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ORIGINAL ARTICLE

Engaging Students with Intellectual Disability in Science, Technology, Engineering, and Mathematics Learning

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ABSTRACT

Recent studies show that many of the current and future careers involve some form of science, technology, engineering, and mathematics (STEM) integration. The new development of school STEM education provides opportunities for students to acquire the necessary knowledge, skills, and attitudes to face the challenges ahead. Involving students with different disabilities in STEM learning is of particular importance and usefulness because we should not deprive them of opportunities to engage in STEM fields in the future. However, how to expose students with intellectual disabilities (ID) to STEM learning have not been well explored. STEM learning can mean something different to each teacher, and how they integrate it into their classrooms may also differ. There are suggestions to use inquiry, engineering, and technology to support students with special needs. In the design of STEM learning for students who have ID, teachers from a special school constructed a 4E model of engaging, exploring, engineering, and explaining, which emphasizes inquiry and at the same time leverages technology and engineering to integrate learning content into a purposeful and informed way to improve student engagement in lessons. Lesson observations were conducted to study students' cognitive, affective, and behavioral engagement in lessons. Results showed that students with mild ID in the classes responded and worked actively, while those with moderate ID asked for more assistance. Moreover, it was found that students were less involved in explaining. This research provides a practical model and evidence of student engagement in STEM learning.

KEY WORDS: Students with intellectual disability; stem learning; student engagement; inquiry; technology; engineering

INTRODUCTION

There has been increased attention paid to science, technology, engineering, and mathematics (STEM) framed as the acronym "STEM." The focus on STEM has been both educational and occupational (Hwang and Taylor, 2016). Preparing today's students for STEM fields seems logical and functional (Miller et al., 2013). For students with an intellectual disability (ID), who have "significantly subaverage general intellectual functioning existing concurrently with deficits in adaptive behavior. And manifested during the developmental period that adversely affects a child's educational performance" (IDEA, 2018, Sec.300.8), barriers exist in providing access and evidence-based practices for success in STEM-related fields (Jimenez et al., 2010).

In Hong Kong, in the advocate of "One Curriculum for All" approach in 2011 (Fok, 2008; Li et al., 2009), special schools in Hong Kong (schools for children with ID, visual impairment, hearing impairment, physical disability, and schools for social development and hospital school) (Education Bureau, 2020) are implementing a school-based curriculum adapted from the mainstream school curriculum to address the learning capabilities of students with ID (Education Bureau, 2018). Hence, involving students with different disabilities in STEM learning is also a priority of special schools in Hong Kong not to deprive students of learning opportunities for the future. Among the four disciplines of STEM, two of them, science and mathematics, have always been a part of the school curriculum. It would be more productive if technology and engineering, which were originally not included in the school curriculum, could be integrated with mathematics and science in a purposeful way.

Stem Learning for Students with ID

Inquiry approach to learning

Cultivating students' inquiry abilities is important. To solve STEM problems, the ability to inquire, design, and build should be developed (Lin et al., 2020). So et al. (2017) also found that common and important STEM activities are related to the process of science inquiry. As suggested by Miller (2012), inquiry process standards integrate both self-determination and problem-solving skills, and can provide both functional and content instruction for students with an ID. Yet, STEM for students with ID is limited by several factors including the low expectations of the students, lack of instructional strategies, and lack of models for adapting the integrative content (Klimaitis and Mullen, 2021).

Although the development of inquiry is often oriented to the normal learning abilities of students, there is an increasing number of studies which acknowledge the possibilities of

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employing inquiry for ID students. In Lee and So's (2015) study with practicing teachers from special schools, they identified some aspects of concern to facilitate inquiry learning opportunities for ID students. The concerns were generic scenarios which helped motivate the students to participate; simple inquiries were believed to be more meaningful for the ID students; the focused content enhanced the ID students' concentration on learning; small and simple tasks helped the students acquire the connection of concepts; a mixed teaching mode helped scaffold student learning; differentiated activities accommodated students' needs and enhanced their participation; and multi-sensory stimuli enhanced their understanding.

Moreover, a teacher-guided approach to inquiry which provides explicit guidance with systematic practice works well with novices or students with limited prior knowledge and cognitive skills of learning (Clark et al., 2012; Yore et al., 2008). The teacher-guided approach provides a well-planned and supportive inquiry experience to increase student engagement and allows students to gain deeper understanding of knowledge (Kuhlthau et al., 2007; Palincsar et al., 2000). Students are provided with concrete materials, specific methods, and sequential phases of investigation such as a learning cycle (McComas, 2014).

The essential features of classroom inquiry are that students engage in a question; provide evidence in response to that question; explain from their evidence; make connections to scientific knowledge; and communicate and justify their explanations (NRC, 2000). One common inquiry model known as the 5E's (engagement, exploration, explanation, elaboration, and evaluation) is accepted as best practice in science education (Bybee et al., 2006), and is part of STEM learning. Burke (2014) proposed the 6E Learning, including engaging, exploring, explaining, engineering, enriching, and Evaluating to implement the STEM education concept of comprehensive, interdisciplinary education by emphasizing the cultivation inquiry abilities in interdisciplinary STEM classrooms. However, evaluation requires high-order thinking, which may be difficult for students with ID.

Role of science and mathematics

Science education, a focus of the school curriculum, is positioned to cultivate students' curiosity, enhance their scientific thinking, as well as to prepare them to be social participants and life-long learners (CDC, 2001). It was reported that individuals with ID could acquire science concepts and use science knowledge if they received appropriate science education (Özgüç and Cavkaytar, 2014). Jimenez et al. (2012) reported success in teaching students with a moderate ID to use inquiry science skills. Browder et al. (2012) also reported using integrated inquiry when teaching science content standards to secondary students with moderate to severe developmental disabilities on the topic of earth science. Spooner et al. (2011) proposed that inquiry should be a major focus of science instruction for students with an ID and should focus on problem-solving skill sets compared to memorization of science vocabulary that holds less functional value.

It is noted by Stohlmann (2018) that mathematics has not been the focus in STEM integration. Kelley and Knowles (2016) suggested involving mathematical thinking in STEM practices. It was found in So's (2013) study that mathematics and science are closely connected in science inquiry, as mathematics plays the role of collecting data, processing data, and representing data during science inquiry.

Leveraging technology and engineering

Technology is now prevalently applied in the educational environment; however, students with ID still have insufficient access to such technologies in most cases (Wehmeyer et al., 2004). According to Lindquist and Long (2011), technology is an essential component in students' academic lives, and if used efficiently, it can benefit students' learning experience. Bond and Bedenlier (2019) valued the "inherent role" technology plays in education as well as its potential to engage students. With the increasing needs of STEM education, technology is also regarded as a leverage of knowledge across multiple fields of study (Herschbach, 2009).

The importance of integrating engineering education into primary and secondary education curricula is highlighted in the document of *Engineering in K-12 education: understanding the status and improving the prospects* (NRC, 2009). Yet, as NRC (2009) noted, engineering always embraces science, technology, and mathematics, and is not performed in isolation in the real world, in defining the problem to be solved, creating, and testing the solution and refining the solution (So et al., 2017). Therefore, it is unlikely that students are not exposed to learning related the engineering field during their K-12 studies.

Without meaningful instruction and research, it may not be possible to identify relevant instructional strategies and foci for preparing students with an ID to gain relevant life skills in the areas of problem solving and actively interacting with the world around them (Miller, 2012). Computational Thinking is applied to describe the "process that involves solving problems, designing systems, and understanding human behavior" (Angeli and Giannakos, 2019, p. 2).

Taking into consideration the lack of technology and engineering in STEM, which do not exist in the current Hong Kong school curriculum, the leveraging of technology and engineering in planning STEM learning is necessary. Technology and engineering are always included into science and mathematics curricula and it may be overlooked (Yip and Chan, 2019). Thus, there is a low frequency of technology adoption and integration for education (So et al., 2018) and engineering does not exist as a separate subject or course in Hong Kong. In a review to find the common activities in technological learning for primary students, So et al. (2017) identified the two categories of "use of technology" and "innovation and safe use." Teaching students how to code in K-12 classrooms is considered as one of the major keys to

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promoting engineering education in the future (Wong et al., 2015). English (2017) noted that schools play a limited role in promoting engineering education, resulting in its remaining the silent member of STEM education, particularly in elementary and secondary level. Kelley and Knowles (2016) viewed engineering design as a situated context and platform for STEM learning which connects all four STEM disciplines and integrates STEM content with a systematic approach.

Students' engagement in learning

Student engagement has been a concern of researchers (Fredricks et al., 2011) and is considered an important correlate of academic success (Le Lant and Lawson, 2019). It is recognized as being necessary for students to achieve well academically.

Le Lant (2015) and Guthrie and Davis (2003) observed that when students thought a task was too difficult or perceived an error had been made, they would engage in avoidance behaviors while attempting to side-track the teacher from the task. Information gathered on student engagement behaviors can help drive changes that will enhance student learning experiences (Reschly and Christenson, 2012). Recently, Bond and Bedenlier (2019) found that the role that digital technology plays in affecting student engagement is a particular area of interest, recognizing the inherent role that technology now plays in education, and the potential it has to engage students.

The situation of students with disabilities is of concern because, as Palmgren et al. (2017) argued, students with special needs are largely under-represented in the literature on student engagement. Much of the student engagement research has focused on upper elementary school years and beyond, with less attention given to young students and those with intellectual or other disabilities. Much student engagement research is centered on the perceptions of students via self-assessment or teacher questionnaires (Le Lant and Lawson, 2019). For young students, particularly those with ID, self-assessment can be problematic due to their disability. Teacher questionnaires can also be difficult to administer to such students, as often the engagement behaviors or processes to be identified are internal.

According to the conceptual framework of Bond and Bedenlier (2019), students' engagement commonly consists of three dimensions: Cognitive, affective, and behavioral. Bond and Bedenlier (2019) referred cognitive engagement (CE) to "deep learning strategies, self-regulation, and understanding" (p. 13), affective engagement (AE) to "positive reactions to the learning environment, peer and teacher, as well as students' sense of belonging and interest" (p. 13), and behavioral engagement (BE) to "participation, persistence, and positive conduct" (p. 13).

This research was designed to study ID students' engagement in STEM learning with focuses on scientific inquiry and the leveraging of engineering and technology. The main research question was: How are ID students cognitively, affectively, and behaviorally engaged in STEM learning?

METHODS

Participants

A whole class of ten students aged between 10 and 12 years who are identified with ID in a special school participated in this study with informed consent. All participants were free to participate in and quit this study. Moreover, the researchers have already established a working relationship with the special school community for years. Five of them were regarded as having mild ID and the other five as having moderate ID. The Department of Health of Hong Kong (2017) stated that "Children with mild ID can learn some degree of academic skills and receive prevocational training, while children with moderate ID may be able to learn functional skills of daily living to become independent in familiar surroundings" (p. 2). Students were arranged into three groups with one or two mild ID members and one or two moderate ID members in each group (Table 1). To facilitate data analysis, students with mild ID were named as Herman, Henry, Helen, Hillary, and Harrison (all names are pseudonyms). Students with moderate ID were named as Matthew, Michael, Mary, Moses, and Melody.

Lesson Design

The conceptual framework of lesson design is presented in Figure 1. The lesson design emphasizes inquiry and at the same time leverages technology and engineering, consisting of

Table 1: Grouping of students of different abilities

Groups	Mild ID	Moderate ID
Group 1	Helen	Mary
Group 2	Herman and Henry	Matthew and Michael
Group 3	Harrison and Hillary	Melody and Moses

ID: Intellectual disabilities

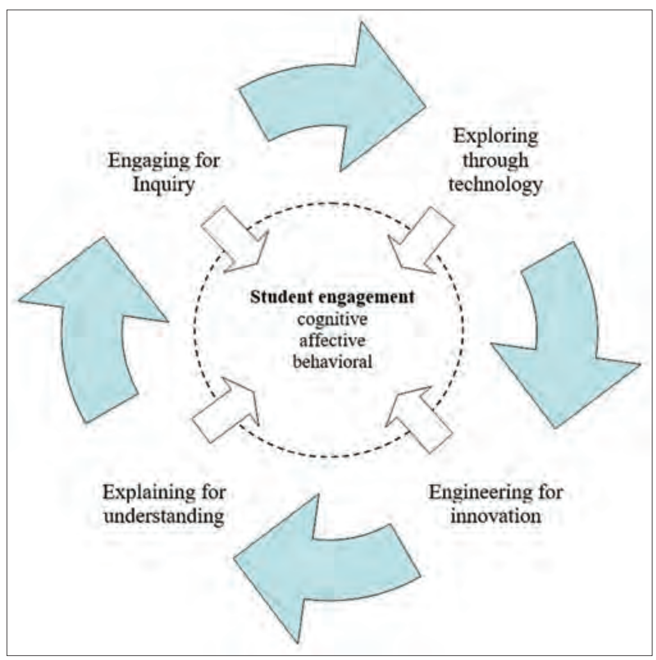

Figure 1: The conceptual framework of lesson design

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engaging in inquiry, exploring through technology, engineering for innovation, and explaining for understanding, which can be concluded as a 4E model. Through engaging in the 4E process, it is expected that student engagement improved during STEM learning.

The topic for STEM learning design was the design of an "Alarm" under the topic "The Opium War." It is part of the General Studies curriculum, a core subject at the primary level integrating science education, technology education, and personal, social, and health education, which is suggested in the curriculum guide (CDC, 2017) to provide students with appropriate STEM learning opportunities. As shown in Table 2, the learning activities were arranged into two lessons, with each lesson lasting for a total of 60 min, separated by recess time and breakout time for students. The two lessons were arranged for 2 consecutive weeks. Different tasks were assigned to students with varied abilities to explore and experience the design of the "Alarm System." Those students with mild ID were provided with a notebook to work with the coding, while the moderate ID students were given worksheets and coding cards to facilitate their learning of coding.

Data Collection and Analysis

A qualitative research methodology was used with observations of students during the lessons. To protect the privacy of students who were receiving special education services and minimize the potential effect for their daily life, the observations were recorded by the research team using field notes and all names are pseudonyms only. And only our research team can access the data and this data cannot be used for other purposes.

To have rich information about ID students' engagement in the STEM activities focusing on inquiry and with a leverage of engineering and technology, the analysis was conducted qualitatively with reference to Bond and Bedenlier's (2019) indicators of student engagement, which can be used to observe or measure the three dimensions of cognitive, affective, and behavioral engagement.

Le Lant and Lawson's (2019) study introduces a student engagement checklist developed to rate the observable task, and the affective and CE behaviors of students with ID when working on academic tasks. Accordingly, the analysis also made reference to Le Lant and Lawson's (2019) student engagement checklist for use with ID students with behaviors that identify cognitive, affective, and task engagement. In the checklist of Le Lant and Lawson (2019), CE behaviors focused on four observable behaviors: Selection, elaboration, monitoring, and problem solving, representing the range of behaviors across the cognitive elements of a learning activity. AE behaviors comprised the following behaviors: Whether the student displayed an interest in the task presented; whether they displayed evidence of emotion through their facial expressions; and whether they continued or persisted with the presented task once faced with a problem or if they perceived they had made an error. Task engagement behaviors focused on whether the student was performing the task quickly and without interruption and was maintaining eye contact with the task materials or teacher. The number of observations for these behaviors under cognitive, affective, and task engagement for all

Table 2: The 4E Model of lesson design

4E Model	First Lesson (60 min)	Second Lesson (60 min)
Engaging for Inquiry	The teacher recapped the causes, processes, and consequences of the Opium War studied in previous lessons, and engaged students in envisaging what and how contemporary technologies could be used to increase the country's defense capabilities with an alarm security system (10 min)	The teacher engaged students in continuing with their work from the previous lesson by summarizing the use of coding the Micro: bit device to input the commands of "repeat unlimited times," "if... then" and "variable," and the functions of these commands (10 min)
Exploring through Technology	The teacher introduced the commands of "When Started" and "Variable" to the students, and combined the code to turn off the RGB LED bar and buzzer when the alarm system was started (20 min) Afterwards, the "repeat unlimited times" and "if…then" commands were introduced to make an alarm system with the functions of repeatedly detecting the surroundings, and the buzzer and RGB LED bar turning on when someone was approaching (12 min)	This was followed by a problem raised by the teacher for students to explore when the command of "repeat unlimited times" was used, the alarm system would not stop. Afterwards, the teacher introduced the new command of "when A button is pressed" to make a "stop button" for the alarm system. (20 min)
Engineering for Innovation	Under the teacher's guidance to recall the learning of coding, students were arranged to use the Micro: bit coding device to design and make an alarm system. Those students with mild ID were guided to input different sound effects for the buzzer. (15 min)	Students were then engaged in hands-on and minds-on opportunities to assemble and test the alarm system, functioning when the infra-red sensor detected approaching objects; the connected RGB LED bar and buzzer would be on. (22 min)
Explaining for Understanding	At the end of the lesson, students were encouraged to conclude the functions of coding command. (3 min)	At the end of the lesson, students were encouraged to suggest how and where the designed alarm could be used in their school campus. The hints provided by the teacher were to alert students approaching exits which were not allowed. Students were able to name the exits on the school campus and to comment on its effectiveness. (8 min)

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students was counted. Specifically, students' engagement in verbal and non-verbal forms including their questions and answers, facial expressions, and actions were recorded to identify the relevance and quality of their engagement, and were categorized into cognitive, affective, and behavioral engagement, and coded through repeatedly observing lesson records.

Findings

Based on the observation of students throughout the two lessons, the individual student's engagement in each group was analyzed and frequency was counted as indicators of their cognitive, affective, and behavioral engagement. The following reports the different degrees of the students' engagement in the two lessons with the four phases of engaging in inquiry, exploring through technology, engineering for innovation, and explaining for understanding.

Phase 1 – Engaging for Inquiry

The two lessons started with "Engaging for Inquiry," which was mostly about the teacher using questions to involve students in the lesson and to improve their interest in learning. Students were required to follow the teacher's questions and guidance for inquiry (Table 3). It was observed that Mild ID students were more concentrated on the teacher guidance and had more positive interactions or actions with the teacher or peers with higher level CE. Most moderate ID students just had some basic CE, such as listening or clapping. Mild ID students had higher level CE along with various types of affective and behavioral engagement. Below are more details about students' engagement in the two lessons.

In lesson 1, with high frequency of basic CE of understanding, Helen of Group 1 was observed to follow through the questions and had positive interaction with the teacher AE by answering the teacher's questions behavioral engagement (BE), while Mary of the same group was not observed to exhibit any actions.

Herman and Henry of group 2 had similar engagement by answering the teacher's questions; for example, Herman said that the alarm system had a sensor, then Henry followed through and answered that the alarm system would turn on when somebody was passing. Both Herman and Henry had CE of understanding, AE of positive interaction with the teacher, and BE of interaction and action. Matthew tried to describe the function of the alarm system, saying that the light would turn on when someone was passing with understanding (CE), follow through (CE), and positive interaction with the teacher (AE) and interaction (BE). Michael in this group did not have any engagement in this phase.

Only Harrison of group 3 was observed not to be engaged. Hillary of the same group was observed to touch the command card correctly when shown by the teacher with cognitive understanding and behavioral action. Melody was observed to listen with concentration (CE) and attention (BE), while Moses presented his emotion with excitement (AE) by clapping his hands (BE).

Lesson 2 continued with tasks of the previous lesson by summarizing the input coding commands. Helen of Group 1 answered the teacher's question on the meaning of "TRUE" and "the sound effects can be chosen by oneself" (CE of understanding, AE of positive interaction with the teacher, and BE with interaction). Helen also corrected her classmate's answer by raising her hand and explaining the reason (CE of learning from others, AE of positive interactions with peers, and BE with interaction). Mary attempted to answer the question about the meaning of code, so she had CE of understanding, showed AE of positive interaction with the teacher, and BE of interaction and action.

Herman and Michael of Group 2 were not observed to have any engagement. By answering the teacher's question and correcting a classmate's answer about the buzzer giving a warning sound, Henry exhibited basic understanding (CE),

Table 3: Frequencies of student engagement in "Engaging for Inquiry"

Student engagement	Indicators	Mild ID students	Moderate ID students
Cognitive Engagement (CE)	Understanding/trying to understand	9	6
	Focus/concentration	1	3
	Follow through/Thoroughness	2	2
	Integrating ideas	1	1
	Teaching peers	1	0
	Critical thinking	2	0
	Justifying decisions	1	0
Affective Engagement (AE)	Interaction	5	4
	Action	7	2
	Staying on questions/tasks	3	0
	Attention	1	2
Behavioral Engagement (BE)	Positive interactions with teacher	8	2
	Positive interactions with peers	2	1
	Positive attitude about learning	2	1
	Excitement	0	1

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had positive affective interaction with the teacher, and had behavioral interaction. Moreover, Matthew shook his head, thinking that if the time was set to "repeat unlimited times" it was equal to never stop (CE of understanding, thoroughness and BE of action and staying on questions) and found the commands from the instruction list (CE of understanding, focus/concentration, and BE of action and staying on questions).

Thus, Hillary, Harrison, and Moses of Group 3 showed their positive attitude toward learning (AE) by listening to the explanation (CE of focus/concentration and BE of attention) and pointing to the codes. Melody hoped to discuss with classmates with CE of understanding, integrating ideas and learning with peers, and presented AE of positive interaction with peers and interaction, and staying on task of BE.

Phase 2 - Exploring through Technology

The phase "exploring through technology" mainly provided students with opportunities to explore STEM through technology which included two activities in each of the two lessons (Table 4). It was found in the first lesson that all mild ID students had high frequency of CE of understanding and focus/concentration by following through the teacher's instruction for coding, and had positive affective interaction with the teacher, and action, interaction and staying on task in behavioral engagement. Moderate ID students also showed high interaction when they stayed on task at the behavioral level. Students in the second lesson were making use of a technological tool (Micro: bit) with the guidance of the teacher, and had interactions with the teacher/peers. Mild ID students showed an understanding of the recommended codes, and then explained how the codes connected with each part. Students with moderate ID had some simple CE, positive affective interaction with the teacher and peers, and then they showed their positive attention to the task at the behavioral level. The following are more detailed records of students' engagement in the two lessons.

In lesson 1, when the teacher introduced the first activity "When Started" and "variable" (buzzer, RGB) commands, Helen of Group 1 told her classmate to concentrate with CE of teaching peers and had a sense of well-being (AE) and supporting peers (BE). Then, she entered the code (CE of focus/concentration and understanding, BE of interaction and action) under the teacher's guidance (AE of positive interaction with the teacher) and answered the teacher's question (AE of positive interaction with the teacher and BE of interaction and action) about the alarm light with cognitive understanding and thoroughness. Mary responded (AE of positive interaction with the teacher and BE of interaction) that the code of "FALSE" means the alarm system would keep "silent" (CE of understanding) and then did the worksheet by herself with CE of focus/concentration, understanding, and thoroughness, and had BE of action and staying on task.

Both Herman and Henry of Group 2 successfully followed the teacher's instructions for coding with the notebook computer, showing their CE of focus/concentration, understanding, and BE of staying on task. Matthew selected "FALSE" in response to the teacher's question (AE of positive interaction with the teacher, BE of interaction) and described that "I don't want

Table 4: Frequencies of student engagement in "Exploring through Technology"

Student engagement	Indicators	Mild ID students	Moderate ID students
Cognitive engagement (CE)	Understanding/trying to understand	27	26
	Focus/concentration	17	6
	Follow through/Thoroughness	10	3
	Integrating ideas	4	6
	Learning from peers	4	5
	Teaching peers	1	1
	Positive perceptions of teacher support	1	0
	Justifying decisions	1	0
	Doing extra to learn more	1	0
	Preference for challenging tasks	1	0
	Self-regulation	1	0
Affective engagement (AE)	Positive interactions with teacher	14	12
	Positive interactions with peers	7	6
	Curiosity	4	6
	Positive attitude about learning	3	0
	Interest	1	0
	Enjoyment	0	1
Behavioral engagement (BE)	Interaction	25	21
	Action	18	12
	Staying on questions/tasks	16	8
	Attention	3	3
	Asking the teacher for help	2	0

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to turn on the RGB light at first" (CE of justifying decision and BE of staying on task). Michael discussed how to code with his classmate (CE of understanding, integrating ideas, and learning from peers) and checked the worksheet with his classmate (CE of teacher, self, and peers), so Michael performed positive affective interaction with the teacher and behavioral interaction.

Both Harrison and Hillary in Group 3 answered the teacher's question (CE of understanding, AE of positive interaction with the teacher, and BE of interaction and action). However, Hillary observed the teacher's teaching with attention as well (CE of focus/concentration, AE of interest, and BE of attention), and then did the coding with peer discussion (CE of understanding, concentration, integrating ideas, and learning from peers, AE of positive interaction with the teacher and peers, BE of action and interaction). Melody tried to do the coding tasks (CE of understanding, BE of action) with a smile (AE of enjoyment and BE of attention). She also did the coding tasks with observation (CE of focus/concentration, understanding, AE of positive attitude about learning, and BE of action), recording (CE of focus/concentration and BE of staying on task) and then discussed with peers (CE of understanding, integrating ideas and learning from peers, AE of positive interaction with peers, and BE of interaction).

During the second activity of "repeat unlimited times" and 'if…. then' commands, Helen of Group 1 answered the teacher's question about the meaning and position of the code of "repeat unlimited times" (CE of understanding, thoroughness, AE of positive interaction with the teacher, and BE of interaction, action). Mary corrected her classmate (CE of teaching peers, BE of interaction, and action) about the meaning of the logic code, "TRUE," which represented that the alarm system would ring.

Herman and Henry of Group 2 used the notebook computer to follow the teacher's instruction for coding successfully with CE of focus/concentration and understanding and had BE of staying on task. Matthew and Michael also followed the teacher's question (AE of positive interaction with the teacher), when the buzzer command was changed from "FALSE" to "TRUE," the buzzer would "buzz" (CE of understanding and thoroughness, and BE of interaction and action). However, Michael did the worksheet by himself individually with CE of understanding, AE of positive attitude about learning, and BE of staying on task.

Harrison of Group 3 asked the teacher to explain the color of the light with cognitive understanding and thoroughness. He had AE of positive interaction with the teacher, curiosity and action, interaction and asking the teacher for help behaviorally as well. Harrison did the worksheet (CE of thoroughness and BE of staying on task). Harrison, Melody, and Moses all answered the teacher's question (CE of understanding, AE of positive interaction with the teacher and BE of interaction and action), while Hillary listened carefully and watched the screen by CE of focus/concentration.

In lesson 2, students were required to experience two group activities about programming buzzer sounds. During the first activity, Helen of Group 1 was not only active in AE of positive interaction with the teacher, such as answering the teacher's question (CE of understanding, BE of Interaction, and Action) and telling the teacher which code should be used (CE of understanding, focus/concentration, critical thinking, integrating ideas, and BE with interaction), but also had AE of positive interaction with peers and BE of interaction by trying different sound effects with classmates (CE of integrating ideas, critical thinking, and learning with peers), correcting her classmate's coding error (CE of focus/concentration, thoroughness, critical thinking, and teaching peers), and explained why the light code should be set to "black" (CE of justifying decision). She also showed AE of interest or curiosity and BE of action and staying on task through coding by herself (CE of understanding), exploring how to stop the sound effect with a computer (CE of thoroughness) by adding different codes (CE of doing extra to learn more, and preference for challenging tasks). Mary did the worksheet and coded under the guidance of the teacher (CE of understanding, AE of positive interaction with the teacher, BE of interaction, and staying on task), and then found the bug by herself and corrected it (CE of understanding, integrating ideas, critical thinking, and BE of action).

Three students of Group 2 showed their AE of positive interaction with the teacher and BE of interaction; for example, Herman and Henry discussed and chose their favorite music with instructions (CE of understanding, thoroughness, and critical thinking) and Matthew discussed with his classmate how to build a coding flowchart and then asked other students for their opinions (CE of understanding, integrating ideas, and learning with peers). Only Michael was not observed to have any engagement.

Harrison of Group 3 raised his hand to study the code and listened to the explanation with cognitive focus/concentration and then had positive interaction with the teacher and interest (AE) and action, staying on task and paying attention (BE). Hillary, Melody, and Moses had AE of positive interaction with their peers, or the teacher as follows: Hillary followed the instruction to answer the teacher's question (CE of understanding) and actively sought help from the teacher (CE of positive perceptions of teacher support). Melody answered the teacher's question and selected the code under guidance with CE of understanding. She also had discussion with peers with CE of understanding, integrating ideas, and learning with peers. Moses also answered the teacher's question with CE of understanding. Otherwise, Hillary stopped her classmate from making trouble (CE of self-regulation).

Mild ID students of three groups were able to frequently interact with the teacher and peers with AE and constant actions by staying on task in the behavioral aspect. Four students with moderate ID, except for Michael of Group 3, were observed to follow through the coding using the technology tool.

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During the second activity with the introduction of Micro: bit functions, namely ‘When the A button is pressed’, Helen of Group 1 asked the teacher whether the code she had made was correct with CE of positive perception of teacher support, and had AE of positive interaction with the teacher, and behavioral interaction. With CE of thoroughness, she also tried other codes (AE of curiosity, BE of action, and staying on task). Meanwhile, Mary just did coding with CE of understanding, focus/concentration, and BE of staying on task.

Herman of Group 2 focused more on the coding task, so he presented BE of action and staying on task by entering the code (CE of understanding) and tried different sounds in the code (AE of curiosity). He said the command could be found in “variable” as well (CE of understanding, AE of positive interaction with the teacher, and BE of interaction). Thus, Matthew discussed the division of labor with other classmates (CE of understanding, integrating ideas, AE of positive interaction with peers, and BE of interaction). Neither Henry nor Michael had any observed actions.

Harrison, Hillary, and Melody in Group 3 had AE of positive interaction with the teacher and BE of interaction by raising their hands to ask questions (CE of positive perception of teacher support) and answering questions (CE of understanding). Hillary had AE of positive interaction with the teacher and peer. She discussed the code with her classmate and the teacher (CE of understanding, integrating ideas, learning from peers, positive perception of teacher support, and BE of interaction). Some students also had other types of engagement. Harrison watched the teacher’s demonstration and Moses watched a classmate coding (CE of focus/concentration and BE of attention/focus). Hillary and Melody did the coding by themselves with CE of understanding and BE of action.

Phase 3 – Engineering for Innovation

In this phase, students were offered the opportunity to apply concepts, to practice, and to combine the commands to engineer the alarm system (Table 5). Engineering design was considered as an important part in this phase, as students needed to combine the command codes, input the sound effect of the buzzer, and combine the Micro: bit alarm on the online platform, and then connect each part of the alarm. Students with moderate ID were assigned to tasks of the lower cognitive load such as building the code card, decorating, and associating with peers, whereas students with mild ID were required to do complex tasks with higher order thinking skills, such as coding on the computer and assembling the alarm system. However, students with moderate ID also showed unexpected and outstanding performances than normal engagement in this phase as students with moderate ID are often required to grasp functional skills only. Students with moderate ID are mostly required to do basic level engagement, such as understanding, concentration, and doing some easy hands-on activities in class setting. Yet, students with moderate ID in this phase also presented some higher-level engagement such as correcting errors, discussing with others, having frequent positive interactions with the teacher and peers.

In lesson 1, there was only one activity about combining the code of the above commands, such as explanation of code. Students of Group 1 followed through the teacher’s guidance. Helen used the computer and entered the code (CE of understanding, BE of staying on task) and then answered the teacher’s questions instantly (CE of understanding and thoroughness, AE of positive interaction with the teacher, and BE of interaction and action).

Students of Group 2 focused on operation of the code. Herman successfully changed the buzzer command from “FALSE” to

Table 5: Frequencies of student engagement in “Engineering for Innovation”

Student engagement	Indicators	Mild ID students	Moderate ID students
Cognitive engagement (CE)	Understanding/trying to understand	11	16
	Focus/concentration	4	3
	Follow through/Thoroughness	1	0
	Integrating ideas	2	2
	Learning from peers	0	2
	Teaching peers	3	1
	Critical thinking	1	0
	Positive perceptions of teacher support	3	0
	Justifying decisions	0	1
Affective engagement (AE)	Positive interactions with the teacher	7	8
	Positive interactions with peers	3	3
	Curiosity	2	2
	Positive attitude about learning	1	1
	Interest	0	1
Behavioral engagement (BE)	Interaction	8	8
	Action	7	8
	Staying on questions/tasks	6	7
	Attention	1	3
	Asking the teacher for help	0	1

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"TRUE" with cognitive understanding and focus/concentration and behavioral staying on coding. Henry changed the color of the RGB light from "BLACK" to "RED" through coding with high CE of integrating ideas and critical thinking. Matthew and Michael were assigned to some simple tasks. For example, Matthew chose the right code card (CE of understanding and BE of action and staying on coding) whereas Michael cooperated with classmates and answered the teacher's question about the color of the light (CE of understanding, learning with peers, AE of positive interaction with peer and teacher, and BE of action and interaction).

Hillary of Group 3 coded herself under guidance with cognitive understanding, focus/concentration and then had behavioral engagement of action and staying on task. Melody of Group 3 was interested in the coding. She raised her hand to answer a question and discussed the code with the teacher by CE of understanding, focus/concentration, and integrating ideas. She showed positive affective interaction with the teacher and had BE of action and interaction. Thus, Melody studied the code and discussed lighting colors with classmates (CE of focus/concentration, learning from peers, AE of interest, and positive interaction with peers, and BE of Interaction).

In lesson 2, during the engineering phase of the group activity with the combined Micro: bit alarm, Helen of Group 1 assembled and tested the Micro: bit (CE of understanding, focus/concentration, and BE of action), then she explained why the Micro: bit kept ringing and filled the worksheet under guidance with cognitive understanding and integrating ideas, and had positive affective interaction with the teacher and behavioural action. Helen also tried to teach her classmate how to stop or operate the Micro: bit (CE of teaching peers, AE of positive interaction with peers, and BE of interaction). Mary of Group 1 installed the sensor, pointed out the positive and negative poles, and decorated the card box by CE of understanding, and had BE of action, attention, and staying on task.

Both Herman and Henry of Group 2 failed to complete the coding and needed the teacher's guidance, so they performed positive cognitive perceptions of teacher support, had AE of positive interaction with the teacher, and BE of interaction. Matthew and Michael were observed not to be engaged.

However, students of Group 3 engaged actively in the activity. Harrison watched the demonstration (CE of focus/concentration, AE of curiosity, and BE of attention and staying on task) and coloring (BE of staying on task). Hillary took the initiative to assemble the Micro: bit with CE of understanding, AE of positive attitude about learning, and BE of action and staying on task. She also asked the teacher for help with positive cognitive perceptions of teacher support and had BE of positive interaction with the teacher and asking the teacher for help behaviorally. Melody of Group 3 raised her hand to answer a question and then sought help from the teacher (CE of understanding, AE of positive interaction with the teacher, and BE of interaction and action). Then, she studied the position of the light and recording with CE of understanding and focus/concentration, AE of curiosity, and BE of staying on task and action. Moses of Group 3 tried to assemble the Micro: bit under the teacher's guidance and questions (CE of understanding, AE of positive interaction with the teacher, and BE of action and interaction).

Phase 4 - Explaining for Understanding

The last part of the two lessons involved students in "Explaining for Understanding" (Table 6). Students were required to conclude, communicate, and justify their thoughts, and then they also tried to suggest how to apply the design in school life by transferring concepts to more complex problems. In this phase, it was found that mild ID students constantly reflected their focus, thoroughness, critical thinking, and integrating ideas with interaction with the teacher from a cognitive perspective. They focused more on positive affective interaction with the teacher and then interaction and action by behavioral engagement. However, students with moderate ID just showed their concentration, while Moses tried to teach his peers cognitively. They had positive interaction with the teacher and peers with enjoyment and curiosity in the affective aspect. For behavioral engagement, appropriate interactions and attention were found with simple actions. The following are some details about the students' engagement in this phase.

In lesson 1, students were required to conclude their understanding of the meaning of the code they used. Helen and Mary of Group 1 did not present their opinions in this part. For group 2, only Herman replied to the teacher, saying that "the sensor set to detect was on the negative pole. If something is detected, the buzzer will sound and the RGB light will glow" (CE of integrating ideas, AE of positive interaction with the teacher, and BE of interaction).

Hillary of Group 3 answered questions and tried to prompt others to answer the question (CE of integrating ideas, AE of positive interaction with the teacher and peer, and BE of interaction supporting and encouraging peers). Melody also presented understanding in terms of CE, showing her positive interaction with the teacher in AE, and then responded to the teacher with action in BE. Moses did not have any actions. Mild ID students tried to integrate their ideas cognitively and had positive interaction with the teacher and peers in AE and then provided support and encouragement to peers with interaction in BE. However, students with moderate ID were not active in this task in terms of BE.

In lesson 2**,** the teacher concluded the code that they had studied in these two lessons, and then encouraged students to recommend the place to apply the alarm system in the school.

Helen of Group 1 answered the teacher's question logically; for example, when the teacher asked, "What is the design of your alarm system." She responded that "There are different voices." Moreover, the teacher asked "Where should I use the alarm system," Helen replied, "School! Garden! There will be enemies" (CE of understanding, thoroughness, focus/

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Table 6: Frequencies of student engagement in "explaining for understanding"

Student engagement	Indicators	Mild ID students	Moderate ID students
Cognitive engagement (CE)	Understanding/trying to understand	4	5
	Focus/concentration	1	2
	Follow through/Thoroughness	1	0
	Integrating ideas	3	0
	Teaching peers	0	1
	Critical thinking	1	0
Affective engagement (AE)	Positive interactions with teacher	3	3
	Positive interactions with peers	3	1
	Curiosity	3	0
	Positive attitude about learning	0	1
	Enjoyment	0	1
Behavioral engagement (BE)	Interaction	5	4
	Action	1	2
	Staying on questions/tasks	0	1
	Attention	0	3
	Supporting and encouraging peers	1	0

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concentration, critical thinking, integrating ideas, AE of positive interaction with the teacher and BE of interaction). Mary did not have any performance in this phase. Surprisingly, none of the students in group 2 had any observed actions.

Harrison, Hillary, and Moses all had CE of understanding, and AE of positive interaction with the teacher. However, Harrison and Hillary just answered the teacher's question (BE of interaction), whereas Moses watched the demonstration and said, "It is difficult" (BE of interaction, attention/action). Another engagement was also observed, that is, Harrison coloring with CE of understanding and BE of action. Melody smiled (CE of focus/concentration, AE of enjoyment, and BE of attention/focus) and watched the teacher's demonstration (CE of focus/concentration, AE of curiosity, BE of attention/focus, staying on task). Moses did the worksheet (CE of understanding and BE of attention/focus) and then asked a classmate to color (CE of teaching peers, AE of positive interaction with a peer, and BE of interaction).

Overall Engagement of Mild and Moderate ID Students

Overall, the ID students showed active and various degrees of CE in the four phases (Figure 2). Although students with mild ID presented more high-level and diverse engagement from a cognitive perspective, students with moderate ID also had some high-level CE in the phases of "Exploring through technology" and "Engineering for innovation." Students showed more frequent CE of understanding/trying to understand, focus/concentration, and follow through/thoroughness.

Compared to the moderate ID students, mild ID students presented higher level and various types of CE, such as critical thinking, positive perceptions of teacher support, doing extra to learn more, preference for challenging tasks, and self-regulation.

Both mild ID students and moderate ID students had positive AE in the four phases. Mild ID students frequently performed more positive interaction with the teacher and peers, curiosity, and positive attitude about learning. However, moderate ID students also presented positive emotions such as interest and enjoyment. Table 4 shows the details of student AE in the four phases of STEM learning.

Mild ID students had more behavioral engagement in interaction, action, and staying on questions/tasks than moderate ID students. However, moderate ID students had more attention on their behavioral engagement. Asking the teacher for help and supporting and encouraging peers also happened in the phases of "Exploring through technology" and "Explaining for understanding." Table 5 shows the details of student behavioral engagement in the four phases of STEM learning with higher frequency of action, interaction, and staying on task.

Students showed reactive behavioral engagement in the four phases as a teacher-guided approach was applied in the lessons. Most behavioral engagement from students was stimulated by the teacher's guidance with a few proactive behaviors in the phases of "Exploring through technology," "Engineering for innovation," and "Explaining for understanding."

DISCUSSION

Most ID students in this study engaged deeply and performed well in the lessons with teacher guidance through the four phases of engaging, exploring, engineering, and explaining. This corresponded well with Palincsar et al. (2000), indicating that although students with ID lack STEM knowledge and skills, the teacher-guided approach is effective for STEM teaching and learning in classroom settings, as is the coding task. With the leveraging of engineering and technology, students with ID not only acquired problem-solving skills and linkage to real life (Miller, 2012), but also had active engagement in STEM learning.

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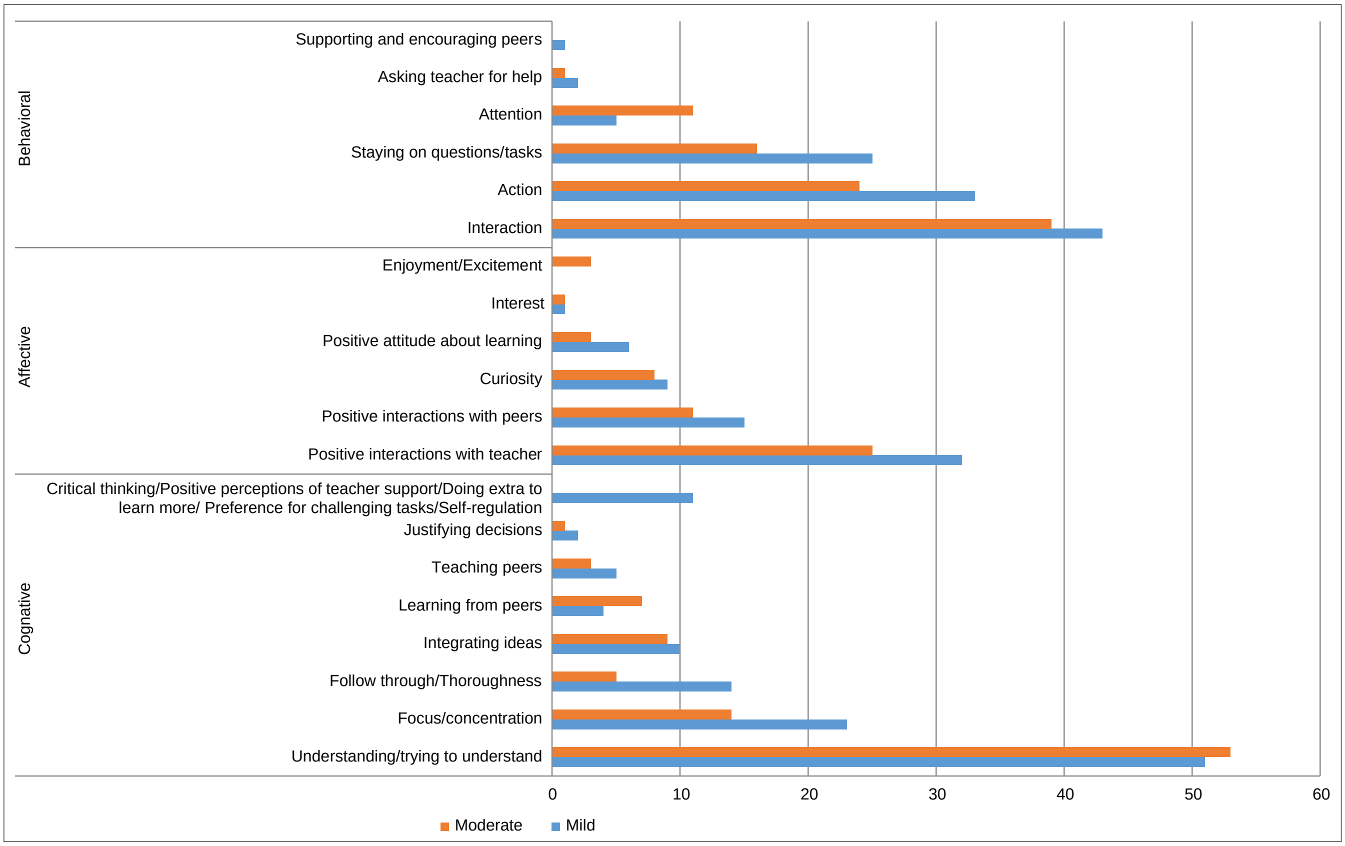

Figure 2: The overall engagement of mild and moderate intellectual disabilities students in the science, technology, engineering, and mathematics learning

Students' Active CE

Lindquist and Long (2011) found in their research that the use of technology such as digital educational tools was considered an approach to facilitate students' engagement with online primary sources. Educational technology that was easy-to-use and met the pedagogical goals was able to arouse students' enthusiasm, enhance their learning experiences, and also help them overcome the difficulties. Nevertheless, in the implementation of STEM integration in K-12, engineering is becoming a new trend and the researchers in professional associations provide some further rationales for integration of engineering into the K-12 curriculum: "(1) Engineering provides a real-world context for learning mathematics and science; (2) engineering design tasks provide a context for developing problem-solving skills; and (3) engineering design tasks are complex, and as such, promote the development of communication skills and teamwork" (Roehrig et al., 2012, p. 33). The leveraging of technology and engineering in the inquiry facilitated students' active CE.

Students' Positive AE

In the research of Hirshon et al. (2016) about designing more accessible STEM learning activities, many students with multiple disabilities appeared to need assistance from their teachers to engage more in the activity. The authors also stated that the STEM activities they joined did not afford much interaction for the students. Students with ID also desired to and are positive about interacting with others, and they may benefit from such positive AE for their STEM learning. Therefore, we should consider how to provide more chances for students with ID to express their thoughts and to interact with teachers and peers alternatively and regularly in their STEM learning. There is a need to create more versions and various STEM learning activities for ID students which incorporate student interactions and guidelines for teachers as facilitators of STEM learning (Hirshon et al., 2016).

Students' Reactive Behavioral Engagement

Wu and Huang's (2007) research indicated that low-achieving students had more engagement and participated more in conceptual discussion in a teacher-centered environment, compared to in a student-centered environment. However, when Gasiewski et al. (2012) investigated the link between students' engagement and STEM courses, it was found that students engaged more emotionally and behaviorally in STEM classrooms where the teacher used a student-centered approach and encouraged students to collaborate with others frequently. Students with higher levels of interaction and hands-on activities and application in science classrooms were found to have higher levels of emotional engagement in science (Hampden-Thompson and Bennett, 2013). Therefore, students' reactive behavioral engagement may reflect the teacher-guided approach, and how to balance the teacher-guided approach and student-centered STEM learning

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environment to boost students' proactive engagement needs further research.

CONCLUSIONS

The "one curriculum for all" in Hong Kong emphasizes that all students, including those with disabilities and special needs, should be included in meaningful STEM education and develop knowledge and skills in STEM areas. This study suggests a 4E model of STEM education to demonstrate how ID students can be actively engaged in diverse STEM learning activities. The findings reveal that ID students were facilitated with cognitive, emotional and behavioral engagement through the process of engaging in inquiry, exploring through technology, engineering for innovation, and explaining for understanding. It is expected that school and teachers consider applying the 4E model to provide more welcoming environments and resources of STEM learning for ID students so that ID students could succeed in STEM in the future.

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