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Effect of Blended Learning on Outcomes of Students Attending a Fundamental Chemistry Course in Higher Education

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Abstract

The blended learning model, when applied to large enrollment introductory chemistry courses, has proven to be a successful method for integrating active learning. By leveraging technology and problem-based learning strategies, the approach not only improves student engagement and understanding but also enhances academic outcomes. The positive feedback from students and the improvement in GPA underscore the model's potential as a viable alternative to traditional lecture-based teaching, making it a valuable tool for large-scale STEM education. Active learning approaches result in improved student learning outcomes compared to traditional passive lecturing. There is a growing need to change the way instructors teach large introductory science courses. Blended classroom modules for large enrollment fundamental chemistry course sequence have been created. Herein is described how student response systems and problem-based case studies have been used to increase student engagement, and how blended classroom modules have integrated these case studies as collaborative group problem-solving activities in 70-100-seat lecture halls. Preliminary evaluation efforts found that the blended classroom modules provided convenient access to learning materials that increased the use of active learning in lecture and resulted in a significant improvement in the course grade point average (GPA) compared to a non-flipped class. These results suggest this approach to implementing a blended class-

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room can act as a model for integrating active learning into large enrollment introductory chemistry courses that yield successful outcomes. The blended classroom is a pedagogical approach that moves course content from the classroom to homework, and uses class time for engaging activities and instructor-guided problem solving. The course content in a first-year level fundamental chemistry course was assigned as homework using MS Teams platforms. In class, students' misconceptions were addressed, the concepts from the video lectures were applied to problems, and students were challenged to think beyond given examples. Students showed increased comprehension of the material and appeared to improve their performance on summative assessments (exams).

Keywords: blended learning model, problem-based learning strategies, active learning approaches

Blended learning, also known as hybrid education, is increasingly acknowledged as a transformative model in higher education, especially within STEM disciplines. It integrates digital resources and virtual engagement with traditional in-person classroom methods to offer a flexible, student-centered learning experience. This instructional approach combines online materials—such as interactive media, games, videos, tutorials, quizzes, and social platforms—with face-to-face sessions. These components, delivered through Learning Management Systems (LMS) and accessible via laptops or tablets, empower students to learn at their own pace, anytime and anywhere (Graham, 2006; Hrastinski, 2019).

Blended learning is not just a response to digital trends but a pedagogical shift that addresses the flexibility and personalization needs of modern learners. It enables students to determine what, when, and how they learn, aligning well with outcome-based education and self-regulated learning models (Hofmann, 2014; Panadero, 2017; Smith & Hill, 2019). The flipped classroom, a widely adopted form of blended learning, moves foundational content—such as short, segmented videos—outside the classroom, reserving face-to-face time for interactive discussions, problem-solving, and immediate feedback (Bergmann & Sams, 2012; Abeysekera & Dawson, 2015). This model enhances conceptual understanding and supports critical thinking.

From a cognitive perspective, breaking down complex content into shorter, structured modules reduces cognitive overload, as supported by Cognitive Load Theory (Sweller, 1988). Additionally, the Community of Inquiry (CoI) framework emphasizes cognitive, teaching, and social presence, all of which are amplified in blended formats through deliberate instructional design (Garrison et al., 2000).

This study contributes to the literature by analyzing the effectiveness of a blended learning approach in a large enrollment, first-year chemistry course at King Mongkut's University of Technology Thonburi (Ratchaburi). Through a structured LMS-supported model—combining asynchronous video lectures, student response systems, and collaborative problem-based learning—this study evaluates its impact on academic performance compared to traditional lecture-based instruction, offering empirical insight for improving STEM education in large-class environments.

Methodology

This research is a preliminary study of the development of a blended learning module for the chemistry course Module: Atoms to Molecules (Table 1) using an LMS for self-directed active learning combined with traditional lectures for first-year students. Literature review and data collection were used as the preliminary study. The steps undertaken included preliminary stages such as literature review and data collection; the development phase began with the design of the instructional process, followed by design validation, design revisions, and practical trials, focusing on the learning outcomes of the students.

Problem-based learning is conducted by having students work on problems and discuss them together in small groups. The Microsoft Teams (MS) platform is used for assigning tasks, submitting assignments, and for instructors to review and provide feedback on assignments. The feedback is then returned to students to check if they have solved the problems correctly. This approach facilitates learning through problem-based learning.

Research instrument and data collecting method included assignments, final tests and student response questionnaires. Assignment and examination completed by a single student so the score was an individual score. The final test was an individual paper test. The distribution of questionnaires was used to determine student responses to the effectiveness of blended learning in Chemistry courses. Questionnaire sheets were given to each student after the final test was held. This questionnaire was used on Google Forms. Students were said to have completed their studies if they had succeeded in obtaining a success rate of 70% (assignment and final test), and classical completeness refers to the proportion of students in a group who successfully achieve the established learning threshold, typically set at 85%. The results of the student response questionnaire were analyzed using descriptive statistics. Data from student response questionnaires were analyzed by adding up student ratings and then calculating the average score. The rating ranges from 1 (not good) to 5 (very good). From the average value, conclusions are drawn which is determined by the score as follows: Not good = 1.00-1.80 Not good = 1.81-2.60 Good enough = 2.61 -3.40 Good = 3.41-4.20 Very good = 4.21-5.00 The chemistry course, Module: Atoms to Molecules, can be concluded to be conducted effectively by using blended learning activity if the response of the students is in good and very good criteria.

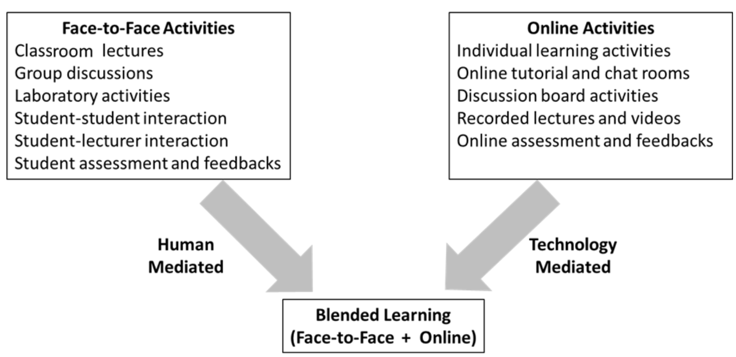
Table 1

Structure and Description for Module: Atoms to Molecules

Module	Week	Learning Topics	Learning Outcomes
Atoms to Molecules	1	L01 Basis of the atomic theory and electronic structures of atoms	Students can apply their knowledge of electronic theories of chemical bonding (VSEPR, VB, MO) to describe the properties of various elements in the periodic table. They can also use these theories (VSEPR, VB, MO) to explain the formation of chemical bonds, the structure, and the properties of molecules.
	2	L02 Periodic properties and representative elements & nonmetals and transition metals	
	3	L03 Chemical bonds (1)	
	4	L03 Chemical bonds (2)	

Figure 1

Key Aspects of Blended Learning Derived



Note. Blended learning combines face-to-face and online learning, offering flexibility and personalized learning experiences. Key aspects include integrating online and in-person activities, allowing for student control over pace and place, and adapting to various learning styles and needs. This approach fosters active learning, critical thinking, and engagement through diverse learning resources and activities as presented in Figure 1.

Results and Discussion

From Table 2, which shows the student grades for the Atoms to Molecules Module, when comparing the academic year 2021-2022, where the teaching method was lecture-based combined with problem-based learning, to the academic year

2023-2024, where the teaching method was blended learning combined with problem-based learning, it was found that the students' grades improved. The average GPA increased by approximately 0.05. The average GPA was 2.48, 2.49, 2.54, and 2.59 in the academic years 2021, 2022, 2023, and 2024, respectively. The percentage of students who received grades A, B+, and B combined was 34.45%, 29.23%, 24.32% and 22.92% in academic year 2024, 2023, 2022, and 2021, respectively. The percentage of students who received grades C+ and C combined was 65.55%, 70.77%, 75.67%, and 77.09% in academic year 2024, 2023, 2022, and 2021, respectively.

Table 2

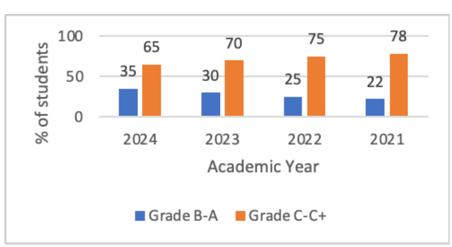
Student Grades for the Atoms to Molecules Module (2021-2024)

	Academic Year			
	Blended Learning		Lecture-Based Learning	
Grade	2024	2023	2022	2021
A	7.78	7.69	10.81	2.08
B+	10.00	13.85	2.70	10.42
B	16.67	7.69	10.81	10.42
C+	24.44	20.00	24.32	35.42
C	41.11	50.77	51.35	41.67
GPA	2.59	2.54	2.49	2.48

Note. This table presents the average student grades for the "Atoms to Molecules" module across four academic years, showing a progressive improvement in performance.

Figure 2

Percentage of Student Grades for the Atoms to Molecules Module (2021-2024)



Note. This graph displays the percentage of student grades across four academic years for the Atoms to Molecules Module, illustrating a trend in performance from 2021 to 2024.

There are no students who received grades lower than C because this is an outcome-based module, which sets the expected learning outcomes at the C level. If students score below a C in the assessment, they must attend a Tutorial Class to achieve the expected learning outcomes. Once it is ensured that the students have met the expected learning outcomes, they will undergo a re-examination to assess their learning outcomes.

Ninety students (in the 2024 academic year) were asked to fill out a response questionnaire after the final test. This was done with the assumption that all worksheets and assignments have been done by students. The results of the student response questionnaire are presented in Table 3.

Table 3

Student Response Questionnaire Related to Blended Learning Courses

Aspect	Range	Average	Criteria
1. Learning motivation	3-5	4.40	Very good
2. Deeper understanding due to review opportunities	3-5	4.62	Very good
3. Can revisit learning materials anytime	3-5	4.66	Very good
4. Student engagement increased through interactive and online activities	3-5	4.57	Very good
5. Self-learning skills improved planning and time management	3-5	4.49	Very good
6. Student satisfaction	3-5	4.69	Very good

In general, students think that blended learning offers the advantage of being able to review lessons anywhere, anytime, if they do not understand the material. They can also manage their study time effectively due to the variety of media available for learning, according to Table 3. Submitting assignments online is convenient for students, and instructors can accurately track submission times. This flexible approach allows students to choose the learning style that suits them best. If students cannot attend onsite classes, other learning formats ensure that they do not miss out on learning opportunities. The goal is to ensure that students achieve the expected learning outcomes.

Conclusion

Blended learning combined with problem-based learning is an appropriate approach for outcome-based modules. This is because it integrates various teaching methods. In the Atoms to Molecules Module (an outcome-based module), video-based learning is used within the university's LMS, along with face-to-face learning combined with MS Teams meetings or Zoom meetings, with recordings available for students to review later. Assignments are checked and feedback is provided through MS Teams, along with other learning materials for students who prefer reading. There are also Tutorial Classes available both face-to-face and via MS Teams or Zoom meetings, with recordings available for review.

The effectiveness of blended learning in this course was shown by the student discipline in doing and submitting assignments on time because, in MS Teams, the teacher can set and adjust the due date time. If the student submits late, the teacher can reduce the score. Another advantage of using e-learning is that student creativity and critical thinking can be enhanced because students can communicate and express freely in the discussion forum. In sum, based on the research results obtained, the learning outcome score and the results of the student response questionnaire, which have very good criteria, it can be concluded that blended learning is effective when combined with problem-based learning.

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