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Effectiveness of Synchronous and Asynchronous Online Learning in Bloom's Taxonomy Framework

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Abstract: Synchronous and asynchronous Learning is usually highly-structured, with course activities, assessments, and technology requirements explicitly written and scheduled. It allows great flexibility and accessibility for learners with strict alignment to the learning outcomes and module learning objectives. However, it is not clear that such synchronous or asynchronous learning is effective in different level of courses which may require different level of cognitive process, knowledge dimensions and combination of both. In this paper, we re-aligned meta-analysis data by Zeng et al. 2023 in cognitive process and knowledge dimensions under revised Bloom's Taxonomy framework. We proposed a metric to compute cognitive complexity level on the re-aligned data. Our proposed metric was able to show that synchronous classes are more suitable for basic cognitive domain learning of factual knowledge and conceptual knowledge, while asynchronous classes are more suited for higher cognitive domain learning of procedural knowledge and metacognitive knowledge. Likewise, our further grouping in educational level were also able to show that asynchronous classes are more effective for learning at higher education levels when the subjects of learning are usually in higher knowledge dimensions. Both observations are congruent in expected trend of cognitive complexity.

Keywords: synchronous learning, asynchronous learning, Bloom's taxonomy

1. Introduction

With the rapid development of the internet and its technologies, online learning has become increasingly popular due to the convenience it offers. Students can stay in the comfort of their homes to learn and gain access to a wider variety of materials. Online learning can be typically divided into two categories – asynchronous and synchronous learning. Synchronous learning is the learning environment where the teacher and student are online and interact at the same time – this typically describes video conferences or webinars. On the other hand, asynchronous learning allows learners to learn at their own time and pace, interact with each other over temporally delayed time periods – through learning management systems (LMS) such as Coursera, consisting of forums and pre-recorded lectures.

The evaluation of online students' learning can be categorized into (1) Learner's perception, (2) Learner's Process and (3) Learner's Product (Hew et al., 2004). Learner's perception can generally be obtained through the learner post-survey on if the course was useful and easy to follow. Learner's process, on the other hand, is more complex, as one attempts to track various types of learning such as cognitive processes, meta-cognitive processes, social construction of knowledge, collaboration processes and problem-solving processes among the learners (Hew et al., 2004). Lastly, the Learner's product measures whether the learner has met the learning outcome through an assessment tool. Many studies have investigated the effectiveness of synchronous and asynchronous learning – evaluating whether one is better than the other using the Learner's product. (Zeng & Luo, 2023) performed a meta-analysis on these studies – they gathered and filtered studies that compared synchronous and asynchronous online learning with an assessment tool. They concluded that an asynchronous learning environment was shown to be more effective in achieving better learning outcome or as least as good as synchronous learning. However, some studies also indicate that synchronous learning may be preferred in learner perception (Fabriz et al., 2019; Amer, 2018).

When designing courses and lessons, teachers typically utilize the Bloom's taxonomy framework (Bloom, 1956; Anderson and Krathwohl, 2001) to write the learning outcomes that the lesson aims to achieve. Bloom's taxonomy framework consists of different levels of cognitive processes - *remember, understand, apply, analyze, evaluate, create (from low to high level of cognition)*. The success of the lesson is typically measured when the proposed learning outcomes are met. Therefore, we seek to explore if the mode of online learning (synchronous or asynchronous) is dependent on the levels of cognition that the lesson aims to achieve. This could help teachers design their online courses better. In this preliminary study, we propose to further expand the meta-analysis conducted in (Zeng & Luo, 2023), using revised Bloom's taxonomy (Anderson and Krathwohl, 2001) for cognitive profiling.

2. Background

2.1 Synchronous and Asynchronous Online Learning

Online learning environments can be classified based on synchronicity into two types: synchronous and asynchronous environment (Ebner & Gegenfurtner, 2019). In the synchronous online learning environment, the teacher and students gather on an online platform at the same time, in which instruction and possibly "real-time" interaction takes place. On the other hand, in an asynchronous environment, learning materials are prepared by the teacher and made accessible to students, who can then peruse the contents and learn at their own time and pace. Both synchronous and asynchronous environments offer advantages and drawbacks. Synchronous learning allows for immediate clarification of doubts and brainstorming since everyone is simultaneously present, but the learning pace is invariable among all participants, possibly leading to some students finding the pace too fast or slow. Whereas asynchronous learning offers teachers and students the freedom to work at their own pace and preferred time, but without the ability to interact in real-time with others.

Past studies have reached different conclusions as to whether synchronous or asynchronous is more effective at promoting learning. Kubey et al. (2001) showed that learners in an asynchronous environment performed better academically than those in a synchronous one. Perera and Richardson (2010) suggested that asynchronous approaches are more effective due to the larger amount of learning materials offered. Conversely, Somenarain et al. (2010) showed that synchronous online learning is better at improving students' conceptual understanding in a biology course. Other studies concluded that synchronous and asynchronous approach produce the same outcome in terms of students' conceptual understanding and academic performance (Duncan et al., 2012; Lim et al., 2022).

2.2 Bloom's Taxonomy

Original work on Bloom's Taxonomy (Bloom, 1956) is basically a hierarchical paradigm that divides into cognitive process namely, Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating, in descending order of complexity for curriculum development and assessment to give teachers the tools they need to scaffold learning experiences and monitor their students' development throughout different cognitive skills. After revision in 2001, the revised Bloom's taxonomy (Anderson and Krathwohl, 2001) included four cognitive dimensions: factual knowledge, conceptual knowledge, procedural knowledge, and metacognitive knowledge in parallel with cognitive processes that students acquire and develop towards mastery of a subject.

Bloom's Taxonomy has been an excellent guide in planning for student learning and learning outcomes. In a recent work by Zeng and Luo (2023), they investigated the effectiveness of synchronous compared to asynchronous online learning by conducting a meta-analysis of previous studies published between 2002 and 2022 across multi-disciplines based on the effect sizes computed in synchronous and asynchronous online learning environments. Their result shows that asynchronous learning is slightly more effective than synchronous learning in promoting students' knowledge. However, the overall effect size does not show a clear trend of change across disciplines and education levels. In this paper, we attempt to re-examine the study under the Bloom's Taxonomy with our proposed metric to highlight the effectiveness of asynchronous and synchronous classes in delivering context of different cognitive complexity.

3. Methodology

We re-aligned the asynchronous vs synchronous learning data in Zeng and Luo (2023) in cognitive process dimension and knowledge dimension in a model created by Rex Heer in 2012 (Heer, 2012). We also attempt to group the effect size with our proposed metric for cognitive knowledge (which will be elaborated in subsequent section) to see the effectiveness of asynchronous/synchronous learning in acquiring knowledge at different complex levels and establish the appropriate learning setup for different educational levels.

3.1 Proposed Metric for Cognitive Complexity Level

	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	List (1)	Summarize (2)	Respond (3)	Select (4)	Check (5)	Generate (6)
Conceptual	Recognize (2)	Classify (3)	Provide (4)	Differentiate (5)	Determine (6)	Assemble (7)
Procedural	Recall (3)	Clarify (4)	Carry out (5)	Integrate (6)	Judge (7)	Design (8)
Metacognitive	Identify (4)	Predict (5)	Use (6)	Deconstruct (7)	Reflect (8)	Create (9)

Figure 1. The cognitive complexity level metric based on revised Bloom's Taxonomy

The cognitive complexity level metric was designed with the revised Bloom's Taxonomy is shown in Figure 1. The lowest cognitive level of 1 is given to the cognitive process of listing and the highest cognitive level of 9 is allocated to the cognitive process of creating.

For each study, we considered the following factors when assigning the cognitive complexity level.

- The educational level of the participant
- The disciplinary field of the participant
- The assessment tool used for determination of achievement

The cognitive complexity level for each course is the sum of cognitive processes present. This provides an indicative score of the cognitive complexity for the given course. There was a total of three raters for the identification of cognitive complexity level, the average score between the three raters were taken.

3.2 Results

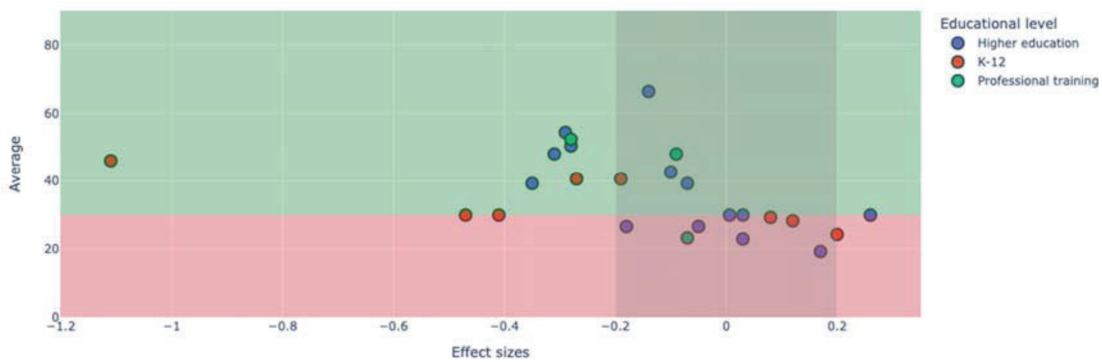

Figure 2. Effect size vs Averaged cognitive complexity score.

The relationship between the effect size and averaged cognitive complexity score is illustrated in Figure 2. The pink region represents the area of lower cognitive complexity score of 30 and below while the green region represents the area of higher cognitive complexity score of 30 and above. The legend reflects the educational level of the different studies. From Figure 2, the K-12 studies generally have courses that falls below cognitive complexity of 30 while the higher education and professional training studies have varied levels of cognitive complexity in the courses. The grey vertical portion of the plot reflects the region of uncertainty where the effect sizes fall below +/-0.2. Many studies fall in that region, indicating that there may not be conclusive evidence that synchronous or asynchronous learning is better. However, there is a trend suggesting studies with higher cognitive complexity score are better delivered in asynchronous classes.

4. Discussion

A good and well-thought-out course design is essential. Synchronous and asynchronous courses are usually highly-structured. The course activities, assessments, and technology requirements should all be explicitly written and scheduled, while also allowing for accessibility for learners with disabilities. They should also be aligned with the learning outcomes and module learning objectives.

Our proposed metric for cognitive complexity level on the studied data that was re-aligned in cognitive process and knowledge dimensions exhibits a trend that suggests synchronous classes are more appropriate for delivering content which requires mostly basic cognitive processing on factual knowledge and conceptual knowledge; while asynchronous classes could be better suited for procedural knowledge and metacognitive knowledge, which require higher cognitive process in learner. Likewise, our further grouping in educational level were also able to show that asynchronous classes are more effective for learning at higher education levels when the subject of learning are usually in higher knowledge dimensions. Both observations are congruent in the expected trend of cognitive complexity.

The effect sizes from (Zeng & Luo, 2023) were calculated based on the outcome of assessments. However, many of the assessment tools that were shared are multiple choice quizzes that seem to be standardized assessments in traditional learning environment. Studies showed that math and reading can be improved using digital formative assessments (See, et al, 2021). Likewise, Ohio state synchronous vs asynchronous class data in K–12 schools delivering online education, showed that these students performed worse in standardized assessments than those in traditional charter and traditional public schools (Ahn and McEachin, 2017). In a review of 52 asynchronous class vs synchronous class, Yan et al (2020) found that personal and contextual factors more than just teacher ability and motivation in conducting formative assessment. A tightly integrated support system is a crucial factor. (See, et al, 2021). Bloom's Taxonomy is basically a core concept for categorizing cognitive skills that emphasize the necessity of developing learners' critical thinking and higher-order cognitive skills and are deemed to expanded upon inclusion of digital technology. Educators can use the taxonomy to develop engaging and relevant learning experiences that match the demands of the digital age by recognizing their commonalities, distinctions, and relative contributions. Digitalizing Bloom's Taxonomy utilizes technology for better learning outcomes by lining up the cognitive levels of Bloom's Taxonomy with digital actions and skills.

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