CULTIVATING HIGHER-ORDER THINKING SKILLS IN ENGLISH-AS-A-FOREIGN LANGUAGE TECHNICAL READING INSTRUCTION

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ABSTRACT

“The need to develop critical thinking has never been so vital,” said in the 2019 report of World Economy Forum. Additionally, several recent surveys of managers also showed that critical thinking is the number one soft skill that managers feel new graduates are lacking and that education systems have done little to help address the skills shortage. With higher-order thinking skills (HOTS) being ranked among the most in-demand skills for job candidates, engineering education should catch up with the global trend with pedagogical innovation to provide training for cultivating students’ HOTS. Although critical thinking has already been listed in the CDIO syllabus under the category of Personal and Professional Skills and Attributes, how to implement HOTS effectively in instruction for engineering students still needs further elaboration. This paper aims at proposing how to cultivate engineering students’ higher-order thinking skills in English-as-a-foreign-language (EFL) technical reading instruction and at understanding students’ responses to the HOTS implementation. Along with the proposed design of HOTS-based activities, students’ awareness, adaptation, and perceived impacts of HOTS are also presented.

KEYWORDS

Higher-order thinking skills, Bloom’s Taxonomy, technical reading instruction, Standards: 2, 7, 8

INTRODUCTION

According to the 2018 World Economy Forum report on 2022 required skills, while global industry’s needs for memory, verbal, auditory and spatial abilities are decreasing, needs for critical thinking and innovation are increasing and have become indispensable. Unfortunately, traditional pedagogical approaches such as disconnected lectures and factual knowledge based discrete-point assessments have been overemphasizing lower-order thinking skills of remembering and understanding. Students in traditional instruction are often striving to meet the requirements of assessment system which is focused on rote memory with little attention paid to the development of higher-order skills including creativity and critical thinking. Similarly, it can be found that the main focus of most engineering curriculum is still on deductive instruction where lectures are delivered with limited application of the disciplinary content to real life engineering (Narayanan & Adithan, 2015).

Teaching English as a foreign language to engineering students is no exception to innovation for cultivating the 21st century skills. A study by Chou, Jai, and Wang (2020) showed that while interpersonal skills were improved through active learning of Freshman English for engineering students, there was still room for critical thinking skills to be enhanced. According to the authors, “it takes time for students to change learning habits from passively receiving knowledge to actively expressing personal views” (p. 80), especially during the period of adaption to a new learning context of higher education in the freshman year. With this instructional goal of enhancing engineering students’ higher-order thinking skills in mind, the Freshman English program for College of Information and Electrical Engineering (IEEFE) was expanded to incorporate higher-order thinking skills (HOTS) and Bloom’s Taxonomy as the framework to guide the design of course objectives, activities, and assessment.

LITERATURE REVIEW

Higher Order Thinking Skills

The notion of HOTS, as claimed by Brookhart (2010), is the process of taking stored information in memory and reorganizing and incorporating the information to achieve a purpose in novel situations. Furthermore, HOTS is categorized into 3 basic concepts of transfer, critical thinking, and problem solving. By definition, transfer is the ability for attaining knowledge and skills and applying them to novel situations. Critical thinking skills are mental activities of understanding problems logically, reflective thinking, and making judgments that can guide the development of beliefs and taking action. Lastly, the ability of problem solving is to define problems creatively and find remarkable solutions. Holistically speaking, HOTS can be thought of as a higher-level of cognitive activity which encompasses the abilities: (a) to transfer knowledge and skills in new situations, (b) to define the problem logically and solve the problem creatively, and (c) to argue critically and make a decision.

Undoubtedly, the type of real-world jobs that will exist in the future is hard to predict or non-existent. Achievements at the lower cognitive levels with knowledge and comprehension do not equip students to meet the challenges of this ever-changing world. However, the proportion of questions posed by engineering faculty pertaining to lower-order thinking skills nowadays still outweighs its counterpart, HOTS (Narayanan & Adithan, 2015). Likely, the English teaching methods used in Taiwan provide opportunities mainly with lower-order thinking skills (Chen, 2017). Even if teachers possess pedagogical competence and knowledge to teach HOTS, it is still comparatively more difficult to teach Asian students to do HOTS “because of their collective and hierarchical cultural backgrounds where students rarely challenge what they learned from the teacher (Chen, 2017). Therefore, it is strongly desirable that HOTS should be incorporated in classroom activities such as group discussion, case studies and problem-based learning in order to nurture students’ higher order thinking skills (Kusumastuti, Fauziati, & Marmanto, 2019).

Bloom's Revised Taxonomy

HOTS are closely linked to Bloom's Taxonomy. The Taxonomy was originally created by Bloom in 1956 to classify curricular objectives and test items, which was later revised in 2011 by Anderson and Krathwohl with the reason to incorporate new knowledge and thought into the original framework (Anderson & Krathwohl, 2001). Ever since, the Taxonomy has been used worldwide to serve as a pedagogical tool for determining the congruence of educational objectives, activities, and assessment in a course or curriculum (Krathwohl, 2002).

A useful application of the Taxonomy is to combine its knowledge dimension with cognitive dimension to serve as a pedagogical tool for designing question-based activities to teach thinking (Krathwohl, 2002). Teachers can use various ranks of questions appropriately to review, assess learning, and challenge students. As with cognitive processes, questions can also be ranked into cumulative orders. While lower-order questions are those that require students to use lower-order skills such as *remember*, *understand*, and *apply*, higher-order questions refer to those that engage students in manipulating information by using higher-order thinking skills such as *analyze*, *evaluate*, and *create*. In general, lower-order questions are referred to as low cognitive, convergent, or display questions, and high-order questions, on the other hand, pertain to high cognitive, divergent, or referential questions (Bloom, 1956). Anderson and Krathwohl's (2001) defined the six skills as follows:

- *Remember*: retrieving relevant knowledge from long-term memory.
- *Understand*: determining the meaning of instructional messages, including oral, written, and graphic communication.
- *Apply*: carrying out or using a procedure in a given situation.
- *Analyze*: breaking the material into parts and knowing how the parts are related to one another and to the overall structure.
- *Evaluate*: making judgements based on criteria through checking and critiquing.
- *Create*: putting elements together to form a novel and coherent whole.

Moreover, psychological and education research has been placing its emphasis on "helping students become more knowledgeable of and responsible for their own cognition and thinking" ever since the publication of Bloom's Taxonomy (Pintrich, 2002, p.219). To sustain such an educational value, metacognition was added to the original Taxonomy as the 4th type of knowledge, which "involves knowledge about cognition in general, as well as awareness of and knowledge about one's own cognition" (Pintrich, 2002, p.219). Krathwohl (2002) defined four types of knowledge as follows:

- *Factual Knowledge*: The basic elements that the students must know to be acquainted with a discipline or solve problems in it.
- *Conceptual Knowledge*: The interrelationships among the basic elements within a larger structure that enable them to function together.
- *Procedural Knowledge*: How to do something.
- *Metacognitive Knowledge*: Knowledge of cognition in general as well as awareness and knowledge of one's own cognition.

In relation to learning effectiveness, research on metacognition has proven that as students act on their awareness, they tend to learn better (Zhao, Wardeska, McGuire, & Cook, 2014). Nevertheless, metacognitive knowledge is still comparatively overlooked in curriculum or course design in engineering education. Considering that students who know about different cognitive and metacognitive activities for learning, thinking, and problem solving will be more likely to use them, it is thus suggested that teachers strengthen students' awareness of cognitive activities in order for them to appropriately adapt to the ways they think and operate.

METHODOLOGY

The purpose of this study was twofold: (a) to develop and implement a HOTS-based pedagogical procedure in technical reading instruction of the Freshman English program for Information and Electrical Engineering Students, and (b) to investigate students' awareness, adaptation, and perceived impacts of the HOTS-based instruction. This paper reports on data collected during the preliminary stages of planning and implementation with all phases being guided by action research cycle of planning, acting, observing, and reflecting (Pelton, 2010). As a practical research approach to improving teaching and learning, action research emphasizes the teacher's "role as a reflective practitioner who is continually observant, thoughtful, and willing to examine personal actions in the light of the best possible practices" (Pelton, 2010, p. 5). In this study, quantitative approach was employed in data collection by using a self-report survey questionnaire to obtain the students' perceptions of HOTS-based activities of the IEEFE program. As for data analysis, descriptive statistics was used in analyzing questionnaire data to obtain important data characteristics at the initial phase of study, which can serve to inform subsequent refinement of instruction.

Participants

In order to explore students' responses to the HOTS-based Freshman English class design and learning tasks, two Freshman English classes of Automatic Control Engineering and two of Communications Engineering (College of Information and Electrical Engineering, IEEFE) with a total of 115 students, 21 females and 93 males, were surveyed in the final week of Fall semester, 2020. As for the students' English learning experience, most of them started learning English at younger ages: 55 students (47.8%) started at kindergarten, 51 students (44.4%) at lower grades of elementary schools. In terms of English language proficiency as measure by Oxford Online Placement Test (OOPT), near three quarters of the students (73.9%) were at or below CEFR B1 (Common European Framework of Reference for Languages). Moreover, 26.1% of the students had heard about HOTS before and about 25% of the students had experienced HOTS-based activities.

The HOTS-based Technical Reading Instruction of IEEFE

The dual goals of Freshman English program for College of Information and Electric Engineering (IEEFE) are: (a) the development of personal skills and attributes as delineated in the CDIO syllabus, and (b) the enhancement of technical reading comprehension in English. In Phase 1 of the IEEFE program from year 2017 to 2019, interpersonal skills and active learning were the primary goals which have been satisfactorily achieved (Chou, Jai, & Wang, 2020). To enlarge the fruitful outcomes of IEEFE, higher-order thinking skills were added to the program goals in year 2020. Unlike in Phase 1 where oral and written presentations in English were highlighted in the course objectives, assessments in Phase 2 focused more on students' ability to think critically and to solve problems creatively.
Out of the two weekly sessions which lasted for 15 weeks, one of the sessions was devoted to technical reading in English with the reading material being compiled by Chairs of the collaborative departments of College of Information and Electrical Engineering. Topics of the reading texts were related to the latest development of technology such as autonomous driving, AI, and virus-killing masks. A main reason for the selected topics were to increase engineering

students’ interest in reading in English. In addition to teaching the reading texts, the IEEFE instructor’s responsibility was to train students’ reading strategies and higher-order skills by ways of question-and-answer strategies such as reading notes, group discussion, and group or individual question-and-answer worksheets. Teacher questioning technique was used to review, examine learning, and challenge students to do higher-order thinking. By answering the teacher’s questions, students were provided opportunities to construct meaning, solve problems, find answers, and find information. The design of questions before, during, and after the technical reading instruction was particularly crucial for activating students’ thinking skills and strengthening reading comprehension as well. Therefore, questions of the cumulative categories of Bloom’s Taxonomy incorporated with types of knowledge (Krathwohl, 2002) were posed at different stages of reading instruction for different purposes.

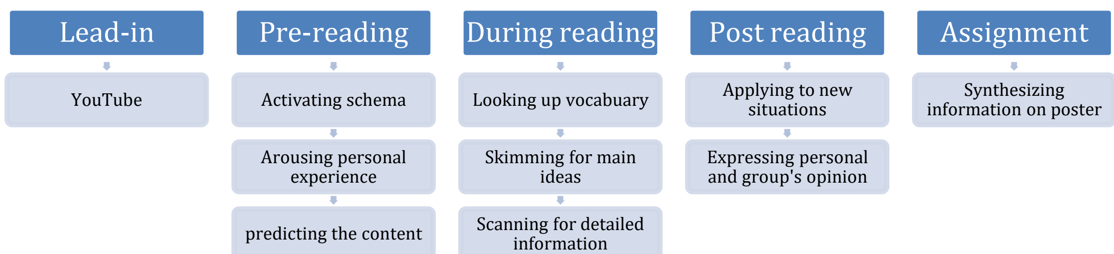

Figure 1. Purposes of questions of the reading instruction

At the Lead-in stage (Figure 1), taking the topic of *Driverless Cars* as an example, a YouTube film entitled *Salto: The cute jumping robot that opens the door for cyborg ninjas* was played to activate interest in the topic. Afterwards, two lower-order questions which combine *factual knowledge* with *understand* of Bloom’s Taxonomy were posed as followed:

- *What does SALTO stand for?*
- *Why is it important to invent a jumping robot?*

As a pre-reading activity, a question: “*Without consulting the article, try to think of 3 adjectives that closely describe the jumping robot and 3 verbs that you think the robot can do”* was posed to elicit students’ creative ideas and predictions on the topic. Later, at the *during reading* stage, a lower-level question in relation to Bloom’s category of *understand*, “*What has Salto been improving in terms of capabilities?*” was asked to encourage scanning strategy for information to ensure reading comprehension. Finally, at the post reading stage, a higher-order question which belongs to *evaluate* and *create* of Bloom’s Taxonomy was posed for students to explore beyond the topic and to communicate personal views. An example of this type of question is: *What is the future use of jumping robots?* As the unit group project, the students were asked to produce a poster (Figure 2) collaboratively on *Salto*. Having exemplified different levels of questions suitable for gradual steps of technical reading instruction, it is important to mention that various levels of cognitive strategies should be embedded within the usual content-driven lessons. Teachers can teach various levels of thinking skills and cognitive processes as they teach other content knowledge to enlarge students’ repertoire of cognitive skills for facing different learning tasks (Pintrich, 2002). Thus, different cognitive processes of Bloom’s Taxonomy are explicitly labelled and made known to the students throughout the stages of reading instruction of IEEFE to raise their awareness of both LOTS and HOTS strategies.

Figure 2. Student Project: Poster on Robot SALTO

Measure and Procedure

Following a semester's implementation of HOTS in the technical reading instruction, a survey questionnaire entitled *Engineering Students' Awareness and Adaptation of HOTS in IEEFE Technical Reading Instruction* was designed by the researchers to collect a general overview of students' perceptions of the design and implementation of HOTS-based activities. The questionnaire consisted of 48 statements based on five-point Likert scales (from *strongly disagree* to *strongly agree*). There are four parts to the questionnaire, which were: (a) background information on gender and English proficiency score obtained from Oxford Online Placement Test (OOPT), (b) awareness of HOTS-based activity design, (c) awareness of cognitive processes, (d) adaption of HOTS-based learning, and (d) perceptions of impacts of HOTS-based activities. Since concepts of thinking levels might be abstract to some students, examples of thinking activities were added to the awareness-related questions to make them more concrete. The questionnaire was administered in the final week of fall semester of 2020. In principle, descriptive statistics was used to obtain a preliminary understanding about the students' perceptions and to gain an overall view of relationships among the variables.

RESULTS AND DISCUSSION

Awareness of HOTS-based Activity Design

As aforementioned, students who act on awareness tend to learn better (Zhao et al., 2014). Accordingly, the teacher would inform the students of the level of thinking skills at the beginning of each activity to raise students' awareness of HOTS. In this study, the survey yielded satisfactory results on awareness of HOTS with item mean scores ranging from 3.79 to 4.47. First of all, the students noticed that the instructional design was different from that of the high school English course (M = 4.37, SD = .87). As for allotted class time, the students perceived that the time lengths for questioning and answering (M = 4.47, SD = .68), for looking for answers (M = 3.97, SD = .81), and for group discussion (M = 3.79, SD = .84) were all greater than that of teacher lecture. Moreover, with regard to types of questions, the students noted that the questions were at both lower and higher levels and of various cognitive categories (M = 3.92, SD = .82). A finding drawn from these *results* indicated that the students were aware that: (a) the HOTS-based activity design was different from the kind of traditional English instruction that they had experienced prior to college, (b) more class time was allotted for group discussions and HOTS activities, and (c) teacher's questions were intended to include both lower and higher orders of thinking skills. Considering that students who act on awareness tend to learn better (Zhao et al., 2014), it is thus suggested that the design of HOTS-based instruction should be introduced explicitly in order to strengthen subsequent HOTS development.

Awareness of Cognitive Processes in Class Activities

According to Zhao et al. (2014), students who know about different cognitive and metacognitive activities for learning, thinking, and problem solving will be more likely to use them. Therefore, the technical reading activities of IEEFE were designed by means of a combination of knowledge dimension and cognitive process of the Bloom's Taxonomy to ensure the depth and breadth of cognitive processes. The results on awareness of cognitive processes showed that all item means were above 4.15, and all categories of Bloom's cognitive processes were equally perceived by the students. Of all categories of cognitive processes, the students were particularly aware of questions which required: application of life experience (M = 4.46, SD = .65), discussion of personal thoughts about a point (M = 4.33, SD = .69), and synthesis of information from the text and give a presentation (M = 4.3, SD = .69). These results may imply that the students spent more time on the HOTS tasks and therefore were more impressed by them. Such a finding may indicate that not only that the students experienced different categories of cognitive processes in the class, they were also able to distinguish tasks which required lower and higher levels of thinking skills.

Adaption of HOTS-based Learning

Changes in instruction may bring about undesirable chaos if students are unaccustomed or even opposing to them (Kusumastuti, Fauziati, & Marmanto, 2019). Hence, for any program or course innovation, it is of little use without students' willingness to adapt to the change. Having been introduced to and experiencing HOTS activities, the IEEFE students expressed that they had been accustomed to the question-based instruction and that they had adapted to be evaluated formatively by how they answered higher-order questions in the class. The survey result on adaption of HOTS-based learning showed that the students had adapted to question-based activities (M = 4.13, SD = .8). In particular, they were used to student-centered instruction which allowed them to decide the most appropriate meanings for English vocabulary based on their own understanding of the technical reading (M = 4.25, SD = .85). In addition, it also showed that the students were able to cultivate active learning habits by engaging in activities which asked them to: (a) solve problems by applying their own life experience (M = 4.11, SD = .87), (b) express personal thoughts about a point in a text (M = 4.09, SD = .84), and (c) to elaborate on the rationale of the response (M = 4.09, SD = .89). Such findings are especially valuable for Taiwanese students who rarely challenge what they learn from the teacher (Chen, 2017) and who have been accustomed to passive and test-driven learning in traditional teacher-centered education.

Perceptions of Impacts of HOTS-based Activities

The next phase of the present study, in addition to exploring students' awareness of and adaptation to HOTS-based instruction, was to explore how they perceived the impact of HOTS activities. Although they only experienced a semester of HOTS activities, the students still expressed relatively positive perceptions of HOTS in technical reading instruction. They responded positively to impacts of HOTS on skills of communication (M = 3.90, SD = .91), problem solving (M = 3.87, SD = .90), and creativity (M = 3.86, SD = .94). In addition, they also considered HOTS activities helpful to enhance focal attention to class learning. Such results can be interpreted that the students had positive perceptions of HOTS activities. They also affirmed the effectiveness the HOTS approach incorporated in technical reading instruction for cultivating their higher order thinking skills.

Despite its positive responses, the results on impacts of HOTS also raise some concerns. In comparison with the mean scores of the previous sections, the item means of this section were relatively lower. Such a finding may imply certain limitations of HOTS implementation in English reading instruction. First, students' English language skills can be discouraging to the students during reading comprehension and communication in English. On average, near 75% of the students were at the elementary and intermediate levels of English proficiency as measure by *Oxford Online Placement Test*. As English-as-a-foreign-language students, the students' struggles in comprehending the reading materials, thinking critically, and expressing ideas orally and in writing in English on the reading topics may become an obstacle in conducting HOTS, which may have consequently impeded motivation and active engagement in activities. Second, unlike traditional EFL reading instruction in which students may respond passively to the teacher's explanations of vocabulary and grammar, HOTS-based activities require students to actively engage in the tasks by understanding the reading material first and then collaborating, discussing, thinking, and creating answers to teacher's questions. It can be sure that higher-order activities can be more time-consuming than lower-order activities especially for EFL students, primarily due to the fact that HOTS is more cognitively challenging and requires more student effort. As a result, class time may not always be sufficient to complete the HOTS-based procedure, which in turns may have deterred the students from being fully benefited from the teaching tasks.

CONCLUSION

The present study aimed primarily to develop a technical reading instruction model which incorporated the use of HOTS tasks to cultivate students' higher-order thinking skills in addition to English reading comprehension and communication. To gain a preliminary view of the effectiveness of HOTS implementation in IEEFE, this study was conducted to examine students' awareness, adaptation, and perceived impacts of teaching technical reading with HOTS. Findings of this study were inspiring for those who plan to implement HOTS-based activities in the classroom. Nevertheless, a limitation of this study is that the HOTS-based instruction was not long enough for the students to fully understand, adapt and benefit from it. Major findings of this study are summarized below.

First, the students were able to perceive about the HOTS-based activity design and cognitive processes, which was different from that of their high school English classes. This finding helps reinforce the necessity of introducing cognitive processes explicitly in classroom practices (Zhao, et al, 2014). Second, the students expressed that they had been able to adapt to different levels of cognitive processes ranging from lower order to higher order thinking skills. Such a finding was particularly encouraging in that, albeit their accustomed passive learning habits in the traditional exam-oriented education system, the students were still able to develop a positive attitude towards HOTS. Last, the students responded positively to the impacts of HOTS on communication, creativity, and problem-solving skills. Specifically speaking, teachers should design classroom activities and assessments which encourage and challenge students to analyze, evaluate and create new information based on the acquired knowledge. Findings of this study may open a door to future incorporation of HOTS to meet the CDIO Standard 7, integrated learning experiences, and Standard 8, active learning. With regards to CDIO syllabus goals of personal skills and attributes, this study inspires engineering educators who strive to cultivate students' creative and critical thinking (CDIO Syllabus Items 2.4.3 and 2.4.4) and communication in English (Item 3.3.1) in the class.

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