS is a self-perceived measure relying heavily on the awareness and experience of students. Although a student's ability to self-assess reflects the progression from dependent teacher-led learning to independent student-led lifelong learning [16], it can create a discrepancy between perceived autonomy and actual autonomy. An accurate self-assessment can be developed through iterative assessment practices. Researchers reported that although students' autonomy actually increased from spending more time studying, they perceived their autonomy did not increase as they progressed through their courses; therefore, the researchers recommended that ALS be combined with other objective measures, such as learner diaries [12].

There is also the establishment of levels of student autonomy for self-assessment emphasizing independence. These are identified as follows: the explorer (level l) needs support to achieve goals; the surveyor (level 2) works on being independent to achieve goals; the navigator (level 3) can work independently to achieve goals; the pathfinder (level 4) works independently to exceed goals [17].

3. Learner Autonomy Levels According to Three Learning Domains

Figure 1 illustrates a conceptual model developed in this study. Competence is the quality of being able to apply a set of knowledge, skills, attitudes, and abilities to perform ill-defined tasks in a defined work setting successfully without supervision. For students to build their competences, they must be able to work on assigned tasks independently, which requires them to have autonomy. As aforementioned, autonomy is the quality accepted by others to attain independence. Variation in autonomy among students is highlighted by the fact that the autonomy and engagement levels tend to reflect previous

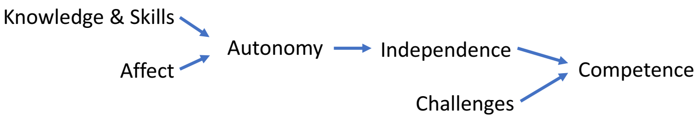

Figure 1. Conceptual model.

learning approaches [18]. Those who experienced only traditional lecture-based learning tend to have less autonomy.

Several factors from diverse backgrounds and experiences influence autonomous learning. These factors include but are not limited to age, aptitude, learning motivation, cognitive style, and personality [19]. They can be classified into social, cognitive, and emotional, which can be internal as well as external factors. The internal factors contributing to learner autonomy relate to knowledge, skills, and affect. It is obvious that students must have knowledge and skills to strengthen learner autonomy. The higher they are equipped with them, the higher autonomy they will have. The affect may be less obvious but is also essential. From simply referring to the fitness with one's need for a thing, action, situation, or experience affecting one's emotion, the meaning has been expanded to cover emotion, feeling, mood, or attitude, which conducts behavior [20]. A recent study reported the influence of affective factors on autonomous learning [19]. Therefore, the ability to control emotions is critical for attaining high autonomy.
According to the combinations of knowledge and skills and affect, four categories of learner autonomy under specific contexts can be identified, as illustrated in Figure 2, depending on the extent to which they have the capability and appreciation/attitude required to complete the activity. For any specific context, the students not capable of performing an activity and who do not appreciate or value the activity are classified as lacking autonomy. They need to be convinced and supported to participate and complete the activity. The students not capable of performing an activity but perceiving the value of doing the activity are classified as developing autonomy. They are interested in doing the activity but need help in doing it. The students capable of performing an activity but without valuing it are classified as having conditional autonomy. They can complete the activity at the current stage but may not pay attention to the detail. If they see the value, the quality of the outcome will be better. The students who can perform an activity and perceive the value of doing the activity are classified as having high autonomy. They illustrate their independence in delivering promising outcomes without supervision.

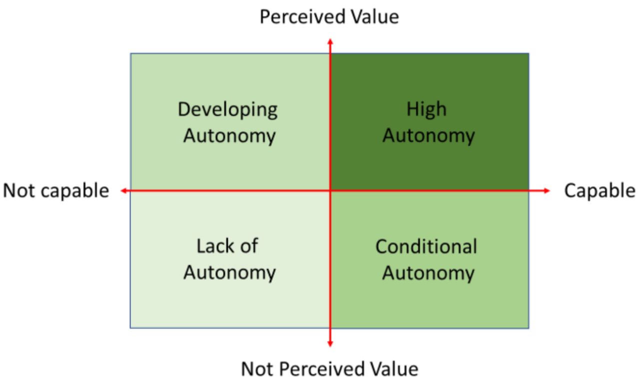

Figure 2. Learner autonomy levels according to knowledge and skills, and value perception.

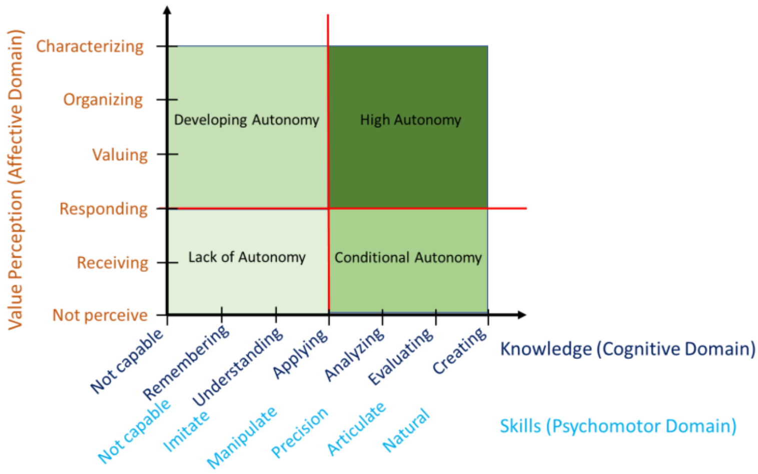

Figure 3. Learner autonomy levels according to Bloom's Taxonomy.

Since knowledge, skills, and affect directly relate to three learning domains: cognitive [21], psychomotor [22], and affective [23], Bloom's taxonomy, established for the evaluation of student learning, is applied for classification as illustrated in Figure 3.

For the cognitive domain, the first three levels, remember, understand, and apply, are considered lower-order thinking levels (LOTs). For these three levels, students can directly use the information or follow the instructions provided. Unlike the next three levels, they analyze, evaluate, and create, which are higher-order thinking levels that allow them to explore the possibility of innovation and the creation of something new out of available resources. Therefore, apply level is borderline.

For the psychomotor domain, students have low autonomy in the case of the first three skill levels: imitate, manipulate, and precision. They perform according to other people's performance or instructions. In the first level, students watch other people perform and mimic them while performing according to what they remember or they follow instructions at the manipulate level. They perform more precisely at the third level relative to the instructions. At the articulate level, where they begin to illustrate their autonomy, they not only perform their tasks precisely but are also able to combine them with other tasks. At the fifth level, they are skillful. They can perform and combine it with others naturally. Therefore, the borderline is at the precision level.

Regarding the affective domain, achieving at the first two levels (receiving and responding) involve engaging with learning that others initiate. At the receiving level, students show awareness and are willing to follow activities initiated by others while at the responding level, they interact with others. For the valuing level, they begin to invest their thoughts reflecting the values of activities they engage in. At the organizational level, students develop their unique value systems to classify the values received from engaging or experiencing activities. It is at which the level they show they are independent. They act in response to the value perceived according to their established value systems. The borderline is at the responding level.

4. Learner Autonomy Levels in a Product Design and Development Class

A pilot test was conducted with thirteen Master's students taking a Product Design and Development course (PDD) in January 2023. PDD is required for the Industrial and Manufacturing Engineering program at Asian Institute of Technology. Students from other programs also enroll as their electives. In this course, students learn and practice designing products systematically in a team environment. It is a student-centered learning course in which the students actively participate in class activities, including class discussion, case studies, team forming, common product theme selection, weekly project progress reviews, and literature reviews.

This investigation was conducted after completing three quarters of the course. The students were asked to share in writing their thoughts about their value perception of product design and development and the knowledge necessary for designing successful products. For value perception, they were asked to describe the value of product design and development, followed by how the identified values are relevant to them. The first question assessed their general perception of where they were on the first three affective levels. The second one directed them to look deeper into their values for themselves. For knowledge and skills levels, they were asked to identify factors and rate themselves upon the factors. The third question assessed their understanding. The fourth allowed them to evaluate themselves and was combined with the instructor's feedback from class observation as well as the quality and progress of their project to determine the potential for a higher knowledge level beyond understanding. Their answers were collected, recorded and analyzed. Below are examples of their answers.

- An example of answers demonstrating the achievement of the characterizing level
  "In my opinion, customer retention and satisfaction lead to (1) pre-sales of products, (2) demand & supply, and (3) updating features. The most important is "is there a demand?" (4) economic prosperity. The pre-sale concept is very related to me because when I worked on my professional roles, I got inspiration from my boss. The selling solution and then making it - leads - good strategy. The second is whether customers want your solution or not (demand) - retention. Third, gaining profit from solutions inspires me to work even harder."
- An example of answers demonstrating the achievement of the organizing level.
  "*Product specification, Creating new customers, Retaining existing customers, Creating a new experience. For us, we need to set the specification in such a way that the product retains the existing customers as well as creates new customers. We used to create the brand value in such a way that the customers will buy the product for not only the product itself but also the related experiences.*"
- An example of answers demonstrating the achievement of the valuing level.
  "*People can personally experience the whole process of a product from development to sale. By experiencing the whole process of product development, I can get the information of product quality from customers and improve the product.*"
- An example of answers demonstrating the achievement of the receiving level.
  "*The value of the product design & developments are the abilities of the product which meet customers' needs and customers' wants. The identified values are the things that you really focus on making effectively and efficiently not only for you but also for your customers.*"

- An example of answers demonstrating the achievement of the applying level after combining with the student's performance in the class and project. "*Finding an opportunity in the market; Determining whether that opportunity is worth pursuing (Blue Ocean); Identifying the target customer & product description clearly (Mission Statement); Conducting surveys to obtain customer feedback in the designing phase; Filtering & recognizing the customer needs (both directly & indirectly connected with the product); Evaluating using methods like 'Kano' to check whether pursuing the identified needs are worthy; Making detailed specifications & connections between the worthy needs (QFD).*"
- An example of answers demonstrating the achievement of the understanding level after combining with the student's performance in the class and project. "*Product design, Risk assessment, Data research, and Data analysis.*"

Table 1 presents the students' knowledge, skills, and value perception of PDD. They are listed according to their project teams forming at the beginning of the course by taking turns adding one new member into the teams round by round. The first group (G1) had four members from four countries in the same region. Some members had work experience. The second team (G2) had five members from the same country, and some had work experience. The third team (G3) had four members from three countries from different regions. Most were freshly graduated from school.

Table 1. Assessed students' knowledge and skills and value perception of PDD.

Group	Student	Knowledge & Skills	Value Perception
G1	1	Analyzing	Characterizing
	2	Analyzing	Organizing
	3	Applying	Valuing
	4	Understanding	Valuing
G2	5	Understanding	Responding
	6	Understanding	Receiving
	7	Remembering	Valuing
	8	Understanding	Responding
	9	Understanding	Valuing
G3	10	Remembering	Receiving
	11	Understanding	Valuing
	12	Understanding	Responding
	13	Remembering	Responding

As illustrated in Figure 4, overall, the majority were in the developing autonomy category meaning that most of them perceived the value of PDD and could gain an understanding of the course from the class activities and projects. Still, they needed guidance and more practice in applying it correctly. Before taking this course, most students had been taught, trained, and experienced in solving problems in specific disciplines, with limited exposure to viewing a holistic picture and systematic design. Given their unfamiliarity with the nature of the topics, they needed time to adjust themselves. Through class activities and projects, the majority have shown learning progress. Some have stood out, but some have yet to show improvement. According to the weekly progress review of the project, group one has demonstrated their understanding and has been able to apply tools learned from class properly. Some team members have also shown analytical skills and have been able to give constructive comments and suggestions to the other groups. Their prior working experience has become beneficial in driving the project. Group two has performed well in class activities when problems' sizes are small, specific, and well-defined but has encountered challenges when working on their selected product. Their good problem-solving skills have stimulated them to reach conclusions quickly while having yet to understand and formulate their real design problems. As a result, they asked for clarification to learn more when other groups updated their progress. Similar to group two, group three has been able to perform in-class activities, but they were slower when required to perform new tasks. They have demonstrated a lack of project management skills, probably because of no working experience. Among them, one member regularly participated in the discussion allowing the instructor to recognize the level of understanding of project activities of that particular member. Students benefited from constructive comments and suggestions from both their class peers and the instructor.

According to the assessment, this learner autonomy analysis tool can reveal the students' autonomy and provide the class performance, enabling the instructor to plan actions for each group to enhance their autonomy.

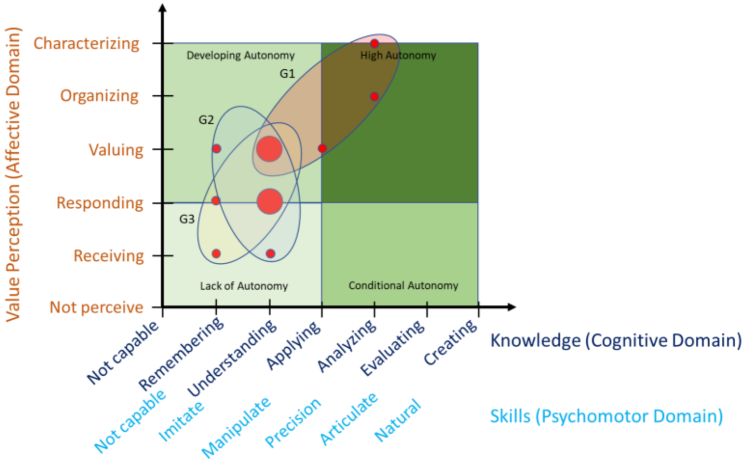

Figure 4. Learner autonomy levels in Product Design&Development Course.

5. Conclusion

Learner autonomy analysis according to three learning domains has been developed to support instructors in being aware of students' autonomy levels in class to better scaffold them as part of their competence development from class learning. Its implementation in the pilot test shows a promising result. It can assist the instructor in revealing the students' autonomy and depicting the overall picture of the course enabling the instructor to plan actions specifically for each group to enhance their autonomy.

The foreseen challenge of using this tool is the understanding of the students through their expressions and class performance from the related learning domains to correctly map them on this learner autonomy tool.

Acknowledgement

This work has been developed under 'Reinforcing Non-University Sector at the Tertiary Level in Engineering and Technology to Support Thailand Sustainable Smart Industry

(ReCap 4.0)' project that has been funded with support from the European Commission (Project Number: 619325-EPP-1-2020-1-TH-EPPKA2-CBHE-JP). This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

References

[1] O.A.B. Hassan, Learning theories and assessment methodologies – an engineering educational perspective, *European Journal of Engineering Education*, 2011, Vol. 36 No. 4, pp. 327-339.

[2] S. Sajjad, Effective teaching methods at higher education level, *Pakistan Journal of Special Education*, 2010, Vol. 11, pp. 29-43.

[3] J. Biggs, *Teaching for Quality Learning at University*, SRHE / OU Press, Buckingham, 1999.

[4] M.T. Tsai and K.W. Lee, A study of knowledge internalization: from the perspective of learning cycle theory. *Journal of Knowledge Management*, 2006, Vol. 10, No. 3, pp. 57-71.

[5] P. Koomsap, D. Hussadintorn Na Ayutthaya, T. Nitkiewicz, R.M. Lima and H.T. Luong, Course Design and Development: Focus on Student Learning Experience, *International Symposium on Project Approaches in Engineering Education, Hammamet, Tunisia*, 2019, pp. 144-153.

[6] M.D. Prieto, A.F. Sobrino, L.R. Soto, D. Romero, P.F. Biosca, and L.R. Martínez, Active learning-based laboratory towards engineering education 4.0, *2019 24th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA)*, Zaragoza, Spain, 2019, pp. 776-783.

[7] M. Hernández-de-Menéndez, A.V. Guevara, J.C.T. Martínez, D.H. Alcántara, and R. Morales-Menendez, Active learning in engineering education. a review of fundamentals, best practices and experiences, *International Journal on Interactive Design and Manufacturing*, 2019, Vol. 13 No. 3, pp. 909-922.

[8] H. Holec, *Autonomy and Foreign Language Learning*, Pergamon, Oxford, 1981.

[9] E. Lee and M.J. Hannafin, A design framework for enhancing engagement in student-centered learning: own it, learn it and share it, *Educational Technology Research and Development*, 2016, Vol. 64, pp. 707-734

[10] D. Little, Language learner autonomy: some fundamental considerations revisited, *Innovation in Language Learning and Teaching*, 2007, Vol. 1 No. 1, pp. 14-29.

[11] E.L. Deci, and R. Flaste, *Why We Do What We Do: Understanding Self-Motivation*, Penguin, New York, 1996.

[12] D.C. Henri, L.J. Morrell, G.W. Scott, Student perceptions of their autonomy at university, *Higher Education*, 2018, Vol. 75, pp. 507-516.

[13] D.M. Fazey and J.A. Fazey, The potential for autonomy in learning: perceptions of competence, motivation and locus of control in first-year undergraduate students, *Studies in Higher Education*, 2001, Vol. 26, No. 3, pp. 345-361

[14] A. Macaskill and E. Taylor, The development of a brief measure of learner autonomy in university students, *Studies in Higher Education*, 2010, Vol. 35, No. 3, pp. 351-359.

[15] M. Fisher, J. King and G. Tague, *Development of a self-directed learning readiness scale for nursing education, Nurse Education Today*, 2001, Vol. 21, No. 7, pp. 516-525.

[16] D.J. Nicol and D. Macfarlane-Dick, Formative assessment and self-regulated learning: a model and seven principles of good feedback practice, *Studies in Higher Education*, 2006, Vol. 31 No. 2, pp. 199-218.

[17] Mary Lou Fulton Teachers College, Arizona State University, *Levels of Student Autonomy*, Accessed: 31.03.2023. https://workforce.education.asu.edu/wp-content/uploads/2021/07/Levels-of-Student-Autonomy.pdf.

[18] H. Lowe and A. Cook, Mind the gap: are students prepared for higher education?, *Journal of Further and Higher Education*, Vol. 27 No. 1, 2003, pp. 53-76.

[19] W. Qian, The influence of affective factors on autonomous learning in English among non-English majors in independent university, *International Journal of Education and Humanities*, Vol. 5 NO. 3, 2022, pp. 106-116.

[20] J. Arnold, *Attention to Affect in Language Learning*, Cambridge University Press, Cambridge, 2011.

[21] D. R. Krathwohl, A revision of Bloom's taxonomy: an overview, *Theory into Practice*, 2002, Vol. 41 No. 4, pp. 212-218.

[22] R.H. Dave, Psychomotor levels, In R.J. Armstrong (ed.): *Developing and Writing Behavioural Objectives*, Educational Innovators Press, Tucson, Arizona, 1970, pp.20-21.

[23] D. Krathwohl, B. Bloom, and B. Masia. *Taxonomy of educational objectives: Handbook II: Affective domain*, David McKay Co., New York, 1964.