RESEARCH ARTICLE

You Get What You Pay For: Three Years of Applied Behavior Analysis in Hong Kong With Relative Cost

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Abstract

There are decades of research literature that support the effective application of applied behavior analysis (ABA) in schools that have students with special needs, including autism spectrum disorder. Students ranging in age from preschool through secondary have benefited from ABA and its effectiveness. In light of the global economic downturn over the last decade, the costs of services for children with special needs has been analyzed and scrutinized across many levels of bureaucratic systems. Through its evidence-based methods, its focus on relevant outcome data, and its systematic measurement practices, ABA has offered many educational stakeholders the best way forward for one of modern society's biggest behavioral health problems. The present study replicates a cost-benefit analysis and shows the outcomes of instruction in terms of cost in dollars. We reviewed 3 years of outcome data from an international school for students with special needs in Hong Kong. Special instruction with ABA was provided in individual, group, and inclusive classroom settings using learn units as the basic unit of instruction. A cost-benefit analysis showed the relative dollar amounts of the learn unit and instructional objectives, adjusted for inflation and compared across previous studies.

Keywords Applied behavior analysis · Autism · Cost-benefit analysis · Learn units · Inclusion

Applied behavior analysis (ABA) program models have been effective in the remediation of learning problems for young children with special education needs (SEN) and autism spectrum disorder (ASD) for decades (Anderson & Romanczyk, 1999; Cooper, Heron, & Heward, 2007; Greer, 2002; Greer, Keohane, & Healy, 2002; Greer, McCorkle, & Williams, 1989; Greer & Ross, 2008; Lovaas, 1987; Twyman, 1998; Weiss, 2001, 2005). Treatments derived from the science of ABA and early intensive behavioral intervention (EIBI) are generally accepted as the most effective for children with ASD. The cost of these services has been analyzed and scrutinized in recent years as the prevalence of ASD has increased globally. Early research was conducted to investigate the cost of the service or expansion of that service in the United States (Jacobson, Mulick, & Green, 1998) and more recently in the United Kingdom (Bate et al., 2017; The Challenging

Behaviour Foundation, 2014) and Canada (Motiwala, Gupta, Lilly, Ungar, & Coyte, 2006; Piccininni, Bisnaire, & Penner, 2017). The financial repercussions of having a child with ASD, as well as the difficulty in measuring these decisions and outcomes (Stabile & Allin, 2012), have been discussed from family and societal perspectives (Jacobson & Mulick, 2000). Investigations into the financial projections of the savings that would result from EIBI across an entire state in the United States have also been made (Chasson, Harris, & Neely, 2007). All research in this area points to the high cost of intensive services for young children with ASD. However, outcomes are generally positive and can lead to very significant savings in the costs of schooling compounded over time. Politicians and educational policy makers ought to strongly consider these outcomes when considering the balance between effective educational outcomes for people with SEN and the public's need for efficient social systems.

The science of ABA has been instrumental in providing tools for practitioners to assess the effectiveness of their interventions for a given individual student, to identify the principles of behavior responsible through experimental design, and to measure the outcomes of teaching. Research on *learn units* (LUs) has been at the core of many of these findings (Albers &

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Greer, 1991; Greenberg & Greenberg, 2014; Greer, 2002; Greer et al., 1989; Greer & McDonough, 1999; Greer & Ross, 2008; Ingham & Greer, 1992; Selinske, Greer, & Lodhi, 1991; Twyman, 1998). The LU as a basic unit of teaching and measure of instruction and analysis will be described subsequently.

Increasingly school districts, municipalities, and private schools have become more discerning about the ways in which their schools are spending funds. The cost of education is high on the public agenda. As schools and their populations grow, their budgets that are based on tax revenues may be shrinking in an inversely proportional direction. Some have proposed a cost-benefit analysis of educational programs so that schools can be compared using a common measure and held accountable for their spending (Greer, 1994, 2002). The LU lends itself appropriately to an analysis based on cost using dollars (e.g., tuition costs in dollars, fee-for-service contracts). The number of objectives met or taught by the teacher can be used as a metric for comparison purposes to assess both the effectiveness and efficiency of an educational program. We illustrate how the LU can be used in the [Method](#) section.

Cost-effectiveness reports have been performed on interventions to treat conduct disorders in elementary students (Olchowski, Foster, & Webster-Stratton, 2007). Olchowski et al. (2007) provide a tiered analysis based on different hypothetical budgets to treat inappropriate behaviors; however, no measures of direct student academic responses were reported. The present study using LUs provides an analysis based on direct measures of teaching and learning as they relate to tuition-based costs.

In 1994, Greer's paper titled "The Measure of a Teacher" was the first report that quantified the actual cost of the teaching and learning process using direct observations of student and teacher interactions (Greer, 1994). Greer used the LU to calculate the actual costs of learning and mastery of learning objectives for students with ASD and other SEN across 5 years of instruction. This meta- or macro-analysis of instruction resulted in a cost-benefit analysis that showed that instructional outcomes can be viewed through an economic lens. A quantitative analysis of instruction and its outcomes expressed in terms of cost represents a metric that holds value to policy makers. Subsequently, those outcomes and the so-called bottom line may be used by policy makers to inform their decisions on educational policies on a large scale. Providing decision makers with another metric in which to evaluate program effectiveness and efficiency is advantageous to all stakeholders in the system. The fundamental principle of accountability can be achieved in educational systems using this methodology.

Greenberg and Martinez (2008) conducted a descriptive research study using Greer's cost-benefit analysis technique for one classroom of young students with ASD who received early intervention services. The costs and outcomes were

compared to the original study by Greer (1994). The results showed that in both schools that used ABA and LU instruction in a treatment package, students learned and skills were mastered at a relatively low cost.

The present research paper describes 3 years of school-wide data from four classrooms with a total of about 28 students with ASD and SEN in Hong Kong. We highlight the program's behavior-analytic components and include the results of the instruction expressed in a cost-benefit analysis showing the relative cost (and savings) in U.S. dollars, adjusted for inflation so that a relative comparison can be made with the research that has preceded the present study.

Method

Population

The Harbour School (THS) is a private and progressive general education and international school in Hong Kong. The student population at THS is about 85% expatriate students coming from more than 20 different countries and country combinations. About 10% of the students at THS receive services from the Children's Institute of Hong Kong (TCI) due to their ASD and SEN. All students participate in THS general education classes and curricula to the maximum extent appropriate. Students receiving ABA services from TCI have one-to-one instruction with teachers. TCI supervisors and teachers are Board Certified Assistant Behavior Analysts or Board Certified Behavior Analysts, or they may be in various stages of progress working toward their certification. Table 1 shows the demographics of students enrolled in TCI across the 3 years reported in the present study.

Description of the Program

Many public and private schools that serve students with ASD using ABA provide instruction in a one-to-one format. Under these conditions, students with ASD and SEN may have few, if any, opportunities to learn in a group setting with their age-appropriate peers. TCI is an agency and program within THS that provides one-to-one teacher support to students with ASD and other SEN. All students participated in the mainstream general education curricula on an individualized basis.

TCI provides ABA services in an environment that combines *LU instruction* and natural environment training across various instructional formats throughout the students' day (McGee, Morrier, & Daly, 1999; Weiss, 2001, 2005). This allows each student to benefit from one-to-one LU instruction while having opportunities to be included in general education classes. All one-to-one program intervention methodology is based on the principles of the science of ABA.

Table 1. Enrolment, instructional hours, and tuition costs across three years of schooling at The Children’s Institute of Hong Kong

	2013-2014	2014-2015	2015-2016
1. Number of students enrolled	18	19	16
2. Tuition dollars per student per year (HKD)	\$372,972	\$387,756	\$409,224
3. Number of instructional days across first 37 weeks	175	174	173
4. Tuition per student per diem (7 hours)	\$1513	\$1582	\$1679
5. Allocated Instruction hours (5/7 hours =71%)	\$1074	\$1123	\$1192
6. Total cost of all students to attend school for one day (Line 1 x Line 5)	\$19,332	\$21,337	\$19,072
7 Total cost of all students to attend school across first 37 weeks (Line 3 x Line 6)	\$3,383,100	\$3,712,638	\$3,299,456

Special instruction is the primary service that the students receive at TCI. ABA is delivered daily in concert with the curriculum objectives of THS, the individualized education program (IEP), and verbal behavior analysis (VBA; Greer & Ross, 2008; Kates-McElrath & Axelrod, 2007; Skinner, 1957). There were five areas of the curriculum (see Table 2). Related services, such as speech and language therapy, were provided outside of the classroom as a “pullout” for about two students during the time that the data were collected in the present study.

In the classrooms, the daily schedules are twofold. Within the TCI classrooms, children received ABA LU special instruction from one teacher in a group or one-to-one instructional format. *Group* was defined as a setting with students attending within a group of three or more peers; however, each child continued to receive one-to-one individual consequences for all responses. Most students also attended THS classes for one or more subjects throughout each school day. The range of inclusive participation was one subject to all six subjects in a given school day. Teachers at TCI used the same ABA data collection and evidence-based methods when presenting instruction in one-to-one or group formats. Furthermore, group instruction was individualized and data based in the same way that the one-to-one programs were applied. Progress was recorded immediately and then graphed daily. Decisions were made on the graphs based on a data decision protocol (Greer, 2002; Keohane, 1997; Keohane & Greer, 2005), and research-based tactics were applied as needed (Greenberg, 2007; Keohane, 1997).

Classroom Model

TCI provides one-to-one special instruction with ABA in the THS international school setting using English as the medium of instruction. Supervisors and teachers are Board Certified Behavior Analysts or are in various stages of the certification process. The IEP team consists of the parents, TCI director, supervisor, ABA teachers, and THS general education teachers, as well as a speech therapist for some students. Parents are a central part of the interdisciplinary IEP teams. Parents were encouraged to be active members of the treatment team. In addition, some parents received training regarding specific behavioral techniques to foster the generalization of skills in the home.

ABA teachers at TCI use many evidence-based practices from the research literature in the field of ABA, such as the LU (Greer, 2002; Greer & McDonough, 1999), personalized systems of instruction (PSI) modules (Keller, 1968), teacher performance rate accuracy (TPRA; Ingham & Greer, 1992), the data decision analysis protocol (Greer, 2002; Keohane, 1997; Keohane & Greer, 2005), and various instructional strategies and tactics. School-wide data are maintained regularly by the head teachers of each of the four classrooms and the director. The school-wide data and outcomes are the subject of this research paper.

ABA Special Instruction

TCI provides ABA special instruction as its sole approach to pedagogy. Each of the children targeted within this study was

Table 2. Results of 37 weeks of instruction at The Children’s Institute in Hong Kong across three years (2013-2014, 2014-2015, and 2015-2016)

Figure		2013-2014	2014-2015	2015-2016
1	School wide learn units correct	328,045	444,752	500,872
2	School wide learn units presented	391,486	536,822	598,026
3	Mean correct learn units per day	115	117	128
4	Mean presented learn units per day	137	141	152
5	Cumulative objectives met per year	2827	4390	4480
6	Mean learn units per objective	149	123	139

enrolled in a 30-hr weekly ABA program. The specific components of the center-based program are described next.

Learn Unit (LU)

The LU is a three-term contingency that may occur in a scripted, automated, discrete, captured, interspersed, or massed form (Greer, 2002). LUs are the simplest elements and smallest step possible for acquiring a learning goal. The skills taught follow a developmentally and behaviorally sequenced curriculum based on the student's IEP that is informed by the educational standards used at the international school, as well as its curricula.

For LUs to occur, the student was presented with an antecedent stimulus. The student's correct response was reinforced by the teacher's delivery of positive reinforcement (e.g., verbal praise; a book, toy, or edible). The student's incorrect response was given a simple correction, whereas appropriate responses are modeled or prompted. Prompt levels provided by the ABA teachers may have varied from verbal prompts to modeling or physical guidance. Prompts were faded as correct responding increased. LUs may be short or long based on the task that the teacher is observing the student do, such as "Point to red" or "Read this page." LUs were present when student learning occurred in teaching interactions and were absent when student learning did not occur in teaching interactions (Greer & McDonough, 1999). Instructional programs were aligned with Skinner's *Verbal Behavior* (1957). This approach has been effective in rapid skill development, functional communication training, and reduction of inappropriate behaviors (Greer & Ross, 2008; Kates-McElrath & Axelrod, 2007).

The natural environment teaching (NET) component relied on naturally occurring opportunities in the environment (e.g., group instruction, captured LUs) to promote learning (Greer, 2002; McGee et al., 1999). NET emphasized student-directed activities (choices) while still incorporating the stimulus-response-consequence paradigm in the form of LUs. Target goals included language, play, and social skills. During NET, antecedents that may be student initiated were paired with multiple cues interspersed by the ABA teachers (Weiss, 2001, 2005).

Group Instruction and Inclusion in the General Education Classroom

THS and TCI provide inclusion opportunities for the students with ASD and SEN. Students were assessed to determine acceptable criteria for inclusion in specific subject areas. Students with ASD or SEN and reader-writer capabilities observed to be within 18 months of age-appropriate academic functioning were integrated into THS with support from a TCI ABA teacher. During inclusion, TCI students were monitored by both the THS teacher and the TCI ABA teacher (Greenberg & Greenberg, 2014).

LU delivery and ABA instructional techniques continued during inclusion instruction. Inclusion consisted of a student seated in a mainstream classroom while attending classes alongside their typical peers. The role of the ABA teacher in the THS classroom was to provide prompts (if needed), present positive reinforcement (e.g., social praise, tokens), or deliver simple corrections and record data on the student's responding across various target behaviors. Students, therefore, continued to receive LUs parallel to their peers in a typical group setting from both THS general education teachers who were leading the lessons and their TCI ABA teachers facilitating their participation in those lessons.

Teacher Training (PSI)

Staff training consisted of PSI (Keller, 1968). Training included mastery of a decision analysis protocol, direct instruction of research-based tactics, and frequent observations by the supervisors (Ingham & Greer, 1992). Supervisors presented content and modules that were completed weekly, which included reading specific chapters in assigned texts, passing written exams on the content of the reading, and clinically applying the subject matter. Training sessions were scheduled weekly and consisted of the delivery of instruction. Teachers received regular and formal observations of their teaching procedures using the TPRA observation procedures (Ingham & Greer, 1992). All teachers either had board certification in behavior analysis or were in various stages of the certification process. The director and supervisor were Board Certified Behavior Analysts.

Data Decision Protocol

The data decision protocol was used by all ABA teachers at TCI to monitor student progress and to make timely data-based decisions regarding the next step in instruction by analyzing the trend in the student's data as viewed through the visual graphic display. Based on the landmark dissertation by Keohane (1997), and subsequent research (Keohane & Greer, 2005), the decision analysis protocol enabled teachers using ABA to teach two to three times more objectives. The decision analysis protocol is an essential component of best practice ABA schools because it enables teachers to function as strategic scientists of instruction and leads to positive and measurably superior outcomes (Bushell & Baer, 1994; Greenberg, 2007; Greer, 2002; Keohane, 1997; Keohane & Greer, 2005).

Supervision

The instructional systems at TCI are established and maintained using techniques from the science of ABA, such as the TPRA observation procedure (Greer, 2002; Ingham & Greer, 1992). TPRA measurements were regularly

administered through direct observation by head teachers, the supervisor, and the director.

The students' instructional LUs were measured as rate by dividing the number of three-term contingency trials by the instructional duration in minutes. Additionally, correct responses and incorrect responses were monitored daily to measure response accuracy and learning. Teachers constructed and maintained visual graphic displays and analyzed the data daily using the data decision protocol. Data decisions regarding interventions for decreasing trends or stable rates of responding were scripted accordingly. All data for all students were graphed daily.

An important feature of the TPRA is the interobserver agreement measure. This procedure ensured that the direct observation and data collection recording techniques of the teachers are calibrated to those of the supervisor and director of the school. Interobserver agreement generally ranged between 90% and 100% point-to-point correspondence.

School-Wide Data

Data are collected and graphed daily by all ABA teachers. Head teachers of each class summarize and graph the data from their own classrooms each week using Microsoft Excel. One graph in each of the five areas of the curriculum is maintained that shows total LUs presented and correct for the whole class each week. A second graph is maintained that shows the cumulative objectives met in each of the five areas of the curriculum. There were four summary graphs that were maintained weekly. Those included total and correct LUs presented for the whole class, cumulative objectives met across all curricular areas, mean number of LUs per objective, and mean number of total and correct LUs per student. The same graphs were maintained for the whole school, and data were summarized for all students. Figures 1, 2, 3, and 4 show the summary data for the whole school for the 2015–2016 school year across 37 weeks of instruction.

Cost-Benefit Analysis

In the present study, the cost-benefit analysis was based on a number of constant and calculated variables. Table 3 shows enrollment, instructional hours, and tuition cost factors across the 3 years that were included in this study. Tables 3 and 4 show the data used in the calculations for cost. Table 5 shows the results of 37 weeks of instruction across 3 years of teaching for all students at the school. After all of the data are recorded and organized, the calculation method is relatively simple. The total cost (Line 7 from Table 3) is divided by each of the six lines from Table 4. The resulting costs are shown in Table 6 and will be described in the Results section subsequently.

One factor that deserves some description is the *allocated instructional time* (Stallings, 1980) that was used to assess the difference between the time a child is in school compared to the time the child is being presented with instruction (opportunities to respond or LUs). For the purposes of this study, 300 min was the duration of time used each day to present LU instruction. The students were in school for 7 hr; however, they received direct instruction for only 5 of those hours (300 min). This factor was used in the calculation of the amount of tuition per day per student.

Reliability

Accuracy in the data and outcomes was ensured through calculations made by both authors who completed calculations separately (see Tables 3 and 4). Agreement in the accuracy of all calculations was 100%.

Results

Throughout the school year, for each of the five curricular areas, there was a total of four visual graphic displays for the school-wide data from the director. One graph showed correct/total LUs, whereas the other showed cumulative objectives met. Another graph showed the mean number of correct/total LUs, whereas the other showed the mean number of cumulative objectives met. Table 3 shows the enrollment, instructional hours, and tuition.

Table 4 shows the results of 37 weeks of instruction at TCI across 3 years: 2013–2014, 2014–2015, and 2015–2016. Table 4 shows the cost-benefit analysis based on the data reported in Tables 3 and 4 in Hong Kong dollars and U.S. dollars (*italics*). Table 6 includes data on the relative cost of LUs and objectives met compared across relative cost research studies in U.S. dollars. Table 7 shows the data in Table 6 adjusted for inflation.

Figure 1 presents the total number of LUs presented and the total number of LUs for 16 children across the 37 weeks of classroom instruction. Visual graphic displays were established and maintained weekly and posted in the classroom each week. The total number of LUs presented was 598,026, and the total number of LUs correctly responded to by the students was 500,872. Correct LUs are a combination of prompted and unprompted responses. The mean number of correct LUs per day was 128, whereas the mean number of presented LUs per day was 152. The trends are highly variable due to the variation in the number of days per week of school. Most weeks of school were 5 days; however, due to holidays and the school calendar, some were 2, 3, or 4 days.

Figure 2 shows the cumulative objectives met that were recorded weekly as the total number of programs that each student mastered (90% accuracy across two consecutive

Fig. 1. Total number of correct (closed circle) and presented (open circle) LUs class-wide for each of 37 weeks of instruction (1 year) at TCI. Instruction occurred in five curricular areas: verbal behavior, academic, social, self-management, and community of reinforcers

sessions). Objectives met were counted as the sum of all instructional programs across all instructional areas. The objectives met were counted as short-term objectives and long-term objectives. Prompted and unprompted responses resulted in the sum of all objectives met for each week. The total cumulative objectives mastered for all 16 children across the year were 4,480.

Figure 3 shows the school-wide mean number of LUs correct and presented for each child per week for the 2015–2016 school year across each of 37 weeks. The mean number of correct LUs per child per day across the year was 86. The

mean number of LUs presented per child per day across the year was 134.

Figure 4 shows the LU per objective. This is the average number of trials or LU needed for the student to master the objective. Objectives were considered mastered when the student met criteria at 90% accuracy across two consecutive instructional sessions. The mean for the year resulted in 213 LUs per objective with a range of 103–750. The trend started off high due to the nature of baseline conditions of instruction that occur at the start of the new school year. The trend was relatively stable throughout the year (see Fig. 4).

Fig. 2. Cumulative number of objectives met class-wide for each of 37 instructional weeks across all instructional areas for 16 students. The total for the year was 4,480 objectives taught. Each objective resulted from student responding at 90% accuracy (correct) across two consecutive instructional sessions

Fig. 3. Mean correct (closed circle) and mean presented (open circle) LUs per day for each student for each of 37 weeks of instruction across all instructional areas

Table 3 shows the enrollment, instructional hours, and the tuition costs for all the students across 3 years of schooling at TCI. Table 4 shows the school-wide LUs, mean LUs per day, the cumulative objectives met, and the mean LUs per objective for 37 weeks of instructions at TCI.

Table 5 shows the results in monetary figures—Hong Kong dollars and U.S. dollars (*italics*)—of the cost for TCI across 3 years. Table 6 shows the comparison of the actual cost of LUs and objectives across four research studies and three years of school-wide data at TCI, including the average in U.S. dollars.

Table 7 shows the comparison of the relative cost of LUs and objectives across four research studies and 3 years of school-wide data at TCI, including the average in U.S. dollars and adjusted for inflation to 2016 prices. Inflation is a measure of the buying power of the dollar over time. Cumulative interest rates from actual U.S. economic data (i.e., the consumer price index) was applied to the LUs and objectives met amounts in dollars.

In terms of a relative cost comparison, all studies listed in Table 6 yielded similar results in that the cost of the LU was

Fig. 4. School-wide mean number of LUs per objective met for the 2015–2016 school year ($n = 16$) for each week across 37 weeks of instruction. The overall mean across the year was 139 LUs per objective

Table 3 Cost benefit analysis for The Children's Institute in Hong Kong across three years (2013–2014, 2014–2015, and 2015–2016). Cost per learn unit and cost per objective met in Hong Kong Dollars & US Dollars* (red)

School Year	2013–2014	2014–2015	2015–2016
Total cost for each learn unit correct (HKD)	\$10.31	\$8.34	\$6.58
	\$1.33	\$1.08	\$0.85
Total cost for each learn unit presented (HKD)	\$8.64	\$6.91	\$5.51
	\$1.11	\$0.89	\$0.71
Cost per objective	\$1196.71	\$84.57	\$736.48
	\$154.20	\$10.90	\$94.89
Cost per day of the mean number of learn unit correct for one student	\$1185.65	\$975.78	\$842.24
	\$152.78	\$125.72	\$108.52
Cost per day of the mean number of learn units presented for one students	\$1183.68	\$974.31	\$837.52
	\$152.52	\$1215.53	\$107.91
Cost per day of the mean number of learn units correct for all students	\$21,341.70	\$18,539.82	\$13,475.84
	\$2,750.01	\$2,388.71	\$1,736.31
Cost per day of the mean number of learn units presented for all students	\$21,306.24	\$18,511.89	\$13,400.32
	\$2,745.44	\$2,385.11	\$1,726.58
Cost of the mean learn units per objective	\$1287.34	\$857.31	\$765.89
	\$165.88	\$110.46	\$98.68
Total cost (compounded for all objectives)	\$3,383,099.17	\$371,262.30	\$3,299,430.42
	\$435,919.13	\$47,834.46	\$425,118.28
Total cost (compounded for all learn units correct)	\$3,382,143.95	\$3,709,231.68	\$3,295,737.76
	\$435,792.19	\$477,895.08	\$424,631.35
Total cost (compounded for all learn units presented)	\$3,382,439.04	\$3,709,440.02	\$3,295,123.26
	\$435,830.22	\$477,935.37	\$424,539.00

*Currency Conversion based on rates from 7 March 2017

around US\$1.00. The range was \$0.58 to \$1.97. The objectives met were calculated to be US\$100.00 or less, with the exception of one outlier that occurred in the TCI 2014–2015 year, where the cost of each objective was calculated to be \$11.04. The range was \$11.04 to \$156.33.

Discussion

In recent years, attention has been given to the cost of “best practices” in education (Prizant & Rubin, 1999; Steege, Mace, Perry, & Longenecker, 2007; Weiss, 2005). It is expected that the use of principles and practices derived from evidence-based research will create the conditions that will lead to

positive and effective student learning. The present study reports on a school-wide treatment package for students with ASD and SEN across 3 years and its relative cost. It was clear that the treatment package resulted in effective instruction and that all students learned and made steady progress toward mastery of their IEP annual goals and objectives. The outcome of the present study can be compared to the relative outcomes of the previous studies that used calculations of this type based on direct measures of student and teacher interactions—namely, the LUs (Greenberg & Martinez, 2008; Greer, 1994). The results of the present study were consistent with those of the previous research studies that used a treatment package consisting of LUs, PSI training for teachers, the TPRA procedure, decision analysis protocols as applied to graphing

Table 4 Comparison of relative cost of learn units and objectives across four research studies in US Dollars

Research study	Cost per learn unit	Cost per objective
Greer (1994)	\$0.84	\$55.58
Greenberg (2007)	\$1.70	N/A
Greenberg & Martinez (2008)	\$0.52	\$69.68
Greenberg & Chung (2017)	\$0.90	\$86.66

*Average of three years (2013–2014, 2014–2015, 2015–2016) of applied behavior analysis special instruction
ADJUST FOR USA INFLATION 1994 - 2016

<https://www.statista.com/statistics/191077/inflation-rate-in-the-usa-since-1990/>

Table 5 Cost-benefit analysis for TCI across 3 years in cost per learn unit and cost per objective in Hong Kong dollars and U.S. dollars (italics)

Figure	2013–2014	2014–2015	2015–2016
Total cost for each LU correct (Hong Kong dollars)	\$10.31	\$8.34	\$6.58
	<i>\$1.33</i>	<i>\$1.08</i>	<i>\$0.85</i>
Total cost for each LU presented (Hong Kong dollars)	\$8.64	\$6.91	\$5.51
	<i>\$1.11</i>	<i>\$0.89</i>	<i>\$0.71</i>
Cost per objective	\$1,196.71	\$84.57	\$736.48
	<i>\$154.20</i>	<i>\$10.90</i>	<i>\$94.89</i>
Cost per day of the mean number of LUs correct for one student	\$1,185.65	\$975.78	\$842.24
	<i>\$152.78</i>	<i>\$125.72</i>	<i>\$108.52</i>
Cost per day of the mean number of LUs presented for one student	\$1,183.68	\$974.31	\$837.52
	<i>\$152.52</i>	<i>\$1,215.53</i>	<i>\$107.91</i>
Cost per day of the mean number of LUs correct for all students	\$21,341.70	\$18,539.82	\$13,475.84
	<i>\$2,750.01</i>	<i>\$2,388.71</i>	<i>\$1,736.31</i>
Cost per day of the mean number of LUs presented for all students	\$21,306.24	\$18,511.89	\$13,400.32
	<i>\$2,745.44</i>	<i>\$2,385.11</i>	<i>\$1,726.58</i>
Cost of the mean LUs per objective	\$1,287.34	\$857.31	\$765.89
	<i>\$165.88</i>	<i>\$110.46</i>	<i>\$98.68</i>
Total cost (compounded for all objectives)	\$3,383,099.17	\$371,262.30	\$3,299,430.42
	<i>\$435,919.13</i>	<i>\$47,834.46</i>	<i>\$425,118.28</i>
Total cost (compounded for all LUs correct)	\$3,382,143.95	\$3,709,231.68	\$3,295,737.76
	<i>\$435,792.19</i>	<i>\$477,895.08</i>	<i>\$424,631.35</i>
Total cost (compounded for all LUs presented)	\$3,382,439.04	\$3,709,440.02	\$3,295,123.26
	<i>\$435,830.22</i>	<i>\$477,935.37</i>	<i>\$424,539.00</i>

Currency conversion based on rates from March 7, 2017

student responses, and other evidence-based components supported by the research literature in ABA. The cost-benefit analysis shows the instructional outcomes and results in U.S. dollars. Our results were relatively consistent with previous research (Greenberg, 2007; Greenberg & Martinez, 2008; Greer, 1994).

The package included PSI modules, the TPRA observation procedure, LUs, group instruction, the data decision protocol, and direct instruction of research-based tactics. These were the

common denominators across all programs reviewed and reported through the cost-benefit analysis from Tables 5 and 6.

The treatment package reported here differed in some significant ways from the previous research. First, the amount of time that the students received NET varied across the studies and was not controlled. Inclusion formats varied as well. Inclusion will result in fewer LUs in a longer time period. This factor was not controlled within the study or across the studies. Therefore, variations in the amount of time that students received one-to-one LU instruction and group instruction, as well as the background and training of ABA teachers, may account for the

Table 6 Comparison of actual cost of LU and objectives across research studies and the present research study data in U.S. Dollars

Research study	Cost per learn unit	Cost per objective
Greer (1994)	\$.84	\$55.58
Greenberg (2007)	\$1.70	N/A
Greenberg & Martinez (2008)	\$.52	\$69.68
Present research study		
TCI 2013–2014	\$1.11	\$154.20
TCI 2014–2015	\$.89	\$10.90
TCI 2015–2016	\$.71	\$94.89
TCI (average across 3 years)	\$.91	\$86.66

Table 6 shows the comparison of actual cost of learn units and objective across research studies the three years of school-wide data at TCI in the present study including the average in U.S. dollars

Table 7 Comparison of relative cost of LU and objectives met across four research studies in U.S. dollars adjusted for inflation based on 2016

Research study	Cost per learn unit	Cost per objective
Greer (1994)	\$1.36	\$90.01
Greenberg (2007)	\$1.97	Not applicable
Greenberg & Martinez (2008)	\$0.58	\$77.68
TCI 2013–2014	\$1.13	\$156.33
TCI 2014–2015	\$0.90	\$11.04
TCI 2015–2016	\$0.71	\$94.89
TCI (average across 3 years)	\$0.91	\$87.42

Inflation calculations were made using <http://www.usinflationcalculator.com>

range of cost that was observed. The range of the cost for all LUs across all studies was \$0.84 to \$1.70, whereas the cost per objective range across all studies was \$55.58 to \$154.20.

The data reported across the 3 years at TCI showed a decrease in the cost per LU. The students and staff during this time were relatively stable, and we interpret this observed effect as the result of the teachers receiving additional supervision during this time. The teachers likely learned how their students learned, so to speak, meaning that they become more efficient at selecting research-based tactics that worked to teach the short-term objectives from the students' IEPs. We would expect that this might happen over time; however, our results suggest that this phenomenon may occur over time with teachers and students in the same learning environment.

Greenberg (2007) applied a teacher-training package to teachers using ABA. The LU cost was calculated across three teachers of three separate classrooms. In that program, the cost per LU for Teacher 1 was successfully lowered after exposure to a treatment package to \$1.70, for Teacher 2 to \$3.14, and for Teacher 3 to \$2.61. Costs per 20 LU instructional sessions were \$33.99 for Teacher 1, \$62.78 for Teacher 2, and \$52.36 for Teacher 3. The results of the present study were consistent with these findings.

Greer (1994) calculated the cost of instruction and objectives for the Fred S. Keller preschool. Results showed LUs to cost in the range of \$0.60 to \$0.70. Objectives had been calculated to cost in the range of \$55.58 to \$155.55. Over a 5-year period, the cost per objective had decreased as instruction had become more efficient. The results of the present study, specifically the 3 years of TCI outcome data and cost, were found to be consistent with these results. Table 6 illustrates this reduction in the cost of LUs and the cost of objectives met over time.

The reason for the observed variability in the cost of the LUs and objectives met is not clear. Frequency of supervision meetings, number of TPRA observations, minor differences in the training or backgrounds of the ABA teachers, variations in the time spent with the students in one-to-one versus group instruction, and other unidentified variables may be responsible for the observed difference across results. These differing components constitute the limitations of the data reported herein. Controlling for variables and internal validity from year to year within a school can be complex, whereas controlling for variables across schools, external validity, and long periods of time such as decades presents a challenge in the partial replication of procedures. These factors present limitations of the findings of the present study.

Greenberg and Greenberg (2014) showed the benefits and savings that resulted from a similar treatment package that resulted in a number of students being faded from the treatment package and included in THS. These results differed from the present study that reported on the specific costs of the LUs and objectives without overall savings that may have resulted from the termination of TCI services.

In summary, we can conclude that our analysis and results closely approximated the evidence-based ABA components from previously published studies. Results clearly demonstrated that the educational program was effective in teaching students with ASD and SEN to master many of their IEP objectives. The results were expressed as cost through the cost-benefit analysis and were relatively consistent with previous studies. Table 6 showed those results as cost adjusted for inflation so that the data can be compared in relative terms across time.

We advocate for an increase in the use of evidence-based ABA components in schools with students having ASD and SEN. The cost-benefit analysis can be used to assess the outcomes of those components. Additional metrics that decision and policy makers can use to inform their decisions about managing programs with students with SEN provide advantages to all stakeholders in the system. Future research can apply the cost-benefit analysis to additional populations of students with SEN across ages and cultures. Additional research is also warranted on the longitudinal effects and educational benefits and cost-effectiveness of ABA schools. Our findings can be used to implement accountability measures in schools and school districts to ensure that stakeholders are receiving the positive outcomes expected by those school systems.

Compliance with Ethical Standards

Conflict of Interest Jeremy H. Greenberg declares that he has no conflict of interest with the research data in the present paper. Tsoi-Yi Chung declares that she has no conflict of interest.

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors.

References

- Albers, A. E., & Greer, R. D. (1991). Is the three-term contingency trial a predictor of effective instruction? *Journal of Behavioral Education*, 1(3), 337–354.
- Anderson, S. R., & Romanczyk, R. G. (1999). Early intervention for young children with autism: Continuum-based behavioral models. *The Journal of the Association for Persons With Severe Handicaps*, 2(3), 162–173.
- Bate, A., Barber, S., Powell, T., Parkin, E., Long, R., Bolton, P., . . . Kennedy, S. (2017). *Early intervention* (Briefing Paper No. 07647). London: Parliament, United Kingdom. Retrieved from <http://researchbriefings.parliament.uk/ResearchBriefing/Summary/CBP-7647>
- Bushell, D., & Baer, D. M. (1994). Measurably superior instruction means close, continual contact with the relevant outcome data. Revolutionary! In R. Gardner III, D. M. Sainato, J. O. Cooper, T. E. Heron, W. L. Heward, J. Eshleman, & T. A. Grossi (Eds.), *Behavior analysis in education: Focus on measurable superior instruction* (pp. 3–10). Pacific Grove, CA: Brooks/Cole Publishing.
- Chasson, G. S., Harris, G. E., & Neely, W. J. (2007). Cost comparison of early intensive behavioral intervention and special education for children with autism. *Journal of Child and Family Studies*, 16(3), 401–413.

- Cooper, J. O., Heron, T. E., & Heward, W. L. (2007). *Applied behavior analysis* (2nd ed.). Upper Saddle River, NJ: Merrill.
- Greenberg, J. H. (2007). Effects of teachers' verbal mastery and application of research-based tactics on instruction and estimated costs to students with pervasive developmental disorders. *Dissertation Abstracts International*, 68(06), UMI No. 3266585.
- Greenberg, J. H., & Greenberg, J. C. (2014). It takes two to tango: Inclusive schooling in Hong Kong. *Global Education Review*, 1(1), 44–55.
- Greenberg, J. H., & Martinez, R. C. (2008). Starting off on the right foot: One year of behavior analysis in practice and relative cost. *International Journal of Behavioral Consultation and Therapy*, 4(2), 212.
- Greer, R. D. (1994). The measure of a teacher. In R. Gardner III, D. M. Sainato, J. O. Cooper, T. E. Heron, W. L. Heward, J. Eshleman, & T. A. Grossi (Eds.), *Behavior analysis in education: Focus on measurably superior instruction* (pp. 283–320). Pacific Grove, CA: Brooks/Cole Publishing.
- Greer, R. D. (2002). *Designing teaching strategies*. New York, NY: Academic Press.
- Greer, R. D., Keohane, D. D., & Healy, O. (2002). Quality and comprehensive applications of behavior analysis to schooling. *The Behavior Analyst Today*, 3(2), 120–132.
- Greer, R. D., McCorkle, N., & Williams, G. (1989). A sustained analysis of the behaviors of schooling. *Behavioral Residential Treatment*, 4, 113–141.
- Greer, R. D., & McDonough, S. H. (1999). Is the learn unit the fundamental measure of pedagogy? *The Behavior Analyst*, 20, 5–16.
- Greer, R. D., & Ross, D. E. (2008). *Verbal behavior analysis*. Boston, MA: Allyn and Bacon.
- Ingham, P., & Greer, R. D. (1992). Changes in student and teacher responses in observed and generalized settings as a function of supervisor observations. *Journal of Applied Behavior Analysis*, 25(1), 153–164.
- Jacobson, J. W., & Mulick, J. A. (2000). System and cost research issues in treatments for people with autistic disorders. *Journal of Autism and Developmental Disorders*, 30(6), 585–593.
- Jacobson, J. W., Mulick, J. A., & Green, G. (1998). Cost-benefit estimates for early intensive behavioral intervention for young children with autism: General model and single state case. *Behavioral Interventions*, 13, 201–226.
- Kates-McElrath, K., & Axelrod, S. (2007). Behavioral intervention for autism: A distinction between two behavior analytic approaches. *Behavior Analysis Review*, 2. Retrieved from <http://www.behavior-analyst-today.com/BAR2007/BAR-VOL-2.pdf>
- Keller, F. S. (1968). "Good-bye teacher . . ." *Journal of Applied Behavior Analysis*, 1(1), 79–89.
- Keohane, D. (1997). *A functional relationship between teachers use of scientific rule governed strategies and student learning* (Unpublished doctoral dissertation). Columbia University, New York, New York.
- Keohane, D., & Greer, R. D. (2005). Teachers' use of a verbally governed algorithm and student learning. *International Journal of Behavioral Consultation and Therapy*, 1(3). Retrieved from <http://www.behavior-analyst-today.com/IJBCT-VOL-1/IJBCT-1-3.pdf>
- Lovaas, O. I. (1987). Behavioral treatment and normal educational and intellectual functioning in young autistic children. *Journal of Consulting and Clinical Psychology*, 55, 3–9.
- McGee, G. G., Morrier, M. J., & Daly, T. (1999). An incidental teaching approach to early intervention for toddlers with autism. *The Journal of the Association for Persons With Severe Handicaps*, 24(3), 133–146.
- Motiwala, S. S., Gupta, S., Lilly, M. B., Ungar, W. J., & Coyte, P. C. (2006). The cost effectiveness of expanding intensive behavioural intervention to all autism children in Ontario. *Healthcare Policy*, 1(2), 135–151.
- Office of Overseas Schools U.S. Department of State (2018, June 4) Retrieved from <http://www.projectaero.org>
- Olchowski, A. E., Foster, M., & Webster-Stratton, C. H. (2007). Implementing behavioral intervention components in a cost-effective manner: Analysis of the Incredible Years Program. *Journal of Early and Intensive Behavior Intervention*, 3(4)–4(1), 284–304. Retrieved from <http://www.behavior-analyst-today.com/JEIBI-VOL-3/JEIBI-3-4.pdf>
- Piccininni, C., Bisnaire, L., & Penner, M. (2017). Cost-effectiveness of wait time reduction in intensive behavior intervention services in Ontario, Canada. *JAMA Pediatrics*, 171(1), 23–30.
- Prizant, B. M., & Rubin, E. (1999). Contemporary issues in interventions for autism spectrum disorders: A commentary. *The Journal of the Association for Persons With Severe Handicaps*, 24(3), 199–208.
- Selinske, J., Greer, R. D., & Lodhi, S. (1991). A functional analysis of the comprehensive application of behavior analysis to schooling. *Journal of Applied Behavior Analysis*, 24, 107–117.
- Skinner, B. F. (1957). *Verbal behavior*. New York, NY: Prentice-Hall.
- Stabile, M., & Allin, S. (2012). The economic costs of childhood disability. *Future Child*, 22(1), 65–96.
- Stallings, J. (1980). Allocated academic time revisited, or beyond time on task. *Educational Researcher*, 9, 11–16.
- Steege, M. W., Mace, F. C., Perry, L., & Longenecker, H. (2007). Applied behavior analysis: Beyond discrete trial teaching. *Psychology in the Schools*, 44(1), 91–99.
- The Challenging Behaviour Foundation. (2014). *Briefing paper: Early intervention for children with learning disabilities whose behaviours challenge*. United Kingdom: Council for Disabled Children Retrieved from <https://councilfordisabledchildren.org.uk/help-resources/resources/briefing-paper-children-learning-disabilities-whose-behaviours-challenge>.
- Twyman, J. S. (1998). The Fred S. Keller School. *Journal of Applied Behavior Analysis*, 31(4), 695–701.
- Weiss, M. J. (2001). Expanding ABA interventions in intensive programs for children with autism: The inclusion of natural environment training and fluency based instruction. *The Behavior Analyst Today*, 2(3). Retrieved from <http://www.behavior-analyst-today.com/VOL-2/BAT-2-3.pdf>
- Weiss, M. J. (2005). Comprehensive ABA programs: Integrating and evaluating the implementation of varied instructional approaches. *The Behavior Analyst Today*, 6(4). Retrieved from <http://www.behavior-analyst-today.com/VOL-6/BAT-6-4.pdf>