CONNECT CURRICULUM TO REALITY VIA CREATION-BASED LEARNING: THE PRE-EXPERIMENT OF THE CLEAR PEDAGOGY AMONG STEM STUDENTS

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Abstract

Students fear exams. Workforce fears deadlines. Exams are based on remembering things, and deadlines are based on creating things. There's a gap between the two realities. Our school systems are not updated enough to prepare students for the future employment in a very creation-based society. Thus, students are bored and distracted in classrooms without being able to see learning as meaningful and helpful for the future. It is, therefore, important to introduce creation activities into classrooms so that students will feel more connected and actively engage in the learning activities. The pedagogical model of CLEAR (an acronym for Create, Learn, Extend, Apply, and Reflect) promotes tight connections of curriculum to reality and positions creation as the core of the learning experience. This explorative research evaluates the effectiveness of CLEAR using a single group pre-test/post-test pre-experiment research design. A total of 17 students at the Toyohashi University of Technology (TUT) participated in a one-month pilot course on the topic of "creative commons open licensing" that utilized both Moodle and Mahara systems. Data came from the Moodle system logs, Moodle grades report, online quizzes, and online survey. Descriptive analysis methods visualized the data distribution and frequency as well as revealed different grades and engagement levels between demographic groups using SPSS. Results showed that the CLEAR-designed course was effective in lifting students' topical understanding to at least an over-average level. The demographics (nationality, gender, education level, and specialization) demonstrated impact on course grades and engagement levels; however, such impact needs a bigger sample size to further evaluate its credibility. Most participants found the creation-based learning experience satisfying and would like to take more courses alike in the future. Due to the small sample size and the absence of a control group, it was difficult to credit the grade improvement solely on the design of the course. Randomized controlled trials of the CLEAR-designed curriculum should be implemented to further test the teaching model and the findings from this research.

Keywords: *STEM, technical education, active learning, instructional design, creativity*

Introduction

In Japan STEM (Science, Technology, Engineering, and Mathematics) teaching becomes more teacher-centerd starting from upper secondary education and it is rarely taught in connection with real-life (Ogura, 2013). As a result students doubt the usefulness of STEM for their future, express a lower level of learning joy, and a relatively small percentage consider taking relevant jobs (Ina et al., 2020; Nakamura, 2015; Ogura, 2013). The disengagement of youth in STEM is not uncommon worldwide. It was argued that our conventional lecture-oriented curriculum significantly contributed to the problem with its emphasis on passive learning and blocking students from appreciating the scope, meaning, and limitations of science (Volpe, 1984). It is urgent to reform the STEM education classrooms because "we depend on STEM graduates to creatively design items, processes, and services to satisfy human needs" (Kanematsu & Barry, 2016, p. 16). Among an ever-widening range of pedagogical methods swaying away from lecture-style teaching, the most successful has been active learning for STEM education (Fendos, 2018). Active learning constantly engages students by doing and reflecting on what they are doing (Corrigan, 2013). The obvious advantages of active learning over traditional lecturing to impact undergraduate students' performance in STEM courses have been verified by over two hundred studies (Freeman et al., 2014). Despite the abundant research evidence, the in-class practice of active learning has been slow even in the USA (Fendos, 2018), which indicates a necessity to regularly update STEM teachers on research evidences of active learning.

However, to merely inform teachers of the potential and benefits of active learning as a pedagogic approach is insufficient. It is equally important to introduce the corresponding instructional design processes to teachers so that they can have a prescriptive and normative orientation towards improving teachers' performance

(Bruner, 1966). Since the 1980s, exponentially advancing technology have made human life even more intertwined with various technologies resulting in multiple realities of online, offline, and blended modes. Meanwhile, most instructional design models emerged between 1970s and 1990s before the expansion of internet-based media and technologies and are now outdated. The instructional designs of online instruction were much blamed by scholars especially during the COVID-19 pandemic period, when emergency eLearning actions were implemented worldwide (Charbonneau-Gowdy & Galdames, 2021). The misalignment between popularity of technologies in our digital age and missing of technologies in current instructional models need to be addressed properly by more research and practices.

The CLEAR model is a novel instructional design model to enable active learning in classrooms by promoting student-centered creation activities and utilization of various digital technologies (Lin, 2021). CLEAR was an acronym initially for Create, Learn, Extend, Apply, and Remember, but later revised to be for Create, Learn, Extend, Apply, and Reflect. The model is a response to a constantly discussed problem of disengaged students especially online. This explorative study reports the evaluation of an online course, which followed the instructional design model "CLEAR" and required students to deliver their creational works as learning outputs. The associated research aimed to tackle the following questions: (1) Is the CLEAR-designed course effective in improving students' understanding of the topic? (2) How do demographics differentiate grades and engagement level among students? (3) What are the students' feedbacks on taking the CLEAR-designed course?

The rest of this paper is organized as follows. It will first introduce the CLEAR model and move forward to explain the technical configuration to enable Mahoodle. The design of the course will then be in detail elaborated. The methodology section will explain the research design, data collection and analysis methods. Finally, the evaluation results of the course will be presented and discussed. The paper will end with a summary of the research, addressing the research limitation, and some suggestion for future research.

Course design and Methods

Following the CLEAR model, an experimental course, *Creative Commons: Create, Distribute, and Use Content on the Internet*, was developed to be a completely online and self-regulated learning experience for its participants. The course's structure of content and assessment can be viewed in Table 1.

Table 1. The structure of the course

	Course resources and activities
(Orientation)	Page: introducing the CLEAR model and learning outcomes URL: assessment and grades Choice: topic familiarity check Forum: Q&A Quiz: Pre-test
Create	Assignment: Submit Mahara page (Grade: 40)
Learn	Page: Lecturing videos and scripts
Extend	URL: External links
Apply	Forum: Peer interaction on assignment (Grade: 10)
Reflect	Forum: Self-reflection on the learning experience (Grade: 10) Quiz: Post-test (Grade: 20)

The creation assignment accounted for half of the total final score and was assessed following the criteria in Table 2. Students were expected to choose a media and make a representation to explain what CC licenses are and compatibility among CC licenses. They then created a web page in Mahara, embedded their representation, and submitted the page to the creation assignment of the course in Moodle.

Table 2. The assessment criteria for the creation assignment

	Criteria	**Grade**
1	Introduce CC licenses overall	5
2	Introduce CC licenses one by one	10
3	Explain the CC License Compatibility Chart	15
4	Apply one CC license to your creation	5
5	Creativity and exceeding expectation	5

The Moodle (version: 3.10.9+) platform was used as the Course Management System (CMS) for this course and the Mahara (version: 21.10.1) ePortfolio creation platform was a supplementary online space for students to present and submit their creations. The two platforms were bridged through the XML-RPC/MNet authentication, which allowed Moodle users to directly sign-on to Mahara. The Maharaws plugin was installed on Moodle to allow teachers to add Mahara assignment activity to their courses, and students to select their pages/collections on Mahara and submit them as response to the assignment.

Throughout the one-month course in January 2022 there was no live teaching, and the instructor was only available when replying to students' questions or communication in forums or reminding students of deadlines in the course.

Due to the small number of participants this study adopted the pre-experiment (one-group pre-test-post-test) as the research design. A group of 17 undergraduate and postgraduate students at the Toyohashi University of Technology completed the course and received incentives. No control or comparison group was employed.

The students' engagement levels with the course were logged automatically by the system and at the end of the course they completed an online survey. The pre-test (Q1) and the post-test (Q2) shared identical 19 questions, which were available as online quizzes to students in the CMS. The pre-test was taken before the course and the post-test was taken after students submitted the Mahara assignment. Two scores were recorded and compared.

Descriptive analysis was applied to report students' score change from the pre-test to the post-test, scores in the assignment of creation, and the total course grade's distribution. The demographics of participants, including nationality, gender, department (specialization), education group, were as well reported. Access hours were calculated by summing duration of all active sessions. If the distance between two sessions was less than 30 minutes, it was considered a continuous and active session. The log data were counting the number of logs for each activity in the course (e.g., *C_AssignmentLog* is the count of log records corresponding to the creation assignment page). Finally, student responses to the online survey, distributed through using the service of SurveyMonkey, were analysed through descriptive analysis.

Results and Discussion

Demographics of participant: Among 17 students there were 13 international students and four Japanese students. Although TUT only had 277 international students compared to 697 local students in 2021, the lack of Japanese students in this course was mainly because the instruction language was English and many Japanese students at TUT were not confident of their English skills. Among 13 international students, there were five Malaysian, two Egyptian, one India, one Pakistani, one Mongolian, one Tanzanian, one Chinese, and one Afghan. Consistent with the overall 12.6% female student ratio at TUT, a dominant number of male students were found in the sample with 15 males and only two females. Such a gender gap can be explained by the facts that girl become less motivated to pursue STEM topics during their adolescent years (Kijima et al., 2021) and TUT only offers degree programs in STEM subjects. Students were from five different faculties at TUT with diverse specializations: mechanical engineering (six), applied chemistry and life science (four), computer science and engineering (three), electrical and electronic information engineering (two), and architecture and civil engineering (two). There were ten undergraduate students, five master's students, and two doctoral students.

Is the CLEAR-designed course effective in improving students' understanding of the topic?: In the pre-test all students scored less than 15 out of 20 points and 75% scored lower than 10 points (Figure 1). In the post-test over 75% of participants scored higher than 15 out of 20 points. Excluding outliers, the distance between the highest score and the lowest score got shortened from 10.3 (in pre-test) to 4.5 (in post-test). The course had greatly improved students' understanding of the topic and balanced the achievement gap across individuals.

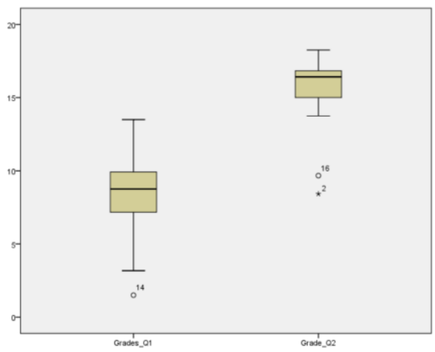

Figure 1. Boxplot of score distribution of pre-test and post-test

For the whole course's final grades, the maximum score obtained was 79, the minimum was 46, and the mean score was 66 (Figure 2). Around 82% of students scored over 60 points out of 80 (equivalent to over 75 points out of 100). The majority of participants were able to comprehend the topic at an above-average level due to the effectiveness of the course.

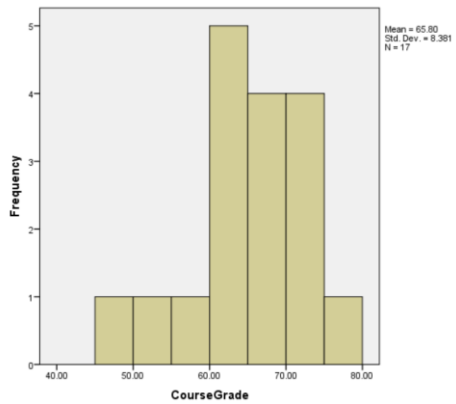

Figure 2. Histogram of final course grades (full score: 80)

More than 75% of students scored over 25 out of the full score of 40 in the creation assignment. However, 50% scored lower than 30 with apparent difficulties in meeting the Criteria 3 (Explain the CC License Compatibility Chart) and the Criteria 5 (Creativity and exceeding expectation) in Table 2, which were connected to more difficult tasks. It appeared that students were able to represent simple content using digital technologies of their choices; however, half struggled to represent difficult concepts using this approach. Although students were given full autonomy to choose digital technologies 71% of them selected PowerPoint as the tool to develop their creational assignment. This finding may be explained by findings of previous research which showed that many students are not confident or engaged in using digital technologies (Howard et al., 2016; Margaryan et al., 2011; Warschauer & Matuchniak, 2010). Consequently, they tended to use already familiar digital technologies to produce required content.

How do demographics differentiate grades and engagement level among students?: Japanese students improved slightly more in the post-test grades and the international students scored slightly higher in the creation assignment (Figure 3.a). It perhaps suggested that Japanese students were more competitive in remembering-oriented tasks but less competitive in creation-oriented tasks when compared with their international peers. It might be related to the cultural values such as that preservation is taken very seriously in Japan and seeking changes can be seen as unconstrained and irresponsible (Ge et al., 2021); therefore, Japanese students are accustomed to receiving information and following instructions in a strict manner.

Female students outperformed male students (Figure 3.b). It might be explained by the characteristics of the course being more testing verbal fluency (a cognitive function that facilitates information retrieval from memory; shorten as VF below) than other mental functions such as mental rotation (ability to rotate mental representations of two-dimensional or three-dimensional objects), and female students in general outperform their male counterparts in verbal fluency (Moè et al., 2021).

Students of higher academic education levels scored better in the creation assignment and the whole course (Figure 3.c). The effect of educational level on VF was proven in a previous study, which suggested that the low educational level group had worse performance than the high educational level group on clustering and switching in three VF modalities: phonemic (PVF), semantic (SVF) and unconstrained (UVF) (Pereira et al., 2018).

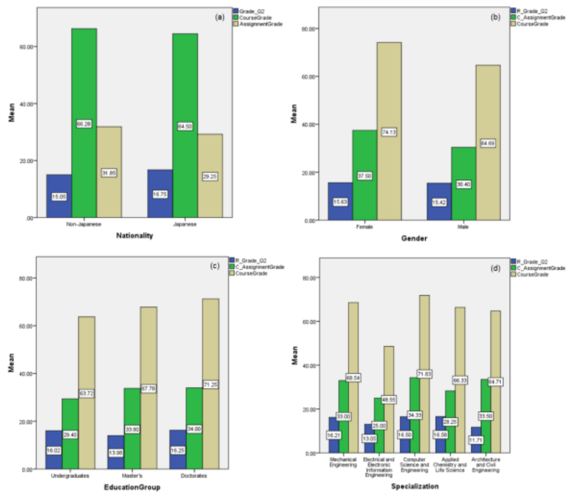

Figure 3. Bar chart of grades by nationality, gender, education group, and specialization

Among students of different specializations, those of the computer science background scored higher (Figure 3.d), which could indicate alignment with some existing findings about digital literacy positively affecting the high level of learning outcomes and academic performance (Kerr et al., 2006; Yustika & Iswati, 2020). To evaluate whether there exist significant achievement differences between demographic groups, a larger sample size will be needed to run correlation analysis.

The log data of Moodle platform reveal the clicking behaviours of its online users. The Figure 4 (a–d) showed the frequency of logs regarding students' interaction with the creation assignment page (*C_AssignmentLog*), the lecture pages (*L_ContentLog*), the additional URLs as extended content (*E_LinkLog*), the peer-interaction forum and the self-reflection forum (combined as *A_R_ForumLog*). Overall, students were much more frequently engaging with activity pages (e.g., assignment, forums) than with content pages (e.g., lecture pages, URLs). A high engagement rate with peer-interaction forum was found in higher performance student groups such as females, Japanese, students of higher education levels, but not in computer science students (Figure 4). The results agreed with a previous research, which tied age and higher grade point average (GPA) to higher levels of engagement with online instruction and found that female participants tended to have higher levels of engagement than their male peers (Thill et al., 2016). The student demographics were reported to significantly impact student engagement (Al-Nimer & Mustafa, 2022). Most students did not pay much attention to the extended content as reflected by the *E_LinkLog* data. However, the high-performance students (Japanese, Females, Doctorates, Computer Science students) were equally or more frequent visitors of the extended content than students of lower performance (Figure 4.d), suggesting a link between inquisitiveness (or willingness to learn more) and academic performance. It agrees with another study's results: students who scored higher also possessed higher levels of inquisitiveness (Blumner & Richards, 1997).

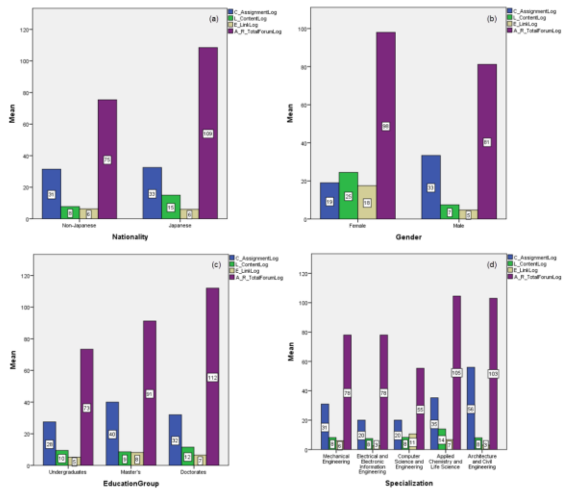

Figure 4. Bar chart of log frequencies by education group

What are the students' feedbacks on taking the CLEAR-designed course?: In the post-course survey, all agreed that the course was well designed in a new way that they never saw before, engaging, intelligently demanding, and that it was a success (Figure 5).

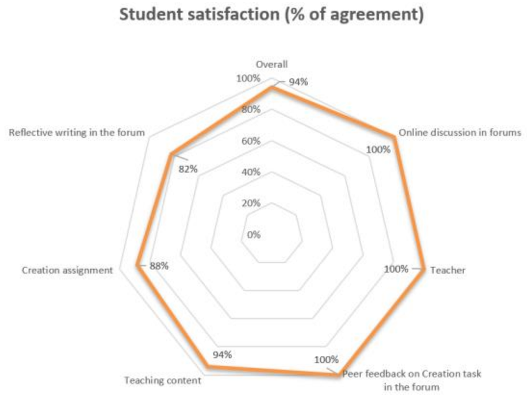

Figure 5. Student satisfaction of each aspect of the course

They were nearly unanimous in their approval of the online discussion activity, the teacher, receiving peer feedback on their creation assignment, and the instructional content. Around 94% were satisfied with the course and enjoyed the experience. Students rated the creation task to be the most time-consuming activity in the course and only 71% agreed that it was simple to complete, but they also expressed that the creation assignment was beneficial and enhanced their learning in the course (94% agreed).

Conclusions

The experimental course, which followed the CLEAR model design, was tested to be effective teaching for a small sample of 17 STEM students, who were mostly male undergraduates and international students from developing countries at the Toyohashi University of Technology in Japan. Most students were satisfied with the online creation-based learning experience, which was designed following the CLEAR instructional design model. Through the course students improved their topical understanding, and demonstrated high level of online engagement with the CMS. It also seemed that students, who were female or of higher education levels or more competent in digital literacy, comparatively benefited more from the creation-based learning experience. Although the CLEAR training design has been positively received by students in this study, more formal evaluations are needed to affirm its effectiveness towards a bigger audience. Due to the small sample size of students and the absence of a control group, it was difficult to credit the performance improvement solely on the design of the course. Randomized controlled trials of the CLEAR-designed curriculum should be implemented to further test the teaching model and the propositions from this research.

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References

Al-Nimer, M., & Mustafa, F. M. (2022). Accounting students' demographics and competencies: The mediating role of student engagement. *Accounting Education*, *0*(0), 1–29. https://doi.org/10.1080/09639284.2021.1999278

Blumner, H. N., & Richards, H. C. (1997). Study habits and academic achievement of engineering students. *Journal of Engineering Education*, *86*(2), 125–132. Scopus. https://doi.org/10.1002/j.2168-9830.1997.tb00275.x

Bruner, J. S. (1966). *Toward a theory of instruction* (Vol. 59). Harvard University Press.

Charbonneau-Gowdy, P., & Galdames, C. (2021). Connecting the Dots: Putting Instructional Design Theory to Practice in Online Courses. *20th European Conference on E-Learning, ECEL 2021*, 80–88.

Corrigan, P. (2013, November 30). Active learning has an ancient history. *Teaching and Learning in Higher Education*. https://teachingandlearninginhighered.org/2013/11/30/active-learning-has-an-ancient-history/

Fendos, J. (2018). US experiences with STEM education reform and implications for Asia. *International Journal of Comparative Education and Development*.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–8415.

Ge, X., Misaki, D., Furue, N., & Xu, C. (2021). Culturally Responsive Engineering Education: Creativity Through "Empowered to Change" in the US and "Admonished to Preserve" in Japan. *2021 ASEE Virtual Annual Conference Content Access*.

Howard, S. K., Ma, J., & Yang, J. (2016). Student rules: Exploring patterns of students' computer-efficacy and engagement with digital technologies in learning. *Computers & Education*, *101*, 29–42. https://doi.org/10.1016/j.compedu.2016.05.008

Ina, V. S. M., Martin, M., Foy, P., Kelly, D., & Fishbein, B. (2020). *TIMSS 2019 International Results in Mathematics and Science*. https://timss2019.org/reports/wp-content/themes/timssandpirls/download-center/TIMSS-2019-International-Results-in-Mathematics-and-Science.pdf

Kanematsu, H., & Barry, D. M. (2016). STEM and Creativity. In *STEM and ICT education in intelligent environments* (pp. 15–23). Springer.

Kerr, M. S., Rynearson, K., & Kerr, M. C. (2006). Student characteristics for online learning success. *The Internet and Higher Education*, *9*(2), 91–105. https://doi.org/10.1016/j.iheduc.2006.03.002

Kijima, R., Yang-Yoshihara, M., & Maekawa, M. S. (2021). Using design thinking to cultivate the next generation of female STEAM thinkers. *International Journal of STEM Education*, *8*(1), 14. https://doi.org/10.1186/s40594-021-00271-6

Lin, J. (2021). The CLEAR Framework to Implement Active Learning in STEM Education. *2021 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*. IEEE TALE2021.

Margaryan, A., Littlejohn, A., & Vojt, G. (2011). Are digital natives a myth or reality? University students' use of digital technologies. *Computers & Education, 56*(2), 429–440.

Moè, A., Hausmann, M., & Hirnstein, M. (2021). Gender stereotypes and incremental beliefs in STEM and non-STEM students in three countries: Relationships with performance in cognitive tasks. *Psychological Research*, *85*(2), 554–567. https://doi.org/10.1007/s00426-019-01285-0

Nakamura, M. (2015, June). New mechanisms for the cultivation of scientific and technological human resources. *MyVision*, *10*. https://nira.or.jp/pdf/e_vision10.pdf

Ogura, Y. (2013, October 21). *The Science Education in Japan Its Strengths and Weaknesses*. GSEE/Kyoto Summit: Initiatives that can change science education, Kyoto, Japan. http://www.gsee-kyoto.kier.kyoto-u.ac.jp/GSEE_Kyoto%20Summit2013/Oct21/Yasushi%20Ogura%20(Kyoto20131021).pdf

Pereira, A. H., Gonçalves, A. B., Holz, M., Gonçalves, H. A., Kochhann, R., Joanette, Y., Zimmermann, N., & Fonseca, R. P. (2018). Influence of age and education on the processing of clustering and switching in verbal fluency tasks. *Dementia & Neuropsychologia*, *12*, 360–367. https://doi.org/10.1590/1980-57642018dn12-040004

Thill, M., Rosenzweig, J. W., & Wallis, L. C. (2016). The relationship between student demographics and student engagement with online library instruction modules. *Evidence Based Library and Information Practice*, *11*(3), 4.

Volpe, P. (1984). The shame of science education. *American Zoologist*, *24*(2), 433–441.

Warschauer, M., & Matuchniak, T. (2010). New technology and digital worlds: Analyzing evidence of equity in access, use, and outcomes. *Review of Research in Education*, *34*(1), 179–225.

Yustika, G. P., & Iswati, S. (2020). Digital literacy in formal online education: A short review. *Dinamika Pendidikan*, *15*(1), 66–76.

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