Compatibility of Computer-Based Learning with Differentiated Learning Styles of Chemical Engineering Students as Evidenced by the Outcomes

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Abstract
The incorporation of more computer-based courses and teaching-learning strategies in the Chemical Engineering (CHE) curriculum prompted educators to use information technology more effectively and efficiently. Thus, this research investigated the compatibility of Computer-Based Learning (CBL) with the learning styles of the CHE students through their learning outcomes. With a quasi-experimental research design, the researcher employed a CBL instrument structured in four steps (see-try-do-explain) and assessed the learning style preferences using the Felder-Solomon Index of learning style. The respondents included all fourth-year students enrolled in the Computer Applications in Chemical Engineering. The study revealed that CHE students are mostly sensing and visual; they found it hardest to transition from step ‘see’ to step ‘try’. Verbal and global learners will most likely survive in the four-step CBL while active learners will lag. However, the research failed to show that CBL was significantly compatible with the differentiated learning styles of the CHE students.

Keywords: Competency-based learning; Four-step e-learning; Teaching strategy; Transition mortality/survival rate

Introduction
The advent of computers forced the transformation of organizational structures and operating procedures of higher education institutions since the quality of its graduates must supplement the needs of the industries and the various sectors of society. For instance, aside from the day-to-day operation in the office, computers have highly significant usability in the operation and processing of chemical plants. Understandably, chemical engineering (CHE) education is at the forefront of providing computer-based learning (CBL) experiences to the students through the inclusion of more computer-based courses and teaching-learning materials, especially on technical courses. In CBL, however, it had been observed that CHE students, who were perceived to perform better academically, were unable to attain the expected level of competence. There were cases though, when non-academic achievers in the chemical engineering courses could outperform the top achievers in other disciplines. This observation is inconsistent with the studies indicating that computers, being both the learning content and subject matter of teaching, provide an edge in performing successfully in e-learning. Kulik and Kulik (2014), for example, found out that in 101 controlled evaluations, there were usually positive effects of computer-based education (CBE) on college students. The effect was small but significant; lower in unpublished studies than published studies and, lower

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in hard, nonlife sciences than in education and social life sciences. Likewise, in 42 studies that yielded 108 effect sizes, the achievement of a typical secondary and college student in science was observed to move from 50th to 62nd percentile when using computer-assisted instruction (CAI) and that it is significantly related to student-computer ratio, CAI mode, and duration of treatment (Bayraktar, 2014).

To build teaching and learning competencies, teachers need to understand how to use computer and networking technology effectively and efficiently. However, considering the complexity of CBE, and today’s millennial and generation Z learners, or tomorrow’s Alpha generation, this direction is a challenge for any educator. Nonetheless, Valencia-Molina et al. (2016) discussed the pedagogical dimensions that created the model on the information and communications technology (ICT) standards and competencies, guiding the evaluation of the strategies and practices of CBE. The model prioritized design, implementation, and assessment as the ICT competencies derived from the pedagogical dimensions. The dimensions of the adoption levels (integration, reorientation, and evolutions) were developed through familiarization, utilization, and transformation. In subsequent models, like the model of incorporating emerging technologies in the classroom (MIETC), infrastructure and ICT competencies proved to be the conditioning factors for incorporating educational technology in the classroom within the principles of teacher reflection, pedagogical flexibility, and dialogic communication and roles (Neira, Ibáñez, & Crosetti, 2018). The cyclical phases in the model include initial reflection and context analysis, with the pedagogical foundation, didactic application, implementation and evaluation phases serving to continuously improve the educational technology (Neira, Ibáñez, & Crosetti, 2018; Psomos & Kordaki, 2012).

However, the studies on the models and frameworks showed that computer-based learning environments (CBLEs) are most beneficial to users who are adept at self-regulating their cognition, motivation, behavior, and context (Greene, Muis, & Pieschl, 2010; Cabellon & Brown, 2017). Hence, Greene et al. (2010) recommended a dynamic model that relates the learners’ epistemic beliefs and self-regulated-learning (SRL) in CBLEs to capture the events on how learners activate and deactivate beliefs about knowledge and knowing as well as various self-regulatory processes. It is deducible from these theoretical precepts that when the learners have similar learning tools and teacher competencies, the manner at which the learner prefers to acquire the knowledge and the design of the delivery of instruction are the emerging points for consideration in CBE.

On this note, therefore, this research investigated the compatibility of CBL to the learning styles (LS) of the chemical engineering students through their learning outcomes. Specifically, the study sought to determine the profile of the chemical engineering students exposed to computer-based learning in terms of the parameters of learning styles and learning outcomes. The study also determined the significance of the degree of compatibility of computer-based learning with the learning styles of the chemical engineering students as evidenced by the learning outcomes.

Throughout the years, studies had resulted in the development of the LS models which have similarities and differences in the dimensional preferences. Pashler et al. (2008) conducted a systematic and critical review of the various influential models, with three of these models presented in the ensuing discussions.

First, the LS model of Dunn and Dunn (Learning Styles, 2010; Hanzelka, 2013) recognizes the unique combination of the learner’s preferences of the stimuli and their corresponding elements. Such combinations are: (a) environmental -
sound, light, temperature, and seating design; (b) emotional - motivation, conformity/responsibility, task persistence, and structure; (c) sociological - alone, pair, peer, group, authority, and variety; (d) physiological - the perceptual elements (auditory, visual, tactual, kinesthetic), intake, time of day, and mobility; and (e) psychological - analytic, global, impulsive, and reflective.

Second, the Kolb Learning Style Model (Kolb, 2015; McLeod, 2013) presents the following learning styles with their corresponding dominant learning abilities: (a) diverging – real experience and reflective observation; (b) accommodating – concrete experience and active experimentation; (c) converging – abstract conceptualization and active experimentation; and (d) assimilating – active conceptualization and reflective observation.

Lastly, the index of learning styles (ILS) evolved by Felder and Silverman (1988) were found to be a valid and reliable model consisting of four-dimensional preferences (Felder & Spurlin, 2005; Jingyun Wang, 2015; Hosford & Siders, 2010):

- sensing (concrete, practical, fact- and procedure-oriented) or intuitive (abstract, innovative, theory- and underlying meaning-oriented),
- visual (prefer visual representations such as pictures, flowcharts, and diagrams) or verbal (prefer written and oral explanations),
- active (prefer trying things out and working in groups) or reflective (prefer thinking things through, working alone or working with a single or two familiar partners), and
- sequential (prefer linear thinking and learning in small incremental steps) or global (prefers holistic thinking and learning in massive leaps).

Most engineering students are visual, sensing, inductive, and active, and some of the most creative students are global while most engineering education is auditory, abstract (intuitive), deductive, passive, and sequential (Felder & Silverman, 1988). This situation results in a mismatch between learning styles and teaching styles. Specifically, CBL researches had also shown that the students’ learning styles do not mesh with the strategy for delivering learning. According to the meta-analyses of comparative studies with traditional classroom education, these observations exist because the type of application, besides instructor bias, was observed to be a hindrance to the attainment of significant student achievement in CBE (Lowe, 2014).

Franzoni et al. (2008) recognized the need for matching teaching content with the student’s learning style by designing a personalized teaching environment that would result in more efficient and effective learning. Such pedagogy combined the selection of the appropriate teaching strategy and electronic media based on an adaptive taxonomy using Felder and Silverman’s learning styles. The current research, therefore, had to either design a CBL that fits the learning styles of the students or select the best fit from among the many existing CBL designs and strategies, then adopt or modify the design. Adaption was the best option for reasons that were best enunciated by Hanzelka (2013) regarding using learning style in instruction.

Due to the fact that research has not clearly demonstrated the ineffectiveness of mismatched modality, exposing students to other forms of instruction, other than their preferences, should not be harmful to their academic success. Once they enter the working world, employers will not be expected to create visual, auditory, or kinesthetic messages accommodating to each employee’s list of preferences. The amount of time it would require a teacher to design lesson plans around each student’s preference is unimaginable. This is an inefficient and unrealistic idea for the classroom. At the same time, that does not mean teachers
should have, their way or the highway mindset when instructing (Hanzelka, 2013, pp. 22).

Thus, the researcher focused on the four steps (4S) model (Hinterberger, 2007) for structuring the learning environment. Hinterberger concluded that teaching is most effective and efficient using this model. It proceeds with the following steps: See: students must be given the opportunity to see the concepts; Try: students should have the chance to try to apply concepts actively with appropriate guidance; Do: students apply the concept independently; Explain: to verify their competence, they explain their solution to an instructor” (Hinterberger, 2007).

Figure 1 illustrates the 4S CBL structure that complements problem-based learning (PBL). This study aimed to determine whether this model for structuring the learning environment is compatible with the four dimensions of learning styles identified by Felder and Silverman.

**Methodology**

The current research design is a one-group quasi-experiment since the control on the assignment of the student-participants was due to their registration in the course offered by the university (Campbell & Stanley, 2015; Handley et al., 2018, Pitts, Prost & Winters, 2008). The respondents were composed of all enrollees in the fourth-year undergraduate course, Computer Applications in Chemical Engineering (CACHE). This course employs a blended learning strategy. In this research,
the instructional design for organizing the CBL environment adapted the 4S model.

**Instrument**

The LS questionnaire used in this study was the ILS (Felder & Solomon, n.d.). The researcher chose this model based on clarity, ease of scoring and administration, validity and reliability, applicability to the chemical engineering courses, and cost. The model has a free online website application which consists of 44 questions. The evaluation result is sent immediately to the user. Consequently, the 4S learning design adapted the E. Tutorial website of ETH Zurich (Fässler, Sichau, & Dahinden, 2017). In Step 1, the PowerPoint presentation of the introductory concepts came from the reference book on Introduction to Chemical Engineering Computing (Finlayson, 2012). This instructional material had continuously undergone a yearly revision since its creation in 2013. In a face-to-face session, the teacher discussed the introductory concepts and oriented the respondents to the CBL materials and websites. The class website posted the introductory material for reference and for those learners who preferred to go through Step 1 online rather than the face-to-face session. Step 2 used the E. Tutorial on Spreadsheet Simulation (Fässler, Sichau, & Dahinden, 2017). Finally, the project task in Step 4 was part of the instructional materials used in the course which was initially developed by Felder (Wilcox, 2012).

**Data Collection and Instrumentation**

The research focused on the course, Computer Application in Chemical Engineering, since this is a demonstrative course, entirely dedicated to e-learning and, can be taught using any CBL mode. The students enrolled in this course qualified into the fourth-year level and had already completed the courses on Computer and Internet Literacy, and Computer Fundamentals and Programming. At the onset, the students performed learning tasks posted on the course website to be familiar with the e-learning application and expose them to projects that resemble the expected course output.

The website created in Google served as the platform of the 4S learning model. The site provided specific instructions on how the user navigates, including questions meant to monitor their actions. Also, the researcher conducted online supervision (real-time) to guide the students and further monitor their accomplishment. It was possible because the learning activity was made available only at the scheduled time that was announced online and during the face-to-face sessions.

These activities were embedded into the course since the spreadsheet simulation is an introductory lesson of the course. Thus, the students were initially unaware that they were part of the experiment. Nonetheless, just like any other class activity, they needed to do their best to complete the learning tasks. When the student logs-in to a step, the website starts recording their progress. A completed task gets a score of 1 while the inability to complete the tasks within the specified duration of a specific step results in a zero score. A student will be scored 1 in the next step upon completing the tasks in such step. However, since 4S is designed to foster self-direction, students who manifested their choice to skip the step immediately succeeding a completed step, are still scored 1. Lastly, before the submission of their solution to the problem task in step 3, the students were made aware that they were part of this experiment. The researcher also informed the students that those who wanted to continue participating in the experiment would have to proceed to the ILS website and later, explain to the instructor their output in step 3.

To gather the data on the learning styles of the students, the researcher posted the uniform resource locator of the ILS questionnaire on the course website. The students then submitted their online evaluation results to the same course website. The
collated 4S learning data excluded those students who did not provide their ILS results.

Statistical Treatment

To determine the significance of the degree of compatibility of CBL with the learning styles of the CHE students, the Chi-Square test for association was employed. The frequencies of the students in each learning step distributed among the learning styles’ categories were tallied in the chi-square table. The Chi-Square value was then computed and tested at .05 level of significance and calculated degrees of freedom.

Results and Discussion

Figure 2 provides the learning styles distribution of the learners who participated in all four steps of the CBL. It was necessary to ensure that those who completed the 4S learning should join in the learning style survey, however, given the real-life classroom setting and class policies, some student submissions were no longer accepted while other students dropped or elected to participate in the 4S CBL only. A total of 75 observations were collated at the start of the CBL activity, ending with 64 observations in the last step.

The frequency counts in Fig. 2 represent the learners who completed the tasks in each Step in the quasi-experiment; hence, the data reflects the performance outcomes. For step 1, the chemical engineering students were predominantly sensing and visual, followed closely by the active and sequential learners.

Figure 3 further shows that percentage-wise, across steps 1 to 4, visual learners in step 2 were highest at 21.88% but sensing learners were highest in steps 1, 3, and 4. Their counterparts such as the verbal learners were lowest at 3.13% in step 2 while intuitive learners maintained the lowest proportion in steps 1, 3, and 4.

The present study, therefore, showed differences in the learning styles of the CHE students. Among other previous studies, Tulsi et al. (2016) reported the same findings, i.e., most of the engineering students, except mechanical engineering, which was found to have active, sensing, visual and sequential learners. However, in a problem-based learning environment (a structure similar to the 4S-CBL), Kolmos and Holgaard (2008) slightly deviated since they found out that the first-year CHE students were mostly active learners.

The learning outcomes in the course are best visualized in Fig. 4. The bars in the graph above zero represent mortality rate during the transition from one step to the next step in the CBL design while the bars below zero represent survival rate.

Figure 4 shows that the highest mortality rate across Steps 1 to 4 is during the transition from Step 1 to 2. This result is evident also in Fig. 2 which shows a considerable drop in the frequency of observations in step 2. During the same transition, the highest mortality rate among the learning style groups transpired with the verbal learners (83%) while the lowest mortality rate occurred with the visual learners (46%). Across steps 1 to 4, the verbal learners also had the highest survival rate of 500% during the transition from steps 2 to 3 thus, resulting in an average survival rate of 417%. These are approximately six times and five times, respectively, higher than its mortality rate in step 1 to 2. Nonetheless, based on the average data, all types of learners will survive in the 4S-CBL design, but the active learners (average transition mortality rate of 14%) will lag behind the other types of learners, who were then in the survival mode. Moreover, there was no more mortality in all group of learners during the transition from steps 2 to 3.

Finally, to determine the significance of the compatibility of the learning styles with the 4S-CBL, the software Minitab statistical was used for the chi-square test for association (Minitab, n.d.). The statistical analysis resulted in a Pearson Chi-Square equal to 4.656 at df=21 and p-value of 1.000 while
the likelihood ratio Chi-Square was equal to 4.965 at df-21 and p-value of 1.000. Since both p-values are higher than the significance level of 0.05, there is therefore not enough existing evidence to reject the null hypothesis that there is no significant compatibility of computer-based learning with the differentiated learning styles of the chemical engineering students, as evidenced by the learning outcomes. However, based on the contributions to the Chi-square, it was observed that: (1.) with a value of 1.11795 and 0.33790, the most likely to survive in the transition from step 1-2 and step 2-3,
respectively, are the verbal learners; and (2.) with a value of 0.19159 during the transition from step 3-4, the most likely to survive are the global learners. Therefore, it can be deduced that computer-based learning that is characterized by the features of steps 1 (See), 2 (Try), and 3 (Do) will likely be compatible with verbal learners while those characterized by the features of steps 3 (Do) to Step 4 (Explain) will be likely compatible with global learners.

These results coincide with previous studies showing no significant interactions between learning styles and instructional approach. For example, Cook (2012) indicated that cognitive and learning style (CLS) did not improve the efficiency of computer-assisted instruction alongside a previous study of Cook et al. (2009) which showed that there was no association of the sensing-intuitive styles with their learning outcomes in web-based learning. Akkoyunlu and Soylu (2008) likewise found out that there were no significant differences between students’ achievement level according to their learning styles. Nonetheless, the compatibility of the learning styles to specific pedagogical steps in the CBL structure implies support to other studies that report prior knowledge as significantly related to learning performance and learning style (Hsieh et al., 2011; Saeed, Yang, & Sinnappan, 2009). Learning style is therefore dynamic, i.e., each learning phase gets a cue from the pedagogical features that are most relevant and productive to the epistemic beliefs of the learner (Greene, Muis, & Pieschl, 2010; Romanelli, 2009; Alharbi et al., 2011). With the learning style matching the instruction method, learning performance significantly improved (Greene, Muis, & Pieschl, 2010; Romanelli, 2009; Alharbi, Paul, Henskens, & Hannaford 2011; Hwang et al., 2012). Thus, incorporating a more self-directed learning approach on the 4S-CBL design is expected to improve the learning outcomes of the students with differentiated learning styles.

**Conclusion**

The learning style preferences of most chemical engineering students are
proportionately equal as sensing and visual, then active and sequential. For the teacher who wishes to cater to such varied learning preferences, this seems to be a daunting task but necessary for maximizing the learning potential of the students. This research, therefore, aimed to investigate the compatibility of CBL to the learning styles (LS) of the chemical engineering students through their learning outcomes. In effect, it examined the attainment of the learning outcomes of the different types of learners in a 4S-CBL design and ascertain whether such design maximizes learning.

The current research did not provide support on the significance of the compatibility between computer-based learning and the differentiated learning styles of the chemical engineering students. Nonetheless, during this process, there were essential revelations that emerged. First, the transition from step 1 to 2, wherein the students applied the concepts and their skills through the guidance of a computer-simulated program, was difficult for all learners. This result suggests that the instructional tools and strategies in step 1 lack the elements which would make all types of learners more productive in the hands-on exercise. Second, in a CBL environment, where active learners are expected to do well, the same students lagged from their counterparts. Third, when they applied these concepts in solving a computer-related problem task (step 3), most types of learners completed their task. This finding implies that the E.Tutorial in step 2 effectively led to the accomplishment of the problem task in step 3. The intuitive learners, however, could barely accomplish the problem task. Fourth, the verbal and global learners benefit more from the 4S-CBL. The most probable reason for this is the element of motivation brought-in by the following learning steps. The E.Tutorial was merely a tool for completing steps 3 and 4 since they were confident that they could better explain their output in step 3, thus proving their competence.

Given the circumstances as mentioned earlier, despite having failed statistically in establishing the compatibility of the 4S-CBL structure to the learning styles of the chemical engineering students, this instructional design can cater to the different learner style preferences more positively without being relatively imposing on the time and workload of the teacher. Therefore, within the limitations of the resources available to the teacher, it is recommended that the instructional materials used in step 1 should be more informative and the time limit of the orientation process should be longer. In step 3, aside from the problem task already embedded in the CBL design, there should also be non-routine problems to encourage more critical thinking among learners. The researcher also suggests continuing research to validate the incompatibility of the 4S-structured CBL and learning style. In the future, it is recommended to use test results administered at the end of each step for assessing the compatibility of the variables; and to incorporate on the 4S-CBL design the applicable strategies used in the programming tutoring system (Klasnja-Milicevic et al., 2011; Abech et al., 2016).

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