Data Modeling for Identification and Classification of Learning Outcomes in Flexible Educational Learning Units

Umaporn Supasitthimethee
School of Information Technology
King Mongkut's University of Technology Thonburi
Bangkok, Thailand
umaporn.sup@kmutt.ac.th

Tisanai Chatuporn
School of Information Technology
King Mongkut's University of Technology Thonburi
Bangkok, Thailand
tisanai.cha@kmutt.ac.th

Chorthip Rahong
School of Information Technology
King Mongkut's University of Technology Thonburi
Bangkok, Thailand
chortip.rah@kmutt.ac.th

Kriengkrai Porkaew
School of Information Technology
King Mongkut's University of Technology Thonburi
Bangkok, Thailand
kriengkrai.por@kmutt.ac.th

Abstract— **Due to the growth of technology and the change of population demographics, traditional and formal education is not enough to support people of all ages. Higher education institutions play a significant role in providing learning opportunities for them. The educational programs have been designed to provide flexible learning pathways that serve the diverse needs and backgrounds of the target groups. Upskilling and reskilling are alternative educational programs that are shorter than traditional degrees due to the critical need to acquire new and relevant technological skill sets. However, different institutions may use varied names or definitions for their educational learning units. Therefore, the learning outcomes of these units serve as crucial indicators of the knowledge and skills that learners acquire upon completion. Additionally, they have been identified and compared during the credit transfer process across diverse programs or institutions. Due to a descriptive and subjective learning outcome, the levels of learning like Bloom's taxonomy are needed to standardize and classify learning outcomes of an educational learning unit. In this paper, we generalize a range of educational learning programs available through educational or training institutes, including both online platforms and on-site offerings, using common terms and definitions for educational learning units. This enables us to effectively store and organize their corresponding learning outcomes. We then design a data model on both conceptual and logical levels to organize the learning outcomes associated with each learning unit. Finally, we present a web-based prototype that demonstrates how learners track their learning progress and know where they stand from broader outcomes for the entire program. The web prototype also provides recommendations for other relevant programs, allowing learners to focus on specific areas of development and make informed decisions about their learning pathway.**

Keywords—data modeling, educational learning units, learning outcomes.

I. INTRODUCTION

Technologies like Artificial Intelligence, Metaverse, or Quantum Computing are rapidly changing and increasingly faster and higher-powered than ever before. The rise of Generative AI is an example of technological development application that has opened new and more productive possibilities. Organizations that embrace technological advancements have a better position than their peers. As the speed of technologies, upskilling and reskilling have become essential for individuals to keep pace with the changing skill requirements and create opportunities for the organizations to prepare themselves with present-day skills. Higher education institutions play a significant role in providing learning opportunities for them. In Thailand, lifelong education has been proposed as a principle of organizing the whole education system of the country since 1999. Lifelong education in Thailand aims to give services by providing, promoting, and supporting educational activities that should reach all groups of people regardless of age, sex, educational background, occupations, and individual interests [1].

In response to serving learning goals, educational institutes now provide a diverse range of educational programs. These offerings include traditional formal degree programs as well as non-degree programs that break down the knowledge content into smaller learning units. The approach is to address the skills gap and promote lifelong learning by offering more flexible and targeted educational opportunities.

Traditionally, educational programs focus on what knowledge topics the instructor delivers rather than what topics learners will learn and how they learn them. To transform to learner-centered education, the prior knowledge and skills needs of learners are important inputs to design units of learning for them. By understanding their needs, instructors can target the learning contents that require attention, and consequently engagement in learning is increased. Increased engagement leads to greater learner outcomes which is a quality indicator for educational programs [2]. Learning outcomes are measurable statements of what learners should know, be able to do, or value at the completion of study. They help ensure that learning objectives are clearly defined and can be effectively measured and evaluated. Learning outcomes can be designed at program-level (higher level) and divided, more specifically, into smaller sub-learning units (lower level), such as modules or courses.

II. Related Works

Educators in the 21 century realize that students are much different from the previous generation because of the rapid change of technology AND resources available today. Flexible learning provides learners with choices about where, when, and how learning occurs. It allows learners to plan their activities according to their interest and enthusiasm. The research study [3] concluded that flexible learning helps to promote quality education. [4] studied two adult groups of software engineers who have a certain degree of industry experience on software architecture course design. They found that the lack of sufficient work experience might have limited their understanding and led to comments on the course duration. Micro-credentials are shorter and more flexible learning than traditional degrees. They have a major impact as an alternative to traditional education for lifelong learning and reskilling and upskilling of workers. Multiple policy makers from many countries are trying to regulate the growing micro-credentials market, including their definition, scope, characteristics, etc. [5].

Launching Artificial Intelligence (AI) applications like ChatGPT or Bard create opportunities and challenges for the education sector and may drive changes to educational teaching and learning practices. The rise of AI has numerous benefits in teaching and learning, research, and academic service. However, learners might use AI applications to complete their assignments and exams. These raise ethical concerns and cheating issues. Instructors have a responsibility to explain to learners how to use AI technology wisely and properly and verify their knowledge and abilities [6, 7].

Learning outcome statements guide instructors to design learning topics, learning activities, and assessment of learning units. Additionally, learning outcomes have played a significant role in several educational reform initiatives around the world and built trust among institutions in terms of transferability and portability of qualifications [8]. Bloom's Taxonomy [9] provides the measurable action verbs to write specific learning outcomes in three types of learning domains, including cognitive, affective, and psychomotor. The cognitive domain has a hierarchy of six levels (Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating). Learning outcomes statements at each learning unit are accumulated to contribute to or complement other learning outcomes. Learning outcomes are significant evidence in comparing credit transfer that creates education opportunities and facilitates learners' mobility. Instead of comparing course names or course descriptions, learning outcomes can help to compare the output of learning that a learner knows and his/her abilities. The credit transfer committee can track the effectiveness of study by testing how learners met the learning outcomes [8, 10]. [11] proposed the model for identifying and classifying competencies and learning outcomes (MICRA) based on the official documents of the course units that include outlines content and assessment. This model is used for interoperability of learning outcomes in different educational institutions.

In this paper, we present our generalized terms and definitions of educational learning unit, as presented in Section 3. We then propose a data model on both conceptual and logical design to effectively store and organize the learning outcomes associated with each learning unit as explained in Section 4. The web-based prototype implementation based on our data model design and result discussion are presented in Section 5. Finally, the conclusion is presented in Section 6.

III. Our Educational Learning Units Terms and Definitions

Our educational learning unit means a unit of study, provided by an education or training institution, that has at least one valuable learning outcome for academic or employment purposes. Educational learning units might be a topic, a course, a module, or a program. They might offer educational certificates or credits which even turn them into university degrees. We define our terms and definitions as follows:

1) Learning Topic – an instructor explores and selects study topics from the knowledge topics of domain knowledge.

2) Learning Course – a traditional and formal degree-course is an example of learning courses.

3) Learning Module – is a selection of topics or courses that break down the content of degree-course program into smaller units. This type of learning unit is specially designed for non-degree programs, aiming to bridge skills gap and support lifelong learning. Platforms like Coursera or edx offer courses that follow this concept. Additionally, certain degree programs at King Mongkut's University of Technology Thonburi (KMUTT) that have transitioned to an outcome-based module structure are also stored as learning modules.

4) Learning Program – contains a collection of learning modules, courses, topics, or a combination thereof. It can be a degree or non-degree program.

5) Learning Provider – refers to educational or training institutes as well as online platforms, such as edx or Coursera.

(6) and (7) are the source of knowledge for the above learning units.

6) Domain Knowledge – contains a collection of sub domains. For example, in ACM/IEEE IT2017 [12], there are ten essential IT domains such as *Web and Mobile Systems (ITE-WMS)*, *Software Fundamentals (ITE-SWF)*, *System Paradigms (ITE-SPA)*, etc. *Applications concepts and Development Frameworks* are sub-domain examples of *ITE-WMS* domain. Each sub-domain has scope of knowledge topics. For example, *Web-based applications and Web Technologies* are knowledge topics of *Applications concepts and Development Frameworks* sub-domain.

7) Domain Cluster – is a collection of relevant domain knowledge defined by the learning society or professional association, such as Association for Computing Machinery (ACM) and IEEE Computer Society. For example, ACM/IEEE IT2017, ACM Data Science 2021, and ACM/AIS IS2020 [13].

IV. Data Modeling for Connecting Learning Outcomes of Flexible Educational Learning Units

We extend our skill-based education framework [14] to introduce the concepts of learning outcomes, their learning outcomes, and learning level classification as shown in Fig. 1. Within this framework, the career context consists of job skills, jobs, career pathways, and industry sectors concepts. On the other hand, the education context consists of educational learning units and their corresponding learning outcomes that link to relevant career skills. The learning content in educational learning units are derived from specific domain knowledge which belongs to domain clusters.

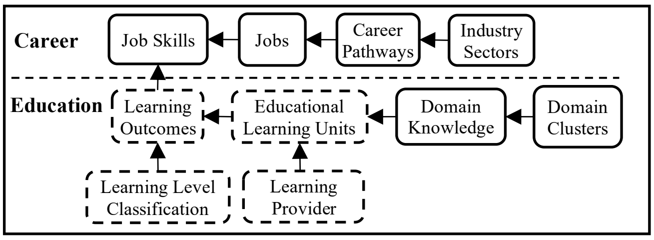


Fig. 1. Extending of the skill-based education framework

Our data model has been constructed through an extensive study of various learning programs, particularly developed at KMUTT, which have successfully undergone transformation towards outcome-based education, as well as well-known online platforms like edx, Coursera, Udemy, and FutureLearn. Educational learning programs consist of diverse sub-learning units, including learning courses, modules, topics, or a combination thereof as defined in Section 3. The learning outcomes associated with these units describe the measurable abilities and knowledge that learners are expected to acquire by the end of their studies. Due to the descriptive and subjective nature of learning outcomes within each educational learning unit, we extract action verbs from them. To ensure standardization and classification, we rely on the action verbs in Bloom's learning level classification [15]. These learning outcomes can be aggregated into higher level learning domains that encompass skills, ranging from lower to higher orders. Consequently, the learning outcome mapping not only stores the relationships between learning outcomes associated with each learning unit but also maps onto the larger higher unit level outcomes as shown in Fig. 2.

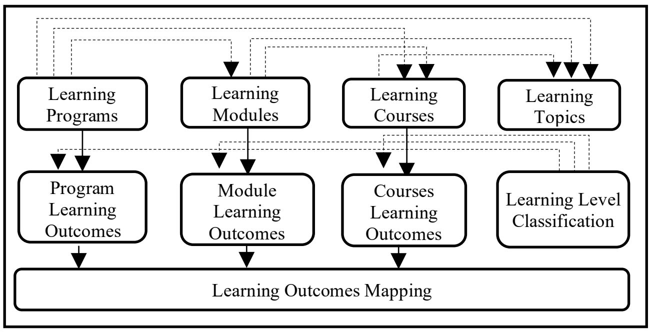


Fig. 2. Conceptual design for connecting learning outcomes of flexible learning units

The logical design is derived from the conceptual design and divides into three parts as shown in Fig 3.

Part 1: Educational Learning Units - This part contains the hierarchical structure of sub-learning units within the learning program. The (1.1) "learningprovider" table stores information about the learning providers. The (1.2) "learningprogram", (1.3) "learningmodule", (1.4) "learningcourse", and (1.5) "learningtopic" tables serve as the base tables of each learning unit. The (1.6) "lpxlm", (1.7) "lpxlc", (1.8) "lpxlt", (1.9) "lmxlc", (1.10) "lmxlt", and (1.11) "lcxlt" tables serve as flexible relationship between sub-learning units. For example, the "lpxlm" table defines the relationship between learning programs and learning modules.

Part 2: Learning Outcomes Mapping – The (2.1) "programlearningoutcome", (2.2) "modulelearningoutcome", and (2.3) "courseslearningoutcome" tables store the learning outcomes linked to each level of learning unit. This part focuses on storing the learning outcomes associated with each learning unit. Additionally, since learning outcomes can be written at different levels, such as course, module, or program, the (2.4) "learningoutcomesmapping" table is used to capture the relationships of each learning outcome that contribute to broader outcomes including across different learning programs. For example, the module learning outcomes "MLO_032", "MLO_033", "MLO_034", "MLO_037", "MLO_041", "MLO_042", "MLO_043", and "MLO_044" contribute to the program learning outcome "PLO_104" as shown in Fig. 4.

Part 3: Learning Level Classification – This part focuses on storing information related to learning level classification. The (3.1) "learninglevelclassificationstandard" table stores information about the classification standards like Bloom's Taxonomy. These standards define the learning domains, such as cognitive, affective, or psychomotor domains which are stored in (3.2) "learningdomain" table. The (3.3) "learninglevelclassification" and (3.4) "llcxllav" tables store the learning levels, ranging from the simplest to the most complex, such as remember, understand, apply, and so on relating to (3.5) "learninglevelactionverb" table that stores the action verbs associated with each learning level. Furthermore, there are additional tables, (3.6) "ploxllc", (3.7) "mloxllc", and (3.8) "cloxllc", that store the links between the learning level classification and learning outcomes of the respective learning units.

V. Implementation and Result Discussion

We developed a web-based prototype using PHP and MySQL. We gathered a collection of educational learning programs, including both online and onsite offerings. To represent the level of learning, we selected Bloom's taxonomies as our sample data. The statistical experiment data from our efforts is presented in Table I.

To evaluate the effectiveness of our model in retrieving relevant learning outcomes, we calculated precision and recall of our test queries as shown in Table II.

$$\textit{Precision} = \frac{\textit{The number of correct learning outcomes returned}}{\textit{The number of learning outcomes returned}} \quad (1)$$

$$\textit{Recall} = \frac{\textit{The number of correct learning outcomes returned}}{\textit{The total number of correct learning outcomes}} \quad (2)$$

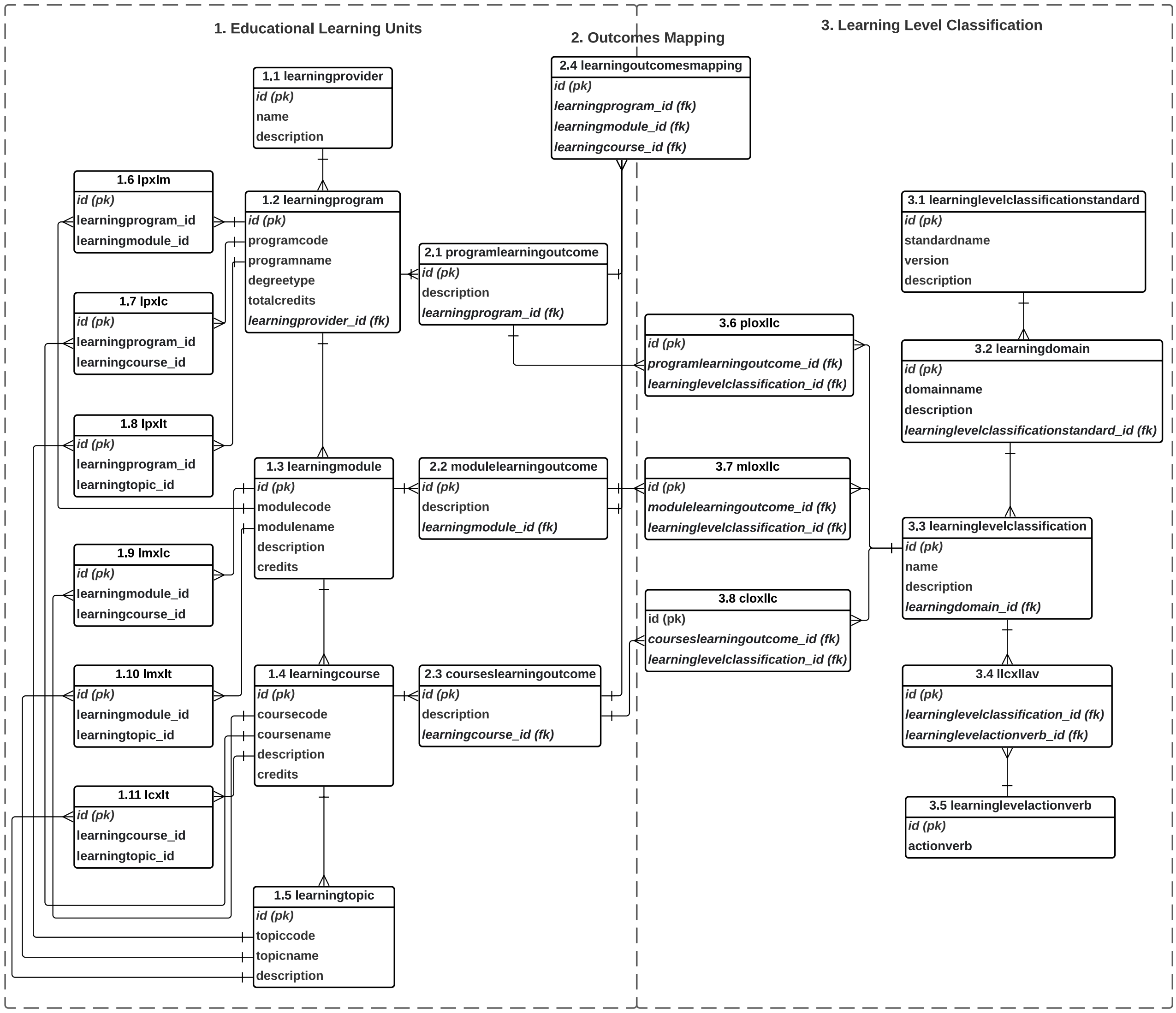


Fig. 3. Logical design for connecting learning outcomes of flexible learning units

TABLE I. TABLE RECORDS STATISTIC

Tables	Records
Educational Learning Units	
learningprovider	3
learningprogram	10
learningmodule	42
learningcourse	17
learningtopic	255
lpxlm	43
lpxlc	12
lpxlt	7
lmxlc	5
lmxlt	165
lcxlt	53
Learning Level Classification	
learninglevelclassificationstandard	1
learningdomain	3
learninglevelclassification	18
llcxllav	142
learninglevelactionverb	122
ploxllc	122
mloxllc	147
cloxllc	193
Learning Outcomes Mapping	
programlearningoutcome	122
modulelearningoutcome	147
courseslearningoutcome	193
learningoutcomesmapping	1,538

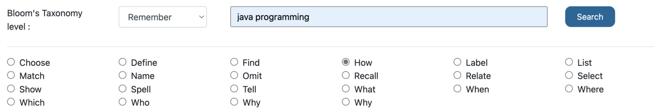
In precision and recall measurement, our correct learning outcomes are defined as the educational learning units that contain all or some of the matched keywords of learning outcomes within the specified learning level.

Our web prototype provides a keyword search feature to allow searchers to find educational learning units that match given learning outcomes. The user interface for the searching consists of two parts: 1) Predefined Bloom action verbs, which the searchers can specify the desired level of learning. 2) Content keywords, which enable the searchers to define the learning context as shown in Fig. 4 (a). The search results are categorized based on the learning programs that contain matching learning outcomes within themselves or their sub-learning units. The input keyword that corresponds to the learning outcomes will be highlighted as shown in Fig. 4 (b). Furthermore, the searchers can explore smaller sub-learning units that contain matching learning outcomes.

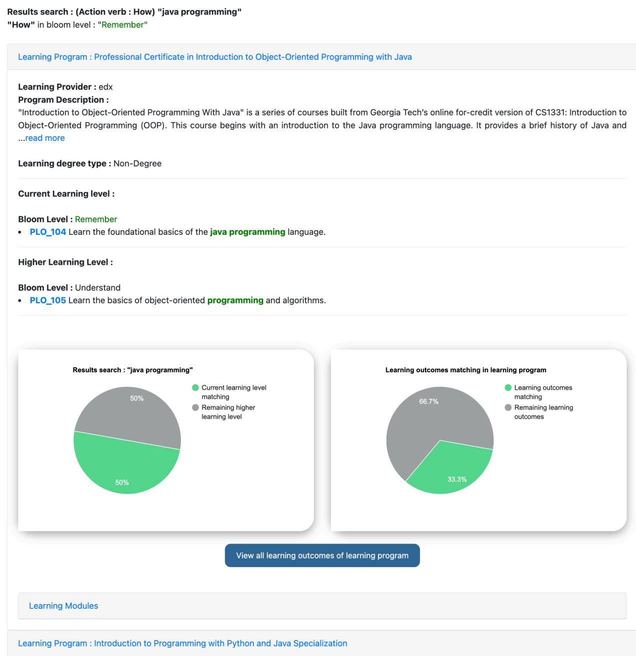
TABLE II. PRECISION AND RECALL OF TEST QUERIES

Keywords	Bloom Learning Levels	Precision (%)	Recall (%)
database	Remember	100	100
database	Understand	100	100
database	Apply	100	100
database	Analyze	100	100
database	Evaluate	100	100
database	Create	100	100
data engineering	Remember	100	100
data engineering	Understand	100	100
data engineering	Apply	100	100
data engineering	Analyze	100	100
data engineering	Evaluate	100	100
data engineering	Create	100	100
java Programming	Remember	100	100
java Programming	Understand	100	100
java Programming	Apply	100	100
java Programming	Analyze	100	100
java Programming	Evaluate	100	100
java Programming	Create	100	100
python web programming	Remember	100	100
python web programming	Understand	100	100
python web programming	Apply	100	100
python web programming	Analyze	100	100
python web programming	Evaluate	100	100
python web programming	Create	100	100
machine learning and artificial intelligence with python	Remember	100	100
machine learning and artificial intelligence with python	Understand	100	100
machine learning and artificial intelligence with python	Apply	100	100
machine learning and artificial intelligence with python	Analyze	100	100
machine learning and artificial intelligence with python	Evaluate	100	100
machine learning and artificial intelligence with python	Create	100	100

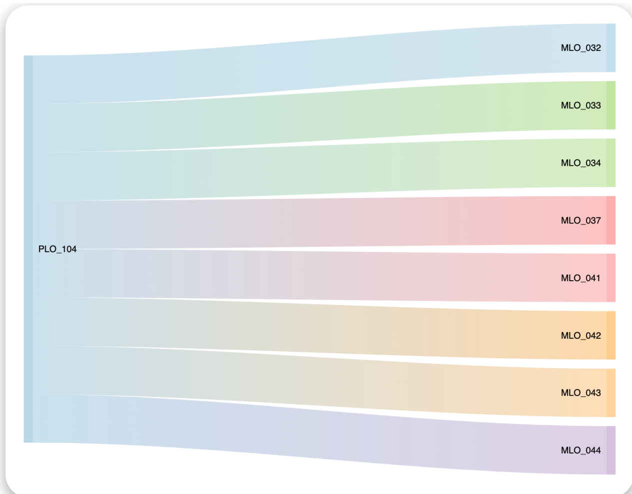
Fig. 4 (b) shows an example of search results. As an example, we conducted a search using the action verb "How" within the "Remember" classification learning level and input two keywords "java programming". The search results return two relevant learning program answers: 1) Professional Certificate in Introduction to Object-Oriented Programming with Java and 2) Introduction to Programming with Python and Java Specialization. Each learning program displays all sub-learning units that match the learning outcome at the specified level. Additionally, summarized graphs are provided to enable searchers to track their learning progress and gain an understanding of their position in terms of broader outcomes. The left graph represents the proportion of matched learning level compared to higher learning levels within the program. This helps searchers know their proficiency in different levels of learning. The right graph displays the ratio of matched learning outcomes in relation to the overall program-level learning outcomes. This enables the searchers to track their progress towards completing a degree or certificate. Furthermore, Fig. 4 (c) displays a Sankey diagram visually representing the flow of sub-learning units that contribute to the selection of specific learning outcomes. This diagram serves as a valuable tool for both educators and learners, as it facilitates a clear understanding of the alignment between program-level learning outcomes and the corresponding lower-level learning units, such as courses or modules.



(a) User interface for learning outcome search



(b) Example learning program of search results



(c) The relationships of module learning outcome that contribute to broader outcomes

Fig. 4. Learning outcome search results

VI. CONCLUSIONS

Understanding job skills and having a long-term plan of career development give learners the chance to focus on what they need to learn. The design of educational learning units according to individual learning needs tailors learning content and experience to the unique needs, abilities, and interests of each learner. Learning taxonomies help learners to know how each skill and knowledge build upon previous foundations. The higher levels of learning cannot be achieved without an ability in the lower levels. In this paper, we proposed our data modeling for identification and classification of learning outcomes in flexible educational learning units. We developed a web-based prototype based on our data model to demonstrate how learners track their learning progress and know where they stand from broader outcomes for the entire program. Additionally, this web prototype offers recommendations for other relevant programs, allowing learners to concentrate on specific areas of development and make informed choices regarding their learning pathway.

REFERENCES

[1] Sungsri, S., Proposed Strategy for Promotion Lifelong Learning in Thailand, 47th Southeast Asian Ministers of Education Organization Council Conference, Hanoi, Vietnam, 2013.

[2] Tarricone, P., Teo, I., Mestan, K., Sundarsagar, K., Killimangalam, A., and Razak, N A., Flexible Strategies for Ensuring Quality Learning Outcomes in Education in Emergencies, UNESCO, 2021.

[3] Joan, D.R.R, Flexible Learning as New Learning Design in Classroom Process to Promote Quality Education, i-manager's Journal of School Educational Technology, Vol.9 No. 1, June-August 2013.

[4] Ouh, E.L., Gan, B.K.S., and Irawan, Y., Did our Course Design on Software Architecture meet our Student's Learning Expectations? 2020 IEEE Frontiers in Education Conference (FIE), October 2020.

[5] Hoyos, C.A. and Kloos, C.D., Experiences with Micro-Credentials at UC3M: Academic and Technological Aspects, IEEE World Engineering Education Conference (EDUNINE), 2023.

[6] UNESCO IESALC, ChatGPT and Artificial Intelligence in Higher Education, Available at: https://world-education-blog.org/2023/04/25/chatgpt-artificial-intelligence-and-higher-education/ 25 April 2023 (updated on: 17 May 2023).

[7] Ahai, X., ChatGPT User Experience: Implication for Education, 2022, Available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4312418.

[8] Fallon N., Learning Outcomes in Credit Transfer: A Key Tool for Innovation in Student Mobility, Ontario Council on Articulation and Transfer (ONCAT), 2015.

[9] Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, E. J., and Krathwohl, D. R., Taxonomy of educational objectives: The classification of educational goals. New York, Longmans, Green, 1956.

[10] FitzGibbon, J., Learning Outcomes and Credit Transfer Example, Issues, and Possibilities, A BCCAT Special Report, 2014.

[11] Goncalves, M.J.A., Rocha, A., and Cota, M.P., Information Management Model for Competencies and Learning Outcomes in an Educational Context, Springer Science Business Media New York, 2016.

[12] Task Group on Information Technology Curricula, Association for Computing Machinery, Information Technology Curricula 2017: Curriculum Guidelines for Baccalaureate Degree Programs in Information Technology, New York, NY, United States, 2017.

[13] ACM Education, Curricula Recommendations, https://www.acm.org/education/curricula-recommendations.

[14] Supasitthimethee, U., Chatuporn, T, Rahong, C, and Porkaew, K., Skill-based Education Framework and Development, National and International Academic Conference Project: 15th Anniversary of the Raapruk University on "New Normal for Sustainability in the Digital Era", 2021.

[15] Anderson, L. W., and Krathwohl, D. R.. A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon, 2001.