Disability and Rehabilitation

ISSN: 0963-8288 (Print) 1464-5165 (Online) Journal homepage: https://www.tandfonline.com/loi/idre20

Assessing the environmental quality of an adapted, play-based LEGO® robotics program to achieve optimal outcomes for children with disabilities

Kendall Kolne, Sunny Bui & Sally Lindsay

To cite this article: Kendall Kolne, Sunny Bui & Sally Lindsay (2020): Assessing the environmental quality of an adapted, play-based LEGO® robotics program to achieve optimal outcomes for children with disabilities, Disability and Rehabilitation, DOI: 10.1080/09638288.2020.1743776

To link to this article: https://doi.org/10.1080/09638288.2020.1743776

Published online: 25 Mar 2020.

DISABILITY AND REHABILITATION
https://doi.org/10.1080/09638288.2020.1743776

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Check for updates

Assessing the environmental quality of an adapted, play-based LEGO® robotics program to achieve optimal outcomes for children with disabilities

Kendall Kolne[a], Sunny Bui[a,b] and Sally Lindsay[a,b,c]

[a]Bloorview Research Institute, Holland Bloorview Kids Rehabilitation Hospital, Toronto, Canada; [b]Rehabilitation Sciences Institute, University of Toronto, Toronto, Canada; [c]Department of Occupational Science and Occupational Therapy, University of Toronto, Canada

ABSTRACT

Purpose: This study assessed the environmental quality of an adapted, play-based LEGO® robotics program for children and youth with disabilities to determine the degree to which the activity setting supports the therapeutic goals of the program.

Materials and methods: We measured the environmental qualities of a robotics program held at a paediatric rehabilitation hospital. We observed and coded video-recordings of the robotics program, specifically one session from each of five different rooms where the program took place. Using the 32-item Measure of Environmental Qualities of Activity Settings (MEQAS), we described the place- and opportunity-related qualities of these settings.

Results: Our observations revealed that, across all five settings, the environments support the therapeutic goals of the program, including providing opportunities for social interaction with peers and adults to a great extent. We also identified several environmental features of the robotics program that support optimal outcomes for children and youth with disabilities.

Conclusions: Our findings lend support for the value of examining environmental opportunities and affordances of play-based therapy within rehabilitation.

ARTICLE HISTORY
Received 12 August 2019
Revised 12 March 2020
Accepted 13 March 2020

KEYWORDS
Environment; robotics; play; inclusion; children; youth; disability; inclusive STEM

➤ IMPLICATIONS FOR REHABILITATION

- Assessing the environmental opportunities and affordances of play-based activities using the Measure of Environmental Qualities of Activity Settings (MEQAS) is valuable for supporting positive outcomes in rehabilitation.
- The settings of an adapted LEGO® robotics program offer children with disabilities opportunities to engage in social interactions with peers and adults, to learn a new skill, and to develop a sense of self-identity.
- Optimal therapeutic outcomes of an adapted LEGO® robotics program can be supported by environmental features, including: large tables with sufficient space for two youth and one or two adult volunteers to interact at eye-level, arranged separately with enough space to invite movement between tables, in such a way that children may also interact across tables.

Introduction

Leisurely activities have a fundamental role in child development [1,2] and are recognized by the International Classification of Functioning, Disability, and Health: Children and Youth version (ICF-CY) as an important health-related component of childhood well-being [3]. Leisure activities include a range of pursuits that children participate in, beyond those mandated by school. Research demonstrates that typically developing children, and children at-risk for poor academic or life outcomes benefit from participation in organized, out-of-school leisure activities [4–7]. Such benefits include enhanced social skills, self-esteem, self-concept and identity [8], as well as improved academic, physical, social, and psychological outcomes [5,7]. Research shows that leisure environments that support exploration, socialization and learning may help to develop play skills among children with disabilities [9].

Play among youth with disabilities

The ICF-CY identifies participation in play as an important part of a child's leisure activities [3]. Play (defined here as a "transaction or activity in which we engage only because we want to, not because we feel we must" [10p. 217], is a leisure activity that is a central occupation during childhood. Understanding children's participation in play is especially important among youth with disabilities, because play can contribute to positive developmental outcomes among children with disabilities [11]. Research shows that play supports the development of children's self-determination, decision-making and problem-solving skills, and their ability to initiate and maintain communication with peers [12–16]. Additionally, play enhances engagement and learning, independent performance, and social inclusion [17,18]. However, children with disabilities have less opportunity to engage in free play, and face barriers in the type and frequency of play [15,19,20].

CONTACT Sally Lindsay slindsay@hollandbloorview.ca Bloorview Research Institute, Holland Bloorview Kids Rehabilitation Hospital, 150 Kilgour Road, Toronto, ON, M4G 1R8, Canada

Moreover, a lack of participation in play can lead to poor self-esteem and social isolation for youth with disabilities [21,22].

Play as an intervention in rehabilitation

Within the context of rehabilitation, evidence suggests that play provides a framework for intervention strategies to achieve therapy goals [23]. Play is an adaptable activity that can be used across multiple settings, and provides a context within which an intervention may be embedded [24]. Play provides a contextually-relevant and developmentally-appropriate opportunity to effectively work towards therapeutic goals, capitalizing on children's focus and interests [25]. Despite its potential benefits as a context for rehabilitation, play is markedly underused and under-investigated as a therapeutic intervention [21,26–28].

The use of play-based interventions has emerged within the context of science, technology, engineering, and mathematics (STEM) learning, specifically through the use of mediums such as LEGO® MINDSTORM® [29] and WeDo 2.0 [30] robotics programs for children and youth. Such programs incorporate STEM learning into a technology-based playful activity [31]. LEGO® is a familiar toy and, when incorporated with a robotics component, can enhance exploration and the development of play [32,33]. Increasingly, play through robotics has been used as an assisting therapy [9], and can increase the motivation and interest in STEM disciplines among children and youth with disabilities [9,34,35].

HB FIRST® Robotics, an adapted, group-based robotics program, was created to meet the needs of children and youth with disabilities engaging in STEM learning [11]. Previous research investigating the outcomes of HB FIRST® Robotics finds that children in the program reported increased interest and competency beliefs in STEM and robotics learning [36,37]. Moreover, studies show that the program facilitated the development of children's play skills, helping them move from solitary play, to more parallel and cooperative play [38]. Through a qualitative study investigating the impact of the program, children reported that the program offered a fun environment, in particular highlighting that they enjoyed the STEM content, the socialization and teamwork [11] and learning new skills [37]. Moreover, parents and staff report that the robotics program enhanced the clinical environment, supporting children in developing their therapy goals, including social skills, teamwork, communication skills, fine motor, fostering independence, and self-advocacy [11]. Thus, HB FIRST® Robotics has shown promising benefits of play-based robotics for children and youth with disabilities.

Assessing environmental quality

The optimal development of children and youth is impacted by their environmental surroundings across the lifespan, as they as they live, learn, and play [39,40]. Increasingly, researchers are investigating how environments can support positive life outcomes for youth with disabilities [41,42]. Findings from such work indicate that enriched program environments, such as afterschool programs, can lead to positive developmental outcomes for youth with disabilities [43]. Moreover, evidence suggests that child development is best supported by stimulating environments that provide youth with opportunities to make choices, interact with adults and peers, and an opportunity to experience belonging, fun, and control [44,45]. Given the evidence for the potential benefits of the adapted, play-based robotics program among youth with disabilities, it is important to examine the environmental quality of this activity setting to assess the extent to which the environmental conditions support the therapeutic goals of the robotics program.

The measure of environmental qualities of activity settings (MEQAS)

King et al. (2014) recently developed a measure with which to provide an objective assessment the quality of environments for youth. The 32-item Measure of Environmental Qualities of Activity Settings (MEQAS-32) provides an observer-rated assessment of environmental qualities of youth leisure activity settings. The concept of *activity settings* is central to the MEQAS. King et al. (2014) define "activity settings" as places where children or young people "do things" at a specific place and a specific time, like reading a book at home, or playing soccer in the park. Activity settings vary with respect to their physical, social, and aesthetic qualities, and offer a range of opportunities and affordances [46]. For example, soccer practice offers opportunity for both physical and social activity, while reading a book provides the opportunity to relax, rest, or reflect. Activity settings refer to the observable features, and any *possible* opportunities for engaging in an activity, regardless of whether or not those activities are observed [44]. The assessment of environmental quality considers the place-related and opportunity-related qualities of the activity setting. The place-related qualities include aesthetic, physical, and social qualities, while the opportunity-related qualities are all of the possible common experiences provided by an activity setting that one could reasonably observe in a short timeframe.

The MEQAS tool was developed to measure environmental qualities of activity settings for young people across various settings, in a generic sense, that is not child-specific [47]. The MEQAS was designed to have research utility, such that it may be used to ensure the presence of particular environmental qualities assumed for research on developmental properties of environmental settings or programs for young people [47]. Moreover, the MEQAS has been shown to be a feasible tool, providing a snapshot of environmental qualities based on short-term observation [48]. King et al. (2014) assessed the activity settings of leisure activities chosen by youth with disabilities, identifying the qualities of the preferred activities among these youth. Additionally, King et al. (2018) used the MEQAS to examine the environmental opportunities of a residential immersive life skills program intended to prepare youth with disabilities for adult roles. Results of this study revealed that the observed opportunities differed by session format and activity type, and indicate the utility of the MEQAS for assessing the environmental affordances of youth programs [49]. The demonstrated utility and feasibility of the MEQAS make it an appropriate tool for assessing the qualities and affordances of the HB FIRST® Robotics activity settings.

Study aims

This study assesses the environmental quality of HB *FIRST*® Robotics, an adapted, play-based LEGO® robotics program for children and youth with disabilities held at a paediatric rehabilitation hospital. This program took place within five different rooms at the hospital (i.e., the activity settings), and we use the MEQAS to evaluate the features of these activity settings. Specifically, we described the place-related and opportunity-related qualities offered by these activity settings, and determine the degree to which these settings offer conditions that support therapeutic goals of the program.

Method

Design

This research study drew on raw data from a larger study focusing on the adaptation of a group-based LEGO® robotics program for children and youth with disabilities, which includes video-recordings of each session of the robotics program [11]. For the present study, five different environments identified in the video recordings underwent observational analysis to determine MEQAS scores.

Description of the robotics program

The present study examined the activity settings of the HB *FIRST*® robotics program, an adapted, group-based robotics program created to meet the needs of children with disabilities [11,35]. This program was developed through a partnership between a paediatric rehabilitation hospital and *FIRST*® Canada (For Inspiration and Recognition of Science and Technology), a non-profit organization operating after-school robotics programs for children [50]. The goal of the program was to create an opportunity for children with disabilities to develop STEM skills, while working on therapy goals, and building self-confidence, independence, communication, and teamwork, all within a play-based setting [11,35]. The curriculum was developed by FIRST®Robotics Canada in close collaboration with multidisciplinary staff at the pediatric hospital to ensure a high degree of learning of building and programming robots and create features to overcome any accessibility barriers. The adaptations to the program included a design software for children who did not have the ability to use hand-over-hand techniques to build LEGO® models but could manipulate a mouse, vocabulary tools and a tool for writing programming language for children using augmentative and alternative communication devices, visual schedules for children with autism, selection mats for children who needed help with fine motor skills, and digital instructions for children with visual impairments [11].

The program was composed of a six-week workshop, held weekly, for two-hour sessions, with up to 10 children in a given workshop. The program was divided into two age groups; the *junior group*, designed for children aged 6–8 years, and the *intermediate group*, for children aged 9–14 years. There were two levels within each age group, an introductory-level for children just starting the program, and a more advanced version for children with more experience in the program [11]. Additionally, a workshop for girls exclusively was created at the junior, introductory level, as a response to low participation rates of girls during early interactions of the program.

Children worked in pairs or groups of three, along with one or two volunteers who have knowledge of robotics and/or children with disabilities. A clinical staff member (i.e., therapeutic recreation specialist) was present to support children's social and communication skills, and a program coordinator who circulated the room and provided additional support. A trained student volunteer, facilitated each two-hour session and provided lecture-style instruction on science related concepts, introduced the building activity, and circulated around the room during building and programming to provide further assistance.

Over the six-weeks, children in the junior group applied math and science concepts to build LEGO® models using WeDo 2.0 [30]. Meanwhile, children in the intermediate group used LEGO® MINDSTORMS® [29] to learn an introduction to robots, mechanisms and simple machines, programming and design, build and testing a robot in a team environment [11,35]. Each session was structured similarly, starting with a 20-min "build to express" activity, where children built something of their own interest while listening to others, sharing, and learning, followed by a demonstration from the instructor on how to build a robot. Children then worked with their partner or group to build and test the robot themselves, concluding with a discussion of what was learned during the session [35].

Table 1. Description of the activity settings observed.

Activity setting	Description
Room 1	Workshop held in a second floor meeting room with one window. All children and adults were seated at one, large rectangle table in the middle of the room.
Room 2	Workshop held in basement meeting room with no windows. The room was set up with three separate tables arranged in a U-shape. Each table seated 1–2 children and 1 volunteer.
Room 3	Workshop held in a first floor meeting room with no windows. The room was set up with 2 rows of three separate tables. Five tables seated 1–2 children and 1–2 volunteers, and one table seated 2 observers.
Room 4	Workshop held in a first floor conference room with one large window. The room was set up with seven separate tables around the perimeter of the room. Four tables seated two participants and 1–2 volunteers, and the remaining tables seated the observers and program coordinator.
Room 5	Workshop held in a first floor conference room with no window. The room was set up with five tables around the perimeter of the room. Four tables had 1–2 children and 1 volunteer, and one table seated the program coordinator and observer.

Description of activity settings

The activity settings evaluated in this study are the five rooms where children built robots in an adapted LEGO® robotics program. All of the activity settings consisted of learning about and building robots in a conference room or meeting room in a paediatric rehabilitation hospital. We observed the qualities of five different rooms where the robotics program was held. The layout of each room was arranged at the discretion of the clinical staff, who organized the seating according to the tables and chairs available in the room. They did so in a way that to help children feel supported while optimizing program outcomes. The room arrangements were maintained across all sessions of the program. A description of each activity setting is provided in Table 1.

Ethics

A Research Ethics Board at a paediatric hospital and the University of Toronto approved the study. Informed written consent/assent (one consent form) was obtained from all children and parents prior to taking part in the program.

Data collection

Measure of environmental qualities of activity settings (MEQAS)

The MEQAS [46] was used in this study to assess the various activity settings of the HB *FIRST*® Robotics program. The MEQAS is a 32-item, global, aggregate, observer-rated measure of qualities and affordances of activity settings for youth, captured based on short-term observation [46,51]. The MEQAS is composed of 32 individual items divided across six scales: Opportunities for Social Activities, Opportunities for Physical Activities, Pleasant Physical Environment, Opportunities for Choice, Opportunities for Personal Growth, and Opportunities to Interact with Adults. Observers rate the extent to which the 32 environmental qualities outlined in

Table 2. Overview of the adults and children present in each of the activity settings.

	Workshop	Children present	Adults present
Room 1	All Girls Spring 2018	3 girls with ASD 2 girls with CP	8 women • 1 program coordinator • 1 research assistant observer • 1 instructor • 1 therapeutic recreation specialist • 4 volunteers
Room 2	All Girls Fall 2018	5 girls with ASD	7 women • 1 program coordinator • 1 research assistant observer • 1 therapeutic recreation specialist • 3 volunteers
Room 3	Junior Level 1 Fall 2017	7 boys with ASD 1 boy with CP 1 boy with skeletal dysplasia	7 women, 4 men • 1 program coordinator • 2 research assistant observer • 1 therapeutic recreation specialist • 7 volunteers
Room 4	Intermediate Level 2 Spring 2018	1 girl with CP 6 boys with ASD 1 boy with developmental delay	6 women, 4 men • 1 program coordinator • 1 research assistant observer • 1 instructor • 2 therapeutic recreation specialist • 5 volunteers
Room 5	Intermediate Level 1 Fall 2018	6 boys with ASD 1 boy with CP	6 women, 3 men • 1 program coordinator • 1 research assistant observer • 1 instructor • 2 therapeutic recreation specialist • 5 volunteers

the MEQAS are present in an activity setting on a 7-point scale ranging from 7 = *to a very great extent* to 1 = *not at all*. The MEQAS evaluates the qualities and opportunities of leisure activity settings for youth, and is intended to consider the features of activity settings for all youth, regardless of individual characteristics (e.g., age, gender, disability, etc.) [46].

The MEQAS has evidence of good internal consistency, with Cronbach's alphas ranging from 0.76 to 0.96 [47]. Evidence from the scale development study indicates that the MEQAS-32 test-retest reliabilities were good to excellent (0.70–0.90) across activity settings, and good to excellent interrater reliabilities, with intra-class correlation coefficients between 0.60–0.93 for all rater pairs, over all activity settings [47]. Finally, King et al. (2014) examined construct validity as part of the MEQAS-32 measurement development by testing predictions across different types of activity settings. Results indicated evidence for construct validity, as the scales discriminated between different types of activity settings as predicted [47]. Thus, ratings on the scales of the MEQAS-32 can discriminate between different activity settings, and compare their features [51].

Training of the raters

Two researchers, one male and one female, trained for approximately 3 h on using the MEQAS independently rated the environmental quality. One rater held PhD in communication sciences and disorders, and the other was a Masters student in rehabilitation sciences with extensive experience in video-coding. The raters each read the MEQAS training manual [51], and met to discuss any questions about administering the measure. Additionally, the two raters met after completing the first two observations to compare ratings, and any discrepancies were discussed. The raters had 95.3% agreement on their first two observations, and data from these observations were included in the final analysis.

Procedure for observations and ratings

The present study examined activity settings where children with disabilities engaged in an adapted LEGO® robotics program. We used the MEQAS to evaluate the environmental quality of the five different rooms where the robotics program was held. The MEQAS scores were interpreted descriptively, as is suggested in the MEQAS-32 user manual [51], and consistent with other research applying this measure [41,43,48,49]. All five rooms were either conference rooms or meeting rooms located in a children's rehabilitation hospital. A breakdown of the individuals who were present, and the group and level of the program is displayed in Table 2.

Two researchers independently rated the environmental quality observed in one session from each of the five rooms. Each session of every workshop was video-recorded using two cameras placed in opposite corners of the room to allow the frame to capture majority of the activity setting. The researchers made observations from these video-recordings. The observations were conducted on the third session of the workshop for each activity setting, to ensure consistency in participants; level of familiarity with the program across all activity settings. The raters focused their observations on the building the robot portion of each session, where children worked with peers and adult volunteers to follow directions and construct the robots.

The raters followed the procedure for observing activity settings, as outlined by King et al. (2013) in the MEQAS-32 user manual. They observed the setting for approximately 10 min before making any ratings, and then continued to watch the video as they completed the items. The raters then verified their ratings while watching the video-recordings from the second camera in the room to ensure that as much of the activity setting as possible could be observed. The focus of these observations was on the activity setting in general, and not on any of the individual children in the setting. Moreover, raters focused on the qualities and opportunities of the settings as they are relevant to a *typical* individual in the setting, rather than the fit between and specific children and the environment [46]. As described in the MEQAS-32 manual, ratings for each activity setting were completed by a pair of observers, and scores were aggregated (i.e., the average score between the two raters for each item), to produce more reliable and less biased judgements [51]. As outlined in the MEQAS manual, an aggregate score for each scale and a total score was generated for each of the five activity settings by taking the average of the scores for the two raters. Cronbach's alpha for our assessments was 0.83, indicating good internal consistency.

Participants

There were thirty-one unique children who were present across the five activity settings assessed in this study. Of these children, eight were girls (25.8%), and twenty-three boys (74.2%). Fourteen children were in the junior group (aged 6–8years), and seventeen children were in the intermediate group (aged 9–14 years). Twenty-four children had a diagnosis of Autism Spectrum Disorder (ASD), five had a diagnosis of cerebral palsy (CP), one child was diagnosed with a developmental delay, and one child was diagnosed with skeletal dysplasia. Of the thirty-one children, four children were present in more than one of the activity settings assessed. These four children were all girls, and each of them was present in one of the all-girls workshops, and one other workshop. A breakdown of who was present in each activity setting, including children, volunteers, and clinicians, is presented in Table 1.

Results

Observations using the MEQAS

The mean scores for each of the six MEQAS scales, and the mean total score across the observed activity settings are displayed in Table 3. The overall mean MEQAS scores, collapsing across the activity settings, revealed that the robotics activity settings provided an opportunity to interact with adults to a great extent ($M = 6.40$, $SD = 0.42$). Additionally, the robotics activity settings provided opportunities for social interaction to a fairly great extent ($M = 5.22$, $SD = 0.36$). There was opportunity for choice to a moderate extent ($M = 4.17$, $SD = 0.62$), while opportunities for personal growth ($M = 3.3$, $SD = .38$), and a pleasant physical environment ($M = 3.5$, $SD = 1.03$) were observed to a small extent. Finally, the overall opportunity for physical activity was observed to a very small extent ($M = 2.83$, $SD = .68$), collapsing across activity settings. While there was some consistency observed across the activity settings, differences were observed between the settings with respect to the qualities and opportunities, as measured by the MEQAS. The similarities and differences between the activity settings for each MEQAS scale are described below.

Opportunities to interact with adults in a typical way

Figure 1 displays the means, medians, and inter-quartile ranges of the items on the six MEQAS scales, for each activity setting, respectively. The most consistent ratings across the activity settings were observed for the opportunities to interact with adults. Across all five rooms, the opportunity to interact with adults is observed to the greatest extent of the six scales. Moreover, across the activity settings, the distribution of ratings for opportunities to interact with adults is limited, with all items receiving ratings between 5 (= a fairly moderate extent) and 7 (= a very great extent). An exception to this pattern is the robotics program in Room 3, a first floor meeting room arranged in two rows of three separated tables. In this setting, while the degree to which the room was a place in which youth are interacting physically or socially with adults, and the opportunity to engage in shared activity with adults were rated highly, (6 (= a great extent) and 7 (= a very great extent), respectively), the opportunity to communicate with adults in a typical way was only observed to a small extent.

Opportunities for social activities

The opportunities for social activities were also consistently rated highly across activity settings, although slightly lower and more distributed than the ratings for the opportunities to interact with adults. The median scores across activity settings ranged from 5 (= a fairly moderate extent) to 7 (= a very great extent). The ratings for this scale also showed a great deal of dispersion around the means and medians. The lower quartiles were as low as 3 (= a small extent), with outliers reaching 2 (= a very small extent), while the upper quartiles were as a high as 7 (= a very great extent). Across all five activity settings, the opportunities for social risk taking were the lowest rated item within this scale.

Opportunities for choice

There was some variability, but a small distribution of responses across activity settings with respect to the opportunities for choice. For rooms 1, 2, and 5, all responses ranged from 3 (= a small extent) to 4 (= a moderate extent). Overall, rooms 3 and 4 showed slightly higher opportunity for choice, with ratings ranging from 4 (= a moderate extent) to 5 (= a fairly great extent). The highest rated item was the opportunity to have a say in what happens in room 4, which was observed be present to a fairly great extent.

Opportunities for personal growth

Similar to the opportunities for choice, there was a small distribution and variability of responses across activity settings with respect to opportunities for personal growth. There was a similar distribution of response for Rooms 1, 2, and 3, ranging from 2 (= a very small extent) to 4 (= a moderate extent). There was more widespread distribution in the range of scores for Rooms 4 and 5. Both rooms had a median of 4 (= a moderate extents), but Room 4 ranged from 2 (= a very small extent), while Room 5 ranged

Table 3. MEQAS-32 scale scores for 5 observed activity settings (Rooms 1–5).

	Opportunities for Social Activities	Opportunities for Physical Activities	Pleasant Physical Environment	Opportunities for Choice	Opportunities for Personal Growth	Opportunities to Interact with Adults
Room 1	4.89	2.00	3.17	3.67	2.70	6.67
Room 2	5.67	2.50	2.50	3.83	3.50	6.50
Room 3	4.83	3.83	2.67	4.67	3.20	5.67
Room 4	5.28	3.08	4.83	5.00	3.70	6.50
Room 5	5.44	2.75	4.33	3.67	3.40	6.67

Note: 1 = not at all, 2 = to a very small extent, 3 = to a small extent, 4 = to a moderate extent, 5 = to a fairly great extent, 6 = to a great extent, 7 = to a very great extent.

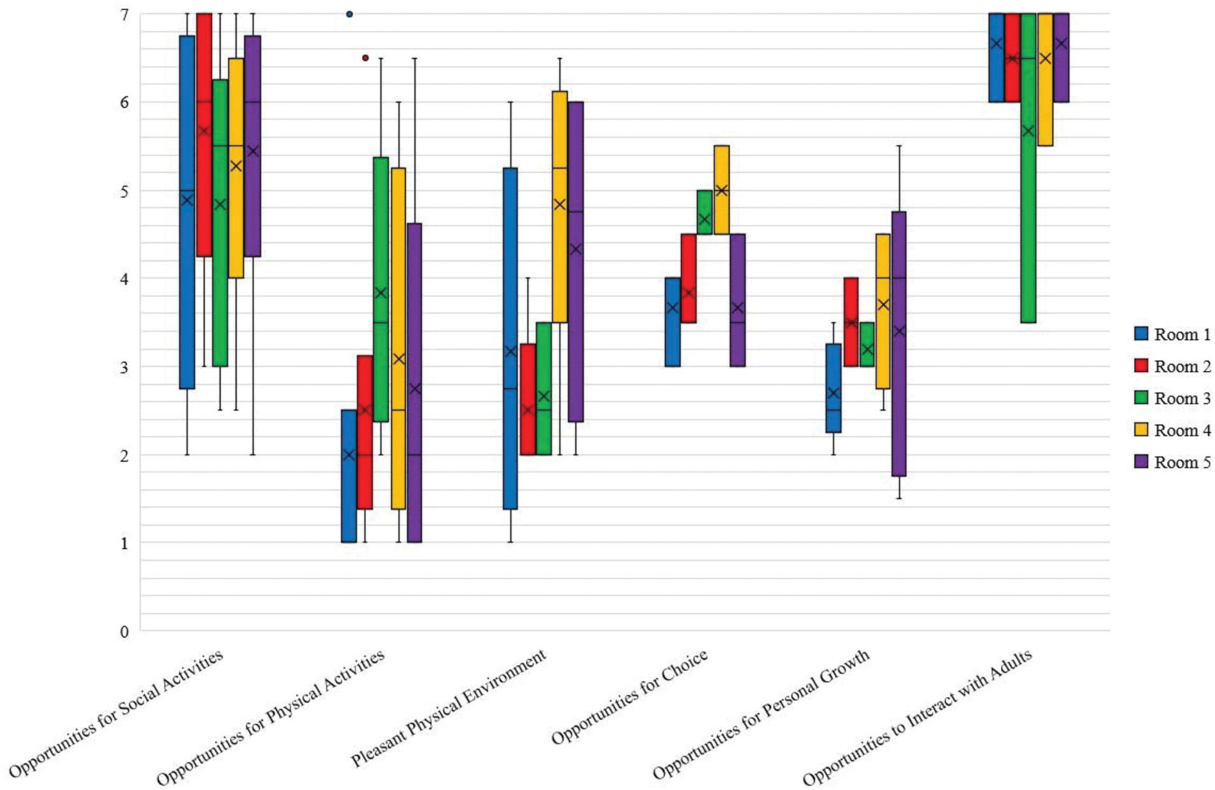

Figure 1. Means, medians, and inter-quartile ranges of the items on the MEQAS-32 scales for each activity setting.

from 1 (= not at all) to 4 (= a very small extent). Across all settings, multiple opportunities for personal growth or social experience was the highest rated item, with the exception of Room 1, where the opportunity for creative expression was the rated highest.

Pleasant physical environment

The activity settings varied greatly with respect to the degree to which there was a pleasant physical environment. Moreover, the scores were widely distributed within each activity setting. Rooms 2 and 3 were similar in their ratings for the pleasant physical environment, ranging from 2 (2 = a very small extent) to 3 (= a small extent). Room 4 showed a considerable amount of dispersion, with items ranging from 3 (= a small extent), to 6 (= a great extent), while Rooms 1 and 2 showed a great deal of dispersion. Room 1 ranged from 1 (= not at all) to 5 (= a fairly great extent), while Room 5 ranges from 2 (= a very small extent) to 6 (= a great extent). Among most of the rooms, the degree to which the physical environment is restful was the lowest rated item, with the exception of Room 1, where the opportunity for privacy was the lowest rated item. Across the activity settings, the highest rated items were a place with warm finishes and an overall sense of welcoming.

Opportunities for physical activities

Overall, the opportunities for physical activities were the lowest rated scale across all six scales of the MEQAS, and scores were largely distributed within each activity setting. The lower quartile observed for Rooms 1, 2, 4 and, 5 was rated at 1 (= not at all), and 2 (= a very small extent) for Room 3. Scores reached an upper quartile of 5 (= a fairly great extent) for Room 5, and 6 (= a great extent) for Rooms 3 and 4. For the most part, all items were rated low (either a 1 (= not at all) or 2 (= a very small extent)) on this scale, while the opportunity to learn a new skill was rated highest across the activity settings (either a 6 (= a great extent) or 7 (= a very great extent). The only rooms that did not follow this pattern were Rooms 3 and 4, where in addition to learning a new skill, the degree to which the room is a place that invites movement were also rated highly.

Discussion

This study assessed the opportunities and affordances offered by an adapted LEGO® robotics program for children and youth with disabilities. The MEQAS was used to evaluate the environmental quality of activity settings for the robotics program, specifically five different rooms in a paediatric rehabilitation hospital where the robotics lessons were held. Overall, we observed that across all activity settings, the robotics program offered an opportunity for children to interact with adults and for social interaction with peers to a large extent. These findings reflect the goal of the program to embed the teaching STEM and robotics principles within a social setting that strengthens critical thinking, problem solving, and teamwork [35]. The MEQAS observations confirm that the robotics activity settings offer sufficient opportunity to engage in social interactions with both peers and adults. Research indicates that children and youth with disabilities have fewer opportunities to engage in meaningful play [22], and in turn may face social isolation and difficulties with social development [52,53]. Thus, engaging in a leisure activity with ample opportunity for socialization like the robotics program may be of great benefit for social development among children with disabilities.

The present findings are comparable to other studies that have used the MEQAS to evaluate the activity settings of youth with disabilities. The MEQAS ratings in this study are similar to research investigating the environmental quality of a residential immersive life skills program for adolescents with physical disabilities [43,49]. These evaluated the activity settings of youth enrolled in the program, which included recreational, active physical, social, skill-based, and self-improvement settings [49]. The opportunity to interact with adults was the highest rated scale in each of these studies, ($M = 5.50$ in King et al., 2016, and $M = 4.77$ in King et al., 2018), as it was in the present study. However, overall opportunity for interacting with adults was rated higher for the activity settings in this study than for the residential immersive life skills program, indicating that the robotics program settings are especially conducive to interactions with adults. Additionally, the opportunities for social interaction were similar to those found in the life skills program, where they were also observed to a moderate extent by King et al. (2016) ($M = 4.38$), and King et al. (2018) ($M = 4.24$ for opportunities for peer interaction). The lowest rated scales in the present study were also similar to those in the life skills program, as the opportunity for personal growth was the lowest rated scale in the King et al. (2016) study ($M = 2.84$), and opportunity for physical activity was the lowest rated scale in the King et al. (2018) study ($M = 2.64$). Moreover, King et al. (2014) used the MEQAS to identify the qualities of leisure activities chosen by youth with disabilities, and the pattern of scale ratings reflects that found in the robotics activity settings. Once again, among the highest rated scales in the King et al. (2014) study were opportunities for interaction with adults ($M = 4.84$), and social activities ($M = 4.16$), while opportunity for physical activity was the lowest rated scale (3.30) [41]. Thus, it seems the opportunities and affordances offered by the robotics program activities settings align with the opportunities offered by other activity settings occupied by youth with disabilities.

Interestingly, unlike the other activity settings where the opportunity to interact with adults was observed to a great extent, in Room 3, the opportunity to communicate with adults was observed only to a small extent. This difference may reflect the arrangement of the room, such that tables were placed separately and arranged in rows. It appears that, given the small size of the tables, the adult volunteers did not sit at the tables with the children during the building activity as they often did in the other settings. Instead, the adults walked around the tables, often standing behind the children as they participated in the building activity. This arrangement reduced the ability of adults to lower to the level of the child and make eye contact, limiting the opportunities for children to engage with adults in a typical way. To ensure that the robotics program allows for the optimal interaction between children and their peers and adults, it is important that the room is set up with tables of sufficient size so that all individuals can interact on the same level, enabling eye contact and social interaction.

Across all of the robotics activity settings, the opportunity for physical activity was rated lowest. This finding was not surprising, given that the goals of the robotics program focused on socialization and STEM learning, and did not address physical activity. Additionally, it is promising that despite overall low scores among the items within this scale, the opportunity to learn a new skill was rated highly across the activity settings. This finding aligns with the primary goal of the program is to allow children and youth with disabilities to learn new skills in STEM and robotics [35].

Some differences in opportunities for physical activities were observed across the activity settings. Specifically, Rooms 3 and 4 were rated highly on the degree to which they invited movement. These rooms were each set up in a configuration of separated tables, with enough space for children to move about in between. While it was not a goal of the program to provide an activity setting that supports physical activity, it may be important to consider the movement needs of the children within an adapted robotics program. Children with physical disabilities require sufficient space to comfortably move about with the room. Additionally, a large majority of children in this study were children with ASD, and these children often require more personal space or access to external play areas [54]. Thus, an optimal setting for the adapted robotics program would include tables configured separately to allow space and invite movement.

The opportunities for choice and personal growth were observed from a small to moderate extent across all five activity settings. Room 4 in particular was rated the highest of all activity settings on these two scales. Within this activity setting, the highest rated items included the opportunity to have a say in what happens, the opportunity for identity development, as well as multiple opportunities for personal growth or social experience. This room was set up with one or two participants at separate tables around the perimeter of the room, along with one or two volunteers. Research on inclusive education among youth with intellectual and developmental disabilities indicates that social engagement may be supported by small group arrangements that allow for peer-to-peer interaction [55]. Moreover, this research suggests that close proximity of adults can reduce the levels of peer-to-peer interactions, while increasing task-related interactions between students [55]. The arrangement observed in Room 4 seems to strike a balance between the benefits of small group, peer interactions and proximity of adults, in turn supporting children with disabilities in their development of social skills and self-identity.

While the MEQAS evaluates the qualities of activity settings for youth, regardless of their individual characteristics, it is important to consider potential gender differences in the impact of the environmental features of the LEGO® robotics program. Research indicates that the physical environment may establish gendered expectations for how children play within a setting. For example, Børve and Børve (2017) show that rooms for kindergarten students are constructed with a strongly coded message for gendered expectations, such that environments perceived as stereotypically masculine tend to be open, allowing space for physical activities, while environments that are more stereotypically feminine are smaller, quieter, and allow for less physical activity [56]. In our study, certain qualities of the activity settings may have coded for gendered expectations for how the rooms were to be used. Rooms 1 and 2 were both rooms used for the girls-only robotics sessions. These rooms received the lowest ratings of all the activity settings for the opportunities for physical activities. The table arrangements in these rooms left little space for children to move about within the room, reflecting the gender stereotype identified by Børve and Børve (2017) that environments for girls require less space for physical activity. These rooms invite movement only to a small extent, which may limit the accessibility of the robotics program for girls with disabilities, who are already under-represented in STEM education [57,58]. To ensure equitable access to the robotics program for all youth with disabilities, it is important that a physical environment avoids gender stereotypes in the layout and invites movement for all participants.

The findings from this study illuminate environmental qualities for the adapted LEGO® robotics program that align with and optimize the goals and intended therapeutic goals of the program. While no single activity setting from this study embodied all of these features, the findings from this study have implications for designing the ideal environment for future iterations of the adapted robotics program for youth with disabilities. Specifically, to accommodate the space needs of youth with disabilities, the ideal setting for the robotics program would include separated tables with sufficient space to invite movement around the room. Moreover, to foster the development of children's social skills and self-identity, approximately two children and one or two adults should work closely in a small group at each table, but tables should be arranged so that opportunities to interact as a larger group, across tables, is also facilitated. Importantly, to support social interaction, tables should be large enough that children and adults can interact at eye level. Incorporating these environmental qualities would provide opportunities for youth that support the goals of the adapted robotics program.

Limitations and future directions

There are some limitations in the methods used in this study to consider. First, although the MEQAS manual recommends that ratings be based on in-person observations, the observations for this study were based on video-recordings. The video-recordings included multiple camera angles to capture the room from a variety of perspective, but it was not possible to capture the entire room environment, and thus observations and ratings are less informed. Future studies should conduct observations of robotics sessions in-person, in real-time, as the sessions take place. Next, there is a possible observer bias in this assessment, as two of the authors of this paper completed the ratings of environments. This bias was minimized as the ratings were completed by following the instructions outlined in the MEQAS manual. However, to reduce potential bias, the authors should not complete the quality assessment ratings. Additionally, while we used the MEQAS-32 to assess environmental qualities, the measure developers have published an updated measure, the MEQAS-48 [46]. This measure offers four new scales to measure place-related qualities and opportunities; including privacy/relaxation, peer interaction, and cooperative group activity. While we chose to use the MEQAS-32 as it was developed to capture the qualities of leisure activity settings specifically, the MEQAS-42 was developed for a broader range of activity settings and has enhanced utility [46]. Thus, the updated 42-item MEQAS measure may have illuminated aspects of the robotics activity settings not captured by the MEQAS-32, and it would be valuable for suture studies to evaluate the robotics environments using this expanded MEQAS measure. It is important to note that in we did not evaluate the effectiveness of the robotics program, so we were unable to statistically analyse the relationship between the MEQAS-32 scores and outcomes of the robotics program. Moving forward, it would be interesting to explore the predictive validity of the MEQAS-32, examining the correlation between MEQAS scores for the robotics program and outcomes of the program, including interest in STEM disciplines. Finally, the present study focused specifically on the portion of the robotics program where children are building robots. It is possible that the environmental quality ratings might vary for the other sections of the robotics program. Future studies should use the MEQAS to evaluate the degree to which the settings of the other sections of the adapted robotics program support the therapeutic goals.

Conclusion

The assessment of the environmental quality of an adapted robotics program for children and youth with disabilities revealed that the environmental qualities of the activity settings for this program are aligned with the therapeutic goals of the program. Specifically, the activity settings of the robotics program offer ample opportunities for children to engage in social interactions with peers and adults, opportunity to learn a new skill, and to develop a sense of self-identity. Through examining the opportunities and affordances offered across the five setting observed in this study, we identified the environmental features of the robotics settings that best support the program goals. The ideal robotics environment for children and youth with disabilities would be composed of large tables with sufficient space for two youth and one or two adult volunteers to interact at eye-level, arranged separately with enough space to invite movement between tables, in such a way that children may also interact across tables. The findings of this study support the value of assessing the opportunities and affordances of play-based activities, and demonstrate that the environment of an adapted LEGO® robotics program can be designed in such a way that supports optimal outcomes for children and youth with disabilities.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was funded in part by the Ontario Ministry of Research, Innovation and Science through an Early Researcher Award to Sally Lindsay.

ORCID

Kendall Kolne http://orcid.org/0000-0002-4125-1362
Sunny Bui http://orcid.org/0000-0001-5052-8848
Sally Lindsay http://orcid.org/0000-0002-5903-290X

References

[1] Brodin J, Lindstrand P. Reflections on children with disabilities and computer play. Bratislava: EUROREHAB; 2000. p. 153–158.
[2] Law M, King G, King S, et al. Patterns of participation in recreational and leisure activities among children with complex physical disabilities. Dev Med Child Neurol. 2006; 48(05):337–342.
[3] World Health Organization. International classification of functioning, disability and health: children and youth (ICFCY); 2007.
[4] Eccles JS, Barber BL, Stone M, et al. Extracurricular activities and adolescent development. J Soc Issues. 2003;59(4): 865–889.
[5] Mahoney JL, Larson RW, Eccles JS. Organized activities as contexts of development: extracurricular activities, after school and community programs. Lawrence Erlbaum Associates; 2005.
[6] Larson R, Jarrett R, Hansen D, et al. Youth programs as contexts of positive development. International handbook of positive psychology in practice: from research to application. New York (NY): Wiley; 2004.
[7] Mahoney JL, Harris AL, Eccles JS. Organized activity participation, positive youth development, and the over-scheduling hypothesis. Soc Policy Rep. 2006;20(4):1–32.
[8] Catalano R, Berglund M, Ryan J, et al. Positive youth development in the US: research findings on evaluations of the

positive youth development programs. Vol. 21. New York (NY): Carnegie Corporation; 1999. p. 2005.
[9] Howard A, Park C, S R. Using haptic auditory intervention tools to engage students with visual impairments in robot programming activities. IEEE T Learn Technol. 2012;5:87–95.
[10] Bundy AC. Assessment of play and leisure: delineation of the problem. Am J Occup Ther. 1993;47(3):217–222.
[11] Lindsay S, Rampertab L, Curran CJ. Therapy through play: advancing the role of robotics in pediatric rehabilitation. New York (NY): CRC Press, Taylor and Francis; 2019.
[12] Case-Smith J, O'Brien J. Occupational therapy for children. Maryland Heights (MO): Mosby. Elsevier; 2010.
[13] Harkness L, Bundy AC. The test of playfulness and children with physical disabilities. Occup Ther J Res. 2001;21(2): 73–89.
[14] Porter ML, Hernandez-Reif M, Jessee P. Play therapy: a review. Early Child Dev Care. 2009;179(8):1025–1040.
[15] Ríos-Rincón AM, Adams K, Magill-Evans J, et al. Playfulness in children with limited motor abilities when using a robot. Phys Occup Ther Pediatr. 2016;36(3):232–246.
[16] Chang H-J, Chiarello LA, Palisano RJ, et al. The determinants of self-determined behaviors of young children with cerebral palsy. Res Dev Disabil. 2014;35(1):99–109.
[17] Brewer JA, Kieff J. Fostering mutual respect for play at home and school. Child Educ. 1996;73(2):92–96.
[18] Perlmutter JC, Burell L. Learning through" Play" As Well As" Work" in the Primary Grades. Young Child. 1995;50(5): 14–21.
[19] Rubin KH, Howe N. Toys and play behaviors: an overview. Top Early Child Spec Educ. 1985;5(3):1–9.
[20] Harper CB, Symon JB, Frea WD. Recess is time-in: using peers to improve social skills of children with autism. J Autism Dev Disord. 2008;38(5):815–826.
[21] Couch KJ, Deitz JC, Kanny EM. The role of play in pediatric occupational therapy. Am J Occup Ther. 1998;52(2): 111–117.
[22] Miller S, Reid D. Doing play: competency, control, and expression. CyberPsychol Behav. 2003;6(6):623–632.
[23] Morrison RS, Sainato DM, Benchaaban D, et al. Increasing play skills of children with autism using activity schedules and correspondence training. J Early Interv. 2002;25(1): 58–72.
[24] Lifter K, Mason EJ, Barton EE. Children's play: where we have been and where we could go. J Early Interv. 2011; 33(4):281–297.
[25] Sandall S, Hemmeter M, Smith BJ, et al. The division for early childhood [DEC]-recommended practices: a comprehensive guide for practical application in early intervention/early childhood special education. Longmont (CO): Sopris West. 2005. p. 307.
[26] Majnemer A, Shevell M, Law M, et al. Participation and enjoyment of leisure activities in school-aged children with cerebral palsy. Dev Med Child Neurol. 2008;50(10):751–758.
[27] Lynch H, Prellwitz M, Schulze C, et al. The state of play in children's occupational therapy: a comparison between Ireland, Sweden and Switzerland. Br J Occup Ther. 2018; 81(1):42–50.
[28] Miller Kuhaneck H, Tanta KJ, Coombs AK, et al. A survey of pediatric occupational therapists' use of play. J Occup Ther Sch Early Interv. 2013;6(3):213–227.
[29] LEGO®. MINDSTORMS®; 2019 [cited 2019 Jun 26]. Available from: https://www.lego.com/en-us/mindstorms.
[30] LEGO® Education. LEGO® Education WeDo 2.0 Core Set; 2019 [cited 2019 Jun 26]. Available from: https://education.lego.com/en-us/products/lego-education-wedo-2-0-core-set/45300.
[31] Lo J-L, Chi P-Y, Chu H-H, et al. Pervasive computing in play-based occupational therapy for children. IEEE Pervasive Comput. 2009;8(3):66–73.
[32] Legoff DB, Sherman M. Long-term outcome of social skills intervention based on interactive LEGO© play. Autism. 2006;10(4):317–329.
[33] Lindsay S, Hounsell KG, Cassiani C. A scoping review of the role of LEGO® therapy for improving inclusion and social skills among children and youth with autism. Disabil Health J. 2017;10(2):173–182.
[34] Ludi S, Reichlmayr T. The use of robotics to promote computing to pre-college students with visual impairments. Trans Comput Educ. 2011;11(3):20.
[35] Lindsay S, Hounsell KG. Adapting a robotics program to enhance participation and interest in STEM among children with disabilities: a pilot study. Disabil Rehabil Assist Technol. 2017;12(7):694–704.
[36] Lindsay S, Kolne K, Oh A, et al. Children with disabilities engaging in STEM: exploring how a group-based robotics program influences STEM activation. Can J Sci Math Techn Educ. 2019;19:387–397.
[37] Lindsay S. Exploring skills gained through a robotics program for youth with disabilities. OTJR: Occupation, Participation & Health. 2020;40(1):57–65.
[38] Lindsay S, Lam A. Exploring types of play in an adapted robotics program for children with disabilities. Disabil Rehabil Assist Technol. 2018;13(3):263–270.
[39] Halfon N, Hochstein M. Life course health development: an integrated framework for developing health, policy, and research. Milbank Q. 2002;80(3):433–479.
[40] Keating DP, Hertzman C. Developmental health and the wealth of nations: social, biological, and educational dynamics. New York: Guilford Press; 2000.
[41] King G, Batorowicz B, Rigby P, et al. The leisure activity settings and experiences of youth with severe disabilities. Dev Neurorehabil. 2014;17(4):259–269.
[42] Petrenchik TM, King GA. Pathways to positive development: childhood participation in everyday places and activities. In: Mental health promotion, prevention, and intervention in children and youth: a guiding framework for occupational therapy. Bethesda (MD): American Occupational Therapy Association; 2011. p. 71–94.
[43] King G, McPherson A, Kingsnorth S, et al. Residential immersive life skills programs for youth with disabilities: service providers' perceptions of experiential benefits and key program features. Disabil Rehabil. 2015;37(11):971–980.
[44] King G, Batorowicz B, Rigby P, et al. Development of a measure to assess youth self-reported experiences of activity settings (SEAS). Int J Disabil Dev Educ. 2014;61(1):44–66.
[45] King G, Gibson BE, Mistry B, et al. An integrated methods study of the experiences of youth with severe disabilities in leisure activity settings: the importance of belonging, fun, and control and choice. Disabil Rehabil. 2014;36(19): 1626–1635.
[46] King G, Rigby P, Avery L. Revised measure of environmental qualities of activity settings (MEQAS) for youth leisure and life skills activity settings. Disabil Rehabil. 2016;38(15): 1509–1520.

[47] King G, Rigby P, Batorowicz B, et al. Development of a direct observation Measure of Environmental Qualities of Activity Settings. Dev Med Child Neurol. 2014;56(8): 763–769.

[48] Gibson BE, King G, Kushki A, et al. A multi-method approach to studying activity setting participation: integrating standardized questionnaires, qualitative methods and physiological measures. Disabil Rehabil. 2014;36(19):1652–1660.

[49] King G, McPherson A, Mosleh D, et al. Program opportunities of residential immersive life skills programs for youth with disabilities. Res Dev Disabil. 2018;83:233–246.

[50] FIRST® Robotics Canada. FIRST® Robotics Canada 2018 Annual Report. 2018.

[51] King G, Rigby P, Thompson L, et al. Manual for the measure of environmental qualities of activity settings – 32 Version (MEQAS-32). Bloorview Research Institute, Holland Bloorview Kids Rehabilitation Hospital. 2013.

[52] Cook A, Encarnação P, Adams K. Robots: assistive technologies for play, learning and cognitive development. TAD. 2010;22(3):127–145.

[53] Pollock N, Stewart D, Law M, et al. The meaning of play for young people with physical disabilities. Can J Occup Ther. 1997;64(1):25–31.

[54] McAllister K, Maguire B. Design considerations for the autism spectrum disorder-friendly Key Stage 1 classroom. Support Learn. 2012;27(3):103–112.

[55] Carter EW, Sisco LG, Brown L, et al. Peer interactions and academic engagement of youth with developmental disabilities in inclusive middle and high school classrooms. Am J Ment Retard. 2008;113(6):479–494.

[56] Børve HE, Børve E. Rooms with gender: physical environment and play culture in kindergarten. Early Child Dev Care. 2017;187(5–6):1069–1081.

[57] Lee A. A comparison of postsecondary science, technology, engineering, and mathematics (STEM) enrollment for students with and without disabilities. Career Dev Except Individ. 2011;34(2):72–82.

[58] Lee A. Students with disabilities choosing science technology engineering and math (STEM) majors in postsecondary institutions. J Postsecond Educ Disabil. 2014;27(3): 261–272.