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Improving the Performance of Children with Autism through an Adaptive Learning System

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ABSTRACT

Children with autism experience significant impairments in social, behavioural and communication skills. These impairment levels varies between children and that made teaching autistics a challenge. Hence, assistive technology offers an alternative way to attract autistics to learning using representational visual illustration as a learning method instead of textual forms. The development of the ALS for children with autism is visually customisable to suite the individuals needs taking in considerations the simplicity of the interface based on the child computer interaction principles. This paper presents the ALS evaluation throughout observations and autism treatment evaluation assessment of traditional learning methods compared to the proposed intervention learning methods. The evaluation results reflect the effectiveness and efficiency of the proposed prototype for children and caregivers at home or at schools to influence children to improve their skills and enhance their performance in their daily life activities.

Keywords: *Children with autism, intervention, adaptive learning, design, learning styles & principles*

1. Introduction

The term 'Autism Spectrum Disorders' (ASD) refers to a cluster of developmental disorders that present from birth or very early in development (Esposito and Venuti 2009, Tsai 2012), with usually life-long effects on essential human behaviours such as social interaction, communication, imagination, and relationships with others (National Research Council 2001). ASD has been characterized as a spectrum of difficulties in these areas that vary in combination and severity, between and within individuals (Charman 2002). ASD includes various conditions such as autistic disorder, Asperger syndrome, pervasive developmental disorder not otherwise specified (PDD-NOS) and Rett syndrome based on American Psychiatric Association reports (American Psychiatric Association 1994) and international classification disease (ICD-10) and World Health Organization (1992). According to the DSM-IV-TR, autism is a severe disorder characterized by the presence of at least 6 out of 12 symptoms concerning communication, joint social interaction, behaviour, and activities that are present from the age of three years (American Psychiatric Association 2000).

While it is controversial whether the popularity rates of ASD are actually growing (Baird et al. 2006, Charman 2002) or, because of factors such as changes in diagnostic conditions and increasing awareness and recognition (Wing and Potter 2002), it appears to be growing, significant occurrence rates are reported by a number of studies. For example, the Australian Advisory Board on Autism Spectrum Disorders reported an estimated popularity rate for ASD across Australia, based on the Commonwealth government's Centreline data, of 62.5 per 10,000 for 6 to 12-year-old children (Williams et al. 2008).

Similar popularity rates have been found in other studies; Charman (2002) reviewed three recent prevalence studies and suggested an average frequency rate of 60 per 10,000 for children under 10 years old. (Wing and Potter 2002)Reviewed 39 studies conducted internationally and reported occurrence rates of 60 per 10,000 for autism and higher rates for the broader spectrum. A prevalence rate of 62.5 per 10,000 indicates there is an average of one child with ASD for every 160 children between 6 and 12 years (Williams et al. 2008).

Significantly, ASD is like other disabilities, has considerable social impact, especially on family and education. (Williams et al. 2008)Points out that, with a popularity rate of 62.5 per

10,000, ASD affects families containing half a million Australians. The families of individuals with ASD experience demands in a variety of family life contexts, including the needs of parents, both as individuals and as a couple (National Research Council 2001), and of siblings.

Children with autism spend less time engaged in social and non-social activities compared to a typical developed children that resulting in reduced learning opportunities for them (Kishida and Kemp 2006, McWilliam and Bailey Jr 1995, Ruble and McGrew 2007). Promoting and supporting engagement is considered as an effective learning intervention for children with autism (Corsello 2005, National Research Council 2001), although certain behavioural, educational, and pharmacological interventions have been demonstrated to be helpful for many individuals with autism, there is currently no cure for the disorder (White, Keonig, and Scahill 2007). Learning and behavioural interventions methods widely used such as: Treatment and Education of Autistic and related Communication handicapped Children (TEACCH) method and Applied Behavioural Analysis (ABA) method, these methods will be explained in section 2.4. And according to Ruble and McGrew (2007) parents admitted that behavioural and educational mixed methods are an effective and productive method as an intervention technique. Additionally, an early intervention can provide long-term improvements to a child's ability to integrate with society (Wetherby and Woods 2006, Matson and Smith 2008).

Education is extremely important for children with autism, and research continues on developing educational goals appropriate for them with the aim of promoting personal independence and social responsibility (National Research Council 2001). Educational interventions have been characterized by active engagement in intensive instructional programs accompanied by ongoing measurements of progress toward educational objectives (National Research Council 2001). However, educational intervention is also used to enhance the treatment of the behaviour impairments found in children with autism specially when applied early and intensively (Matson and Smith 2008). The behavioural interventions are: Treatment and Education of Autistic and related Communication handicapped Children (TEACCH) method and Applied Behavioural Analysis (ABA) method.

Investigation of the subjective experiences of children with autism has the potential to make educational interventions more effective by treating them as independent entities. It allows for a more in-depth mediation between learners' inner world of personal experience and the public world of social knowledge within which they function (Pring 2000).

The educational interventions were admitted by families as a more successful intervention with better outcomes compared to medical interventions (Ruble and McGrew 2007). Therefore, many research studies are directed towards the educational intervention in order to curb the stereotypical behaviour of these population. In addition, education intervention is affordable if compared to the medication interventions, due to the reusability of the educational materials whether manual or systematic form by many children.

Many tools are existed to diagnose children with autism such as Childhood Autism Rating Scale (CARS) (Schopler, Reichler, and Renner 1986), Autism Diagnostic Observation Schedule (ADOS) (Lord et al. 2000), Autism Diagnostic Interview-Revised (ADI-R) (Lord and Schopler 1994), Autism Behaviour Checklist (ABC) (Krug, Arick, and Almond 1980) and Gilliam Autism Rating Scale (GARS) (Gilliam 1995). However, Autism Treatment Evaluation Checklist (ATEC) assessment was developed to provide a free and easily accessible method for caregivers to track the changes of ASD symptoms over time (Rimland and Edelson 1999). Importantly, ATEC was not designed for diagnostic purposes; only to measure changes in ASD severity, making it useful in tracking the efficacy of a treatment over time. Various studies have sought to confirm the validity of ATEC (Al Backer 2016, Geier, Kern, and Geier 2013, Jarusiewicz 2002).

ATEC consists of four subscales: (1) Speech/Language/Communication, (2) Sociability, (3) Sensory/Cognitive Awareness, and (4) Health/Physical/Behaviour. These four subscales are used to calculate a total score that ranges from 0 to 179. A lower score indicates less severe symptoms of ASD and a higher score indicates more severe symptoms of ASD (Rimland and Edelson 1999). The subscales provide survey takers information about specific areas of behaviour which may change over time.

2. Assistive technology intervention

Technology-based educative methods are increasingly regarded as playing a key role in the educating children with autism (Konstantinidis et al. 2009). Educational technology can be used either as a constant assistive tool or used temporarily as a teaching aid (Goldsmith and LeBlanc 2004). The use of technology in educational interventions for children with autism, such as computer-aided learning, has been shown to benefit areas such as literacy skills (Tjus, Heimann, and Nelson 2001, Williams et al. 2002), facial recognition abilities (Tanaka et al. 2010) and social skills (Mitchell, Parsons, and Leonard 2007, Piper et al. 2006). Pennington (2010) also suggests that computer-aided instruction could be beneficial in other academic areas such as mathematics and science. Children with autism frequently need one-to-one adult instruction, but even when this is available there can still be issues with learning due to "non-compliance, lack of motivation, behavioural difficulties and engagement in stereotypical or ritualistic behaviours" (Williams et al. 2002). Technology offers an alternative provision of one-to-one instruction, but also the potential to overcome some of these additional issues.

Previous research has shown that children with autism often exhibit a strong interest and enjoyment interacting with technology as well as a high level of ability in using it (Higgins and Boone 1996, Goodwin 2008, Putnam and Chong 2008). Researchers have cited a number of benefits that technology specifically offers children with autism:

- The level of the child's social skills does not affect the interaction with the technology as it does with the class teacher (Bölte et al. 2010) and is particularly suitable for certain "domain-specific" learning (Williams et al. 2002).
- Technology can be used to teach and reinforce specific skills in which children with autism can exhibit difficulties. It could be possible to use technology for a whole range of skills but previous research has mainly concentrated on communication and social skills (Parsons et al. 2000, Rajendran and Mitchell 2000, Grynszpan, Martin, and Nadel 2008), which are the skills children with autism typically struggle with, and has been shown to have a positive effect on learning.
- The same software can be used at both school and home, allowing the child to practice any areas they are struggling with outside of school in a learning environment they are used to and helping to provide training in generalisation (Panyan 1984).
- A computer screen offers a smaller area of focus than a classroom setting, which means the child is less affected by the external environment and increases concentration on the task (Williams et al. 2002).

- Technology offers a safe environment in which the child can make errors and learn from them without any fear of the consequences, giving the child more confidence to try unfamiliar things (Goldsmith and LeBlanc 2004, Konstantinidis et al. 2009).
- The material can be delivered in a visual way, which is a preferred way of learning for many children with autism (Williams et al. 2002).
- The software can be designed to provide as much additional one-to-one individualized support as required, the level of which can be varied between children adapting to their specific learning and other needs e.g. visual/hearing sensitivities (Higgins and Boone 1996, Williams et al. 2002, Goodwin 2008). This can potentially reduce the amount of one-to-one teaching time the child requires (Panyan 1984).
- Technology can give the child more control over their learning, allowing them to work at their own pace and also are often appealing to children with autism, potentially increasing their engagement in the task (Bölte et al. 2010, Konstantinidis et al. 2009).
- Children with autism do not like change and technology can provide consistency across tasks, as well as being predictable and familiar (Bölte et al. 2010, Konstantinidis et al. 2009).
- Learning through technology has been shown to increase motivation and improve behaviour in children with autism (Williams et al. 2002, Goldsmith and LeBlanc 2004, Konstantinidis et al. 2009).

Although the use of technology in the education of children with autism can be beneficial, it is also important to keep in mind the potential issues that the use of technology could present, which include:

- Reducing the interaction time in class and replacing it with interaction with the technology could further isolate children with autism, reducing their opportunities for social interaction with the teacher and other children (Higgins and Boone 1996).
- Children with autism often have obsessive-compulsive behaviours and the technology could become a focus of one of these, particularly if their special interest is related to technology in some way (Williams et al. 2002).
- It can be hard to tailor technology for each individual child effectively and adapt to their changing needs. When designing technology for this specific group it is difficult to generalise, as what works for one child may not always work for another due the vast differences between children on the autistic spectrum (Constantin et al. 2017).
- Children with autism find it hard to transfer skills they have learnt in one environment into another, and they might struggle applying skills they have learnt through interaction with the technology into a real world scenario (Wood et al. 2017).

- Not all skills are best taught using technology, it should be used to teach or reinforce appropriate skills and not seen as the answer to all problems experienced in the classroom-learning environment (Smith, Cowie, and Blades 2015)

Overall the use of technology in educational interventions offers great potential for this population, and despite the concerns of some researchers there is mounting evidence that computers can provide a wide range of benefits to children with autism. It is however important that this technology is employed in appropriate situations and used to complement other successful teaching methods, to ensure the children still have exposure to social learning situations. This technology also needs to be appropriately designed ideally taking into consideration current theories of autism and structured approaches to learning as well as input from the ASD children population as the system informant which is the source of information, ideas and materials.

It is important for technology designers to be aware of the vast individual differences within autistics and the difficulty in achieving a universal technological solution to educating these individuals. It is also very challenging for neuro-typical adult designers to understand the needs and preferences of children with autism. Suitable customisation and personalization options and the involvement of this user group in the design process offer two potential solutions to these issues and are discussed in the following sections and the literature review chapter as well.

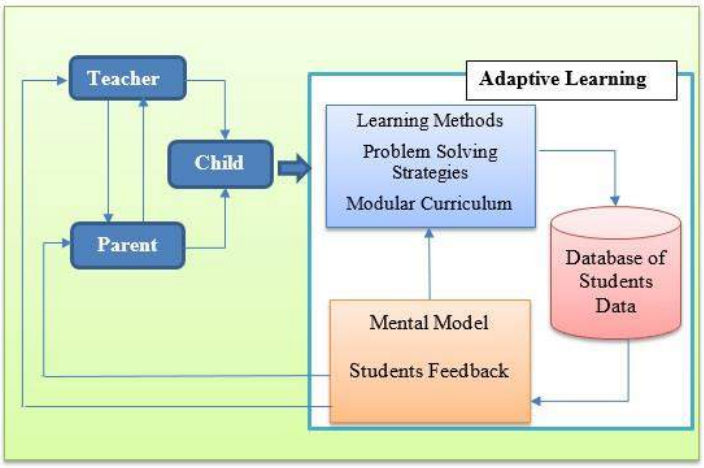

Figure 1: Adaptive learning model design.

3. Adaptive learning approach

Adaptive learning method as seen in Figure 1 took in considerations Kerns (2013) list of many benefits using adaptive learning approach for children with autism such as: it can be personalized which adapts to all learning capabilities, also to provide a real-time feedback to users. Moreover, the adaptive learning approach tends to balance between the face-to-face instructions and the online instructions. It does not mean adaptive learning meant to replace the educators, it just help to initiate a self-paced guidance system and build up the independence aspect into the learners. Nonetheless, it is a motivation factor in the learner's life. Consequently, children can become more engaged with the educational materials or the tasks assigned to them via the system in order to achieve it aiming to a better scores and understanding.

Nonetheless, adaptive learning method as seen in Figure 1 attempts to transform the students from passive receptor of knowledge and information to a collaborator in the educational activity. It also provides valuable information and feedback to teachers and parents as one of its key features in order to use it in a more constructive way.

4. Adaptive learning process

Learning process as Figure 2 shows, teacher or the parent starts the process by identifying the learning objectives such as mathematics, facial expressions and emotion or any desired subject to be taught to the learners, identifying the learning objectives shall make the learning process a goal oriented rather than deviating away from the main objective for starting this process with learners. The learning styles such as video presentations, transitional images, humanoid animations or decorative styles which are determined by the teacher or the parent to assist in achieving the learning process objective. Followed by the learning strategies as a presentational guidelines to the educational materials.

Specifying the materials or the contents which are required to educate the children and applying the learning methods such as the variability of the contents to assist children cognitive skills and learning progress, repetition and reinforcement of the contents to enhance the child's memory, motivation after an achievement which contributes in attracting children to the contents and gives the feel of progressive achievement while learning, and the final learning method is the visualisation which is the contents presentation taking in considerations that the targeted users are autistics with low cognitive abilities as compared

to typical children. Therefore, a simplified visual illustrations of the learning materials and contents are highly recommended.

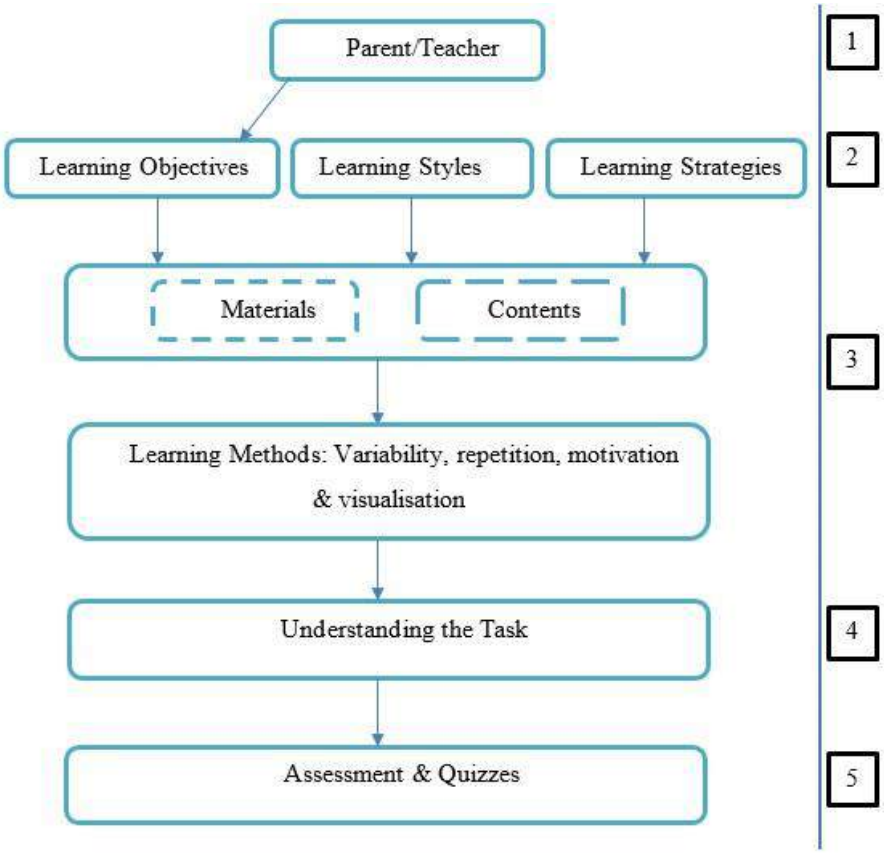

Figure 2: Adaptive learning process.

Learning process is a task that has to be accepted by the targeted learners, they should be self-determined and willing to go through this process. The teacher or parents should observe the learners in order to build the learning environment which aims to empower learners and motivate them in the initial stages so that they could understand the learning process and tasks in order for them to use the system independently. Assessments and quizzes are given to the children at the end of each learning session to evaluate their learning progress.

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Figure 3: ALS welcome page.

Figure 3 is showing the ALS welcome page which navigate the user between tutorial or quiz modules, whereby Figure 4 shows a listing of the available tutorials in the system.

Figure 4: List of available tutorials in ALS application.

Figure 5: Facial emotions tutorial.

A sample of facial emotions tutorial is shown in figure 5, the text "Sad" is written in in decorative style and different samples express the emotion targeted to teach autistics.
After conducting a tutorial session, a quiz module shall start to assess the children with autism learning process, Figure 6 shows a quiz module of the facial emotions.

Figure 6: Facial emotions quiz.

Participants

Ten participants, four girls and six boys were contributed to evaluate the ALS prototype, these participants are diagnosed with mild autism who exhibit low attention level from PRF autism centre the Islamic centre for children with special needs as well as "*Autism Café*" Centre in Kuala Lumpur, Malaysia. Table 1 shows the participating children demographics, the age range of the ten participants was between 4 and 13 years old. The communication skills for the participants are verbal or non-verbal by pointing.

All the ten participating children are familiar with computers and smart devices such as IPad and android devices. However they're from observations like to touch and point to the computer screen instead of using the mouse and keyboard.

The educational classes are following the TEACCH approach in delivering knowledge to the children in the *PRF* autism centre. Another two members of staff and two parents were contributed to the study and assist in the settings as well as the system evaluation.

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Table 1. Participants children with autism demographics

No	Gender	Age (Y)	Familiarity with computer and smart devices	Communication skills	Learning style	Motivation
P1	Female	7	Familiar	Non-verbal	Visual, Auditory & Kinaesthetic	Variability
P2	Female	5	Familiar	Verbal		Variability
P3	Female	4	Familiar	Non-verbal		Variability
P4	Female	9	Familiar	Non-verbal		Variability
P5	Male	8	Familiar	Verbal		Variability
P6	Male	6	Familiar	Verbal		Variability
P7	Male	9	Familiar	Verbal		Variability
P8	Male	13	Familiar	Verbal		Variability
P9	Male	11	Familiar	Verbal		Variability
P10	Male	10	Familiar	Verbal		Variability

Settings

The class setting was teacher to child and the teaching time is shortened to small slots, each slot is between 20 to 25 minutes to make sure the children do not feel bored or to avoid any anxiety in the class so a refreshment break of 5 to 10 minutes are given between learning slots.

The class setting was set with three personal computers (clients) connected via a network to another computer (server) which is installed with the ALS system as Figure 7 shows, The client computers access the server computer via its IP address in order to launch the ALS system.

Figure 7: Class setting with three clients and server.

Procedures

The ten participants were observed during the traditional learning style (baseline) as well as the ALS learning style within a total period of 9 weeks (2 sessions per week and 20 minutes for each session) in two centres. The first 4 weeks were mainly to observe the children as well as the teacher's traditional methods used to educate the children, data collection in the first centre *PRF* autism centre for six participants and from the second centre (*Autism Café*) for four participants. The ATEC is used to evaluate the children's progress scoring.

The following five weeks are maintained to train the teachers/parents on how to use the system and feed the system with educational materials either in the autism centre or at home. The ten participants had the chance to use the ALS system at home as well as at both centres as part of their activities.

Observations methodology

During the first eight session of this study; the observer recorded nearly everything that children and teachers do during each session using field notes as a precaution against any loss of data, video recording as well as teacher's interviews and feedback in order to evaluate the effectiveness of the traditional approach. The children behaviours observation aims to assist in skills analytics of the current state of the traditional rehabilitation approach so that can derive a deep analysis of the phenomenon and are associated to children behaviour.

The teachers were asked to complete the ATEC assessment for all children aiming to monitor the children progress in different subscales such as: verbal and none verbal communication, social, cognitive and the behaviour subscales. Those subscales are the main components of the ATEC assessment. Table 2 shows the ATEC assessment subscales and its measurements, the lower the score, the better the functioning.

Table 2. ATEC subscales and measurements

ATEC subscales	Measurement
Verbal communication subscale	0 - 28
Social subscale	0 - 36
Cognitive awareness subscale	0 - 34
Behaviour subscale	0 - 45
Total	0 - 143

5. Results and analysis

ATEC assessment baseline

Participated teachers and parents were asked to fill up the ATEC assessment on the last session of this study in order to evaluate the overall children progress. The children ATEC assessments readings were calculated and the total accumulated result is presented in Table 3 and figure 8 is the graphical presentation of the subscales for each participant. And as mentioned earlier the lower the total is the better the functioning and the progress.

Table 3. ATEC assessment subscales readings - baseline

No	Participants	Age (Y)	Speech/ Language/ Communication Subscale	Sociability Subscale	Sensory/ Cognitive Awareness Subscale	Health/ Behaviour Subscale	Total
1	P1	7	71.43	63.89	64.71	62.22	65.03
2	P2	5	57.14	69.44	73.53	53.33	62.94
3	P3	4	78.57	63.89	55.88	62.22	64.34
4	P4	9	89.29	72.22	64.71	71.11	73.43
5	P5	8	71.43	69.44	61.76	64.44	66.43
6	P6	6	50	41.67	58.82	46.67	48.95
7	P7	9	42.86	52.78	73.53	73.33	62.24
8	P8	13	50	58.33	67.65	68.89	62.24
9	P9	11	53.57	69.44	55.88	44.44	55.24
10	P10	10	39.29	58.33	67.65	55.56	55.94

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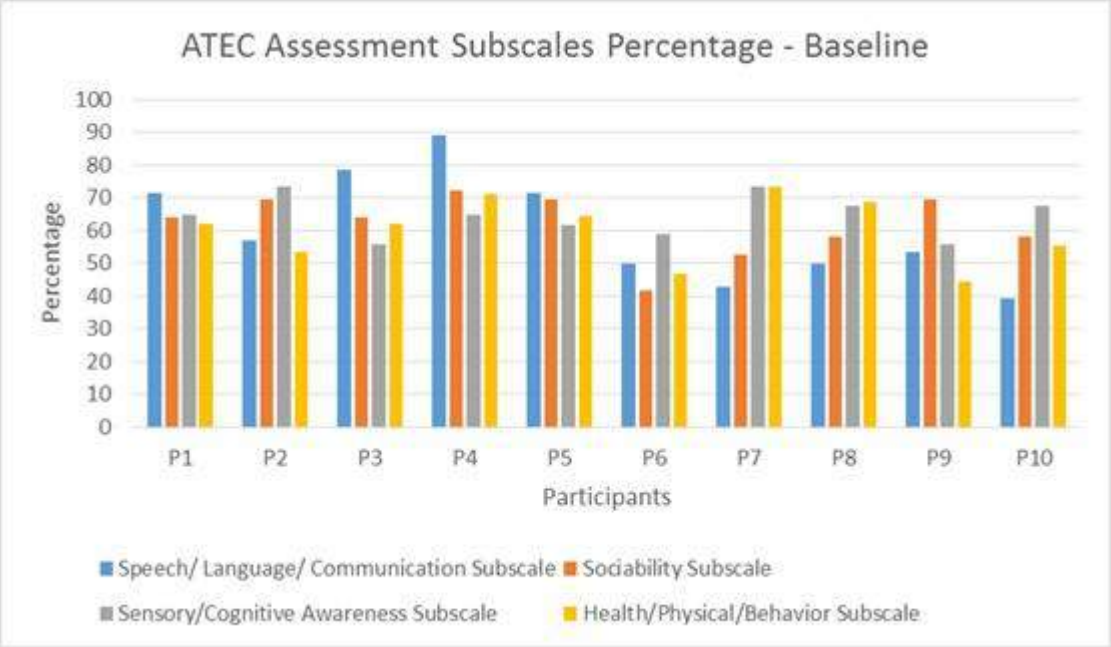

Figure 8: Participants ATEC assessment subscales percentage – baseline.

ATEC assessment intervention

ATEC assessment was filled up after the intervention sessions to document the teachers at centres and parents at home feedback after their observations to the children performance. Table 4 shows the detailed ATEC results for each subscale and figure 9 is the graphical presentation of the subscales for each participant.

Table 4. ATEC assessment subscales readings – ıntervention

No	Participants	Age (Y)	Speech/ Language/ Communication Subscale	Sociability Subscale	Sensory/ Cognitive Awareness Subscale	Health/ Physical/ Behaviour Subscale	Total
1	P1	7	50	63.89	61.76	60	59.44
2	P2	5	57.14	69.44	73.53	53.33	62.94
3	P3	4	46.43	63.89	52.94	53.33	54.55
4	P4	9	64.29	69.44	64.71	68.89	67.13
5	P5	8	57.14	69.44	58.82	71.11	65.03
6	P6	6	50	41.67	58.82	46.67	48.95
7	P7	9	42.86	52.78	73.53	73.33	62.24
8	P8	13	39.29	55.56	61.76	68.89	58.04
9	P9	11	53.57	69.44	55.88	44.44	55.24
10	P10	10	39.29	41.67	50	55.56	47.55

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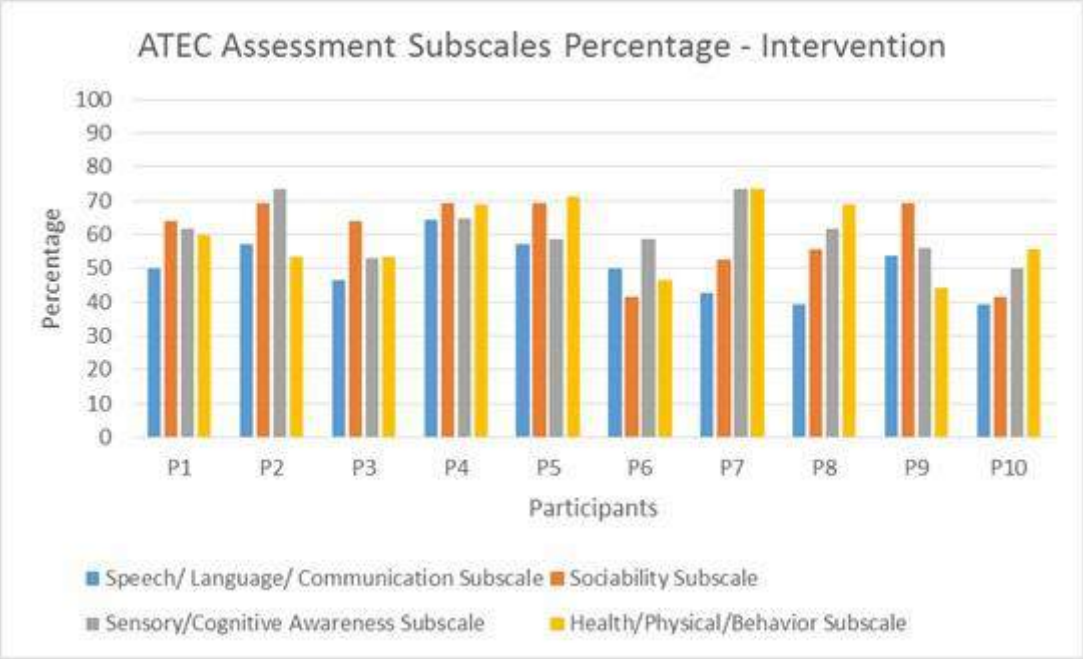

Figure 9: Participants ATEC assessment subscales percentage – Intervention.

Table 5. Baseline and intervention ATEC assessment readings

No	Participants	Baseline	Intervention
1	P1	65.03	59.44
2	P2	62.94	62.94
3	P3	64.34	54.55
4	P4	73.43	67.13
5	P5	66.43	65.03
6	P6	48.95	48.95
7	P7	62.24	62.24
8	P8	62.24	58.04
9	P9	55.24	55.24
10	P10	55.94	47.55

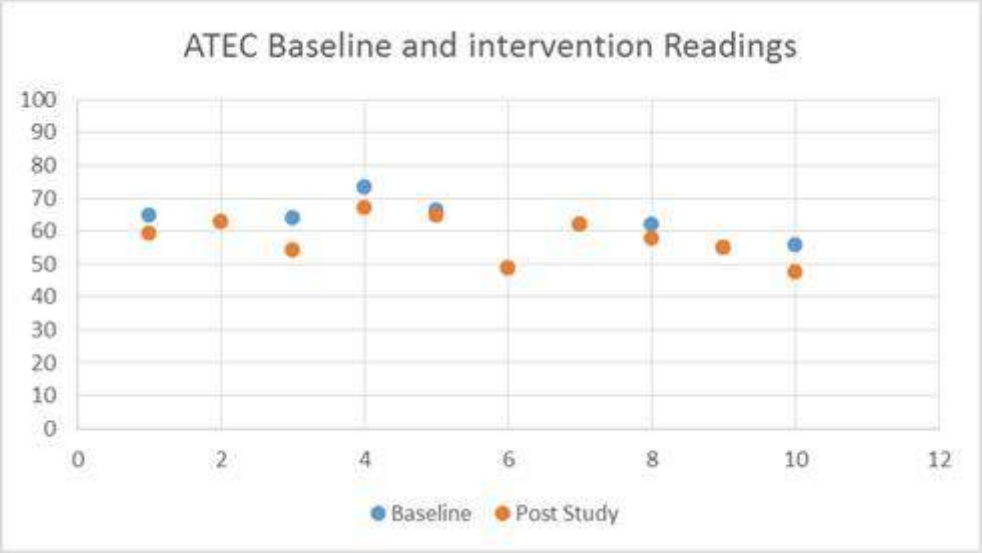

Figure 10: A scatter chart of baseline and intervention.

6. Discussion

Learning application has been one of the interventions used by different studies for correcting some of the impairments in children with autism. There has been quite a number of technology interventions or applications to teach different skills. These interventions have been implemented with different techniques in making them useful for these children because of their learning disabilities which as a result led to difficulty in processing information like the typical children (Happé 1999). Moreover, the "Theory of Mind" plays a vital role in their way of thinking (Baron-Cohen and Wheelwright 2004). They perceive messages differently and understand them best in visual form.

This study proposed an adaptive content management learning system for children with autism as a new intervention tool whereby the parents at home and teachers at school can collaborate to customise the overall look and feel to suite the individuals. The ALS was designed according to Wise (2014) list of characteristics to be followed when the targeted environment is children with autism.

The evaluation is based on the intervention observations which aims to test the prototype use compared to the traditional approaches, and how the ALS model can change the participants' behaviours. Noticeable results presented in Table 5 and Figure 10 which occurred on P1, P3, P4, P5, P8 and P10 which the post study ATEC score is less than the baseline ATEC score.

On the other hand, P2, P6, P7 and P9 did not show any improvement with no significant ATEC score change between using ALS and the traditional methods. However, the majority of participants which is six participants show a noticed improvement when using ALS. Therefore, these results show a higher effectiveness and efficiency of learning children with autism using ALS compared to traditional methods. Thus, the ALS system can be considered as a new and effective method to positively affect children with autism performance.

7. Conclusion

This paper presented the development and evaluation of ALS system as a new intervention tool for children with autism and it is evaluated throughout teachers and parents observations and the ATEC assessment. The results of the participants scoring showed the betterment of the ALS system intervention over the traditional approach in improving the children with autism learning. Moreover, the majority of participants showed an improvement results when using ALS. Therefore, the ALS model is effective in providing a better learning medium for the children with autism compared to traditional method.

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