The Use of Ergonomic Features in Assistive Technology with Children with Fine Motor Delays

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Abstract

The purpose of this study is to explore the use of ergonomically designed assistive technology with children with fine motor delays. This is an exploratory study based on direct observation of children participating in a fine motor activity in a natural setting. This study specifically targets students who have a diagnosis of autism as well as a fine motor delay. The variable targeted for investigation was individual child engagement. Momentary Time Sampling was used to measure and rate student engagement while coloring. Researcher observed students coloring in baseline and treatment conditions with a typical crayon and with an adapted crayon over the course of nine sessions. Researcher analyzed average levels of student engagement and differences in engagement levels from baseline ratings to average. Quantitative and qualitative data were analyzed descriptively within the results. This study fills a gap in research regarding the use of ergonomic design in assistive technology and its influence on student engagement.

Keywords: Fine Motor, Ergonomic, Autism, Engagement, Assistive Technology, Attention, Handwriting

1. Accessibility is key in the discussion of inclusion. How can educators make the materials, instruction, environment, and tools the most accessible so that students can find success? Education professionals must ensure that students have access to the tools that foster the most independence, and helps them experience the most success when attempting a task. Along with access, the tools used must be inclusive in design and assist with removing barriers to participation with same aged peers. The "one size fits all" model of instruction is long gone, and educators need to move beyond that to maximize the educational benefits for a diverse classroom of learners (Messinger-Willman & Marino, 2010).

Accessibility leads to engagement. Bailey and Wolery (1992) define engagement as ''the involvement of situationally appropriate interactions with the physical environment, materials, or other persons'' (p.37). Engagement is thought to be one of the conditions necessary for learning (Raspa, McWilliam, & Ridley, 2001). Engagement with learning is the essential piece that will lead to sustained interaction and practice. Increased engagement leads to increased practice, which in turn produces increased competence, and typically leads to motivation to engage further. This cycle of engagement supports improved student achievement (Irvin, Meltzer, & Dukes, 2007). Student engagement is a critical piece in the instructional process.

When viewing engagement from the lens of autism, researchers often define active engagement as on-task and on-schedule behavior (Bryan & Gast, 2000; MacDuff, Krantz, & McClannahan, 1993). Individuals with autism have significant difficulty engaging and accessing the school curriculum. Autism is a pervasive developmental disorder marked by differences in the areas of communication, socialization, and repetitive behavior. Individuals with autism exhibit varying degrees of difference in each of these areas (National Research Council, 2001). Challenges in engagement pertain to engaging in social communication with others, initiating and maintaining attention to activities, and processing information from the environment (Rao & Gagie, 2006). Students with autism are often less available for learning, or less engaged, during academic instruction.

Increasing access to the environment, while addressing students' challenges with engagement and attention require innovative practices and tools, which fall under the category of assistive technology. IDEA (2004) defines an Assistive Technology (AT) device as "any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve the functional capabilities of a child with a disability" (pg. 1-2). Utilizing AT, students can complete tasks more efficiently and effectively and become more actively involved within their least restrictive environment (Bailey, Meidenbauer, Fein, & Mollica, 2005). AT can range from low-tech devices (e.g., pencil grips, highlighters, reading guides, magnifying lens, and slant boards for writing) to high-tech devices such as text-to-speech software and laptop computers, and should be viewed as a continuum of supports (Kaplan, 2003). When implementing AT, to connect to the ongoing discussion in this article, the goal is accessibility, engagement, and ultimately independence for our students.

This article's purpose is to explore the use of ergonomically designed assistive technology during a fine motor task. The piece of assistive technology is an adapted crayon created using ergonomic design principles. According to the research of Liua, Cuia, & Donga (2015) there are some design features of writing tools that need consideration in writing tool design. "Thickness of grip, axial limitation of grip, contact size of grip, thickness of thumb-index web are a selection of factors that relate ultimately to the importance of providing clear thumb to index positioning and provide better force distribution in hand" (p. 6).

The features of the adapted crayon used in this research study entail a triangular shape, dual triangular ends, and a ridge in the middle of the crayon. These features meet the suggested requirements mentioned above by Liua, Cuia, & Donga (2015). There are additional considerations and benefits of the adaptive crayon design. The crayon includes dual ends with six tips due to its triangular shape. This provides multiple points of contact, therefore, multiple opportunities for children to experience successful attempts at coloring, and the integral ridge is a visual and tactile aid to assist with grip, and to prevent fingers from slipping should a child use greater force when pressing crayon to paper. The dual ends also encourage in hand manipulation, which is a skill that affects handwriting (Stango, 2015). These features were included because they are elements that will maximize a student's opportunity to independently pick up the crayon, hold it effectively, and begin coloring immediately. Maximizing and ensuring independence and attention are critical factors to control when a student already experiences fine motor difficulties and fine motor task aversion.

Children with autism are commonly identified with a weakness in handwriting. In a study by Grace, Enticott, Johnson, and Rinehart (2017), 23 boys aged 8-12 with ASD and 20 boys aged 8-12 in a control group completed a simple digitized task to assess handwriting performance. In the study, moderate to large associations were identified between attention and handwriting performance, ASD symptoms and motor proficiency. The findings suggest a relationship with core clinical symptom severity, attention, and motor behaviors in children with ASD. Building upon the knowledge that children with ASD have fine motor delays, which can lead to decreased handwriting performance, as well as struggle with attention, attempts need to be made to provide adaptations to the tools that these students use to increase the likelihood that students will increase engagement as well as sustain greater attention in fine motor tasks. This research study asks:

Does the addition of ergonomic features in the adaptive crayon change the level of student engagement in a fine motor task?

2. Review of Literature

Why are attention and fine motor skills important to investigate, especially during the early childhood years? Directed and sustained attention is limited at younger ages. Addressing attention is important for independence and task continuation, however it also connects with the speed in which a child can take in information and learn a concept. When children can direct more attention to the cognitive aspect of a task, such as understanding a mathematical concept or decoding words because the act of writing is automatic, quicker academics gains and progress can be made (Becker, R., Miao, A., Duncan, R., and McClelland, M., 2014).

Grissmer, Grimm, Aiyer, Murrah, & Steele (2010) found that fine motor skills are a critical piece of development for a child and a predictor for school readiness and future success, not only academic areas, specifically reading and mathematics, but they are linked to the overall development of cognitive and social skills. They are also associated with social behavior and adaption during a child's preschool to primary school transition (Bart, Hajamib, & Bar-Haimb., 2007), as well as linked with classroom engagement at the end of second grade (Pagani, Fitzpatrick, Archambault, & Janosz, 2010).

To solidify the importance of fine motor developing in early childhood, Cameron et al. (2012) examined the role fine motor skills had in early achievement. The authors found that a sample of 213 middle-class kindergarteners who had higher levels of fine motor skills had higher achievement at kindergarten entry, and these higher skills were a factor in their achievement growth from fall to spring. The children with higher fine motor skills improved more than kindergarteners with lower levels of fine motor skills.

There is clear evidence of the impact that fine motor skills have on student's academic achievement, regulation, and socialization. All three of these are of crucial importance in a child's development. There is overwhelming evidence for the connection of fine motor skills and academic performance, which is why the researcher chose to focus on this area for this study.

When comparing fine motor skills and individuals with Autism, results of a study conducted by Ming, Brimacombe, & Wagner (2007). suggest that fine motor control and programming deficits are common co-occurrence of children with ASD. Abu-Dahab, Skidmore, Holm, Rogers, & Minshew (2013) found that individuals with high-functioning autism had impaired grip strength and motor speed and coordination compared to typically developing individuals aged 5-21. The authors continue to note that intervention in these skills should begin early as they are essential to school performance.

Much of the research on engagement within the special education population has focused on attention and engagement within social and inclusive settings (Hartzell, Liaupsin, Gann, & Clem, 2015) or within a specific academic task (Lambert and Sugita, 2016).

Children with disabilities have greater difficulty in engaging compared to typically developing children (Dunst, McWilliam, & Holbert, 1986), and this increases with severity of disability (Bricker, Pretti-Frontczak, & McComas, 1998. Clemons et al. (2016) investigated how engagement affects specific academic areas or ages. For example, the use of self-monitoring was an effective intervention in improving classroom engagement with high school students with disabilities such as autism, learning disabilities, and intellectual disabilities.

Other research on engagement focuses on the aspect of inclusion and socialization. Children with autism have deficits in communication and social skills, and according to research may engage in less moderate to vigorous physical activity (Ledford, Lane, Shepley, & Kroll, 2014). In research motor in children with autism, MacDonald, Lord, & Ulrich (2013) found that children with weaker motor skills had greater social communicative skills deficits. There is little literature regarding measuring engagement within a fine motor task with children with autism and this area needs further investigation.

The author initiated this research based on experiences teaching in the elementary special education field. The author worked with many students with autism as a special education teacher for ten years and fine motor tasks consistently proved to be difficult, non-preferred activities that student resisted, as well as were a source of behavior incidents. Avoiding these tasks is difficult because fine motor tasks account for a significant portion of a student's day. McHale and Cermak (1992) found that 30% to 60% of the day in the elementary school years was allocated to fine motor activities, with writing tasks being the dominant activity. In U.S. kindergarten classroom, 33% - 66% of daily activities involve fine motor skills, such as drawing, copying, cutting, and coloring (Marr, Cermak, Cohn, & Henderson, 2003). Typical adjustments and interventions did not prove successful for the researcher. When the opportunity to begin research of specific alternatives for drawing and coloring tools to what is currently available, the researcher took advantage of it.

The creation of this specific piece of assistive technology is a product of a research and service learning activity that occurred at a University in NW Pennsylvania from 2015 to 2016. The crayon design was a product of collaboration between the researcher, a faculty member from the University's engineering program, and consultation with a local special education school's occupational therapists. The following sections will describe the methodology used in this research, as well as the results, discussions, limitations, and implications for future research.

3. Methodology

This was an exploratory study based on direct observation of children participating in a fine motor activity in a natural setting. The variable targeted for investigation was individual child engagement. The study used an AB design. The baseline phase involved students coloring for five minutes during one class period using the regular crayons currently being used in the classroom.

The treatment phase consisted of students coloring for five minutes at a time using the adapted crayons during eight different class periods. Using momentary time sampling methods, levels of engagement were recorded during 15-second increments. One baseline and eight five-minute treatment sessions occurred in total. The five-minute duration was chosen by consultation with the special education classroom teacher and her assessment of her students' optimal sustained attention spans on similar tasks.

Momentary time sampling (MTS) has been moderately to strongly correlated with expert ratings of engagement and it consistently demonstrated measurements closer to continuous duration recording compared with partial interval recording and whole interval recording (Wood, Hojnoski, Laracy, Olson, 2016). Momentary time sample was more conducive to use in this naturalistic setting. The researcher recorded observation of student engagement at the end of each time interval of 15 seconds. Because the researcher was observing three to five students at a time, the ability to measure engagement quickly, at single points in the intervals made the data collection more accurate as opposed to using whole interval or continuous duration.

3.1 Setting

The research study occurred within a preschool to 1st grade autistic support classroom at an approved special education school. All observations happened within the classroom, at the same time twice a week, during the regular school day.

3.2 Informed Consent and Confidentiality

Upon approval from the University Institutional Review Board (IRB), participant recruitment was initiated. The Informed Consent was provided to parents of children participating in the study. Parents received details of the study and were ensured that participation was voluntary. The researcher ensured confidentiality though the use of a third-party school personnel collecting the consent forms and assigning a number to each student, which will be used in all research reports and discussion. Information collected was stored in accordance with the Institutional Review Board standards. Collected information included name, grade level, measures of student engagement, qualitative data and anecdotal observations, and notes from interviews with the classroom teacher.

3.3 Participants

A nonprobability convenience sample of children who were served in an autistic support classroom and who all had diagnosed fine motor delays or deficits were recruited for this study. Nonprobability convenience sampling was appropriate as it provided a timely, inexpensive method for recruiting a disorder population in which treatment is warranted (Wheeler and Richey, 2009). A total of nine students, eight male and one female ranging in ages from four to seven enrolled in the study.

3.4 Measures

For this study, the author created the engagement assessment tool using the work of Kashida and Kemp (2006) in their development of the Individual Child Engagement Record (ICER-R). The ICER-R is an observational tool designed to enable practitioners to measure the engagement of children, including children with disabilities, in early childhood settings. Inter-observer agreement and the concurrent validity of the ICER-R were examined as part of the validation process. Preliminary findings indicate that the ICER-R can be a reliable and valid measure of the engagement of children in early childhood settings, and has the potential to be a practitioner-friendly measure (Kashida, Kemp, and Carter, 2008). Using direct observations, engagement is coded as engaged or non-engaged using operational definitions, and occurrence of physical prompts is also coded and recorded.

Rating scales on the measurement tool include items relate to overall engagement and occurrence of a physical prompts, as rated one to five. The inclusion of qualitative data is supported by de Kruif and McWilliam (1999) who maintain that there is value in measuring engagement through both teacher ratings and direct observation. An additional column was used to record anecdotal observations for each child's observation session. Definitions of engagement to which students were measured by are found below.

Definitions of engagement:

A student is actively engaged in the assigned task. Behaviors can include direct contact between the crayon and provided paper/material and continued movement of the crayon on the material for more than 3 seconds. The child may take a momentary break from coloring, but returns to the task either independently or with prompting. During this break student can look at the paper and/or hold the crayon, however, there is no movement or act of coloring occurring.

Definition of non-engagement:

Verbal or physical activity that is not directly associated with the assigned coloring task. This type of behavior should not be confused with repetitive physical or verbal movements that are associated with a child's disability and that are not within his or control. Behaviors can include manipulating objects not related to the coloring task, physically touching another student, turning around or turning away from the task while in one's seat). Passive behaviors can also include staring out the window or at the wall, sitting quietly while not engaging in any physical movement, looking around the room.

3.5 Procedures

Students were placed into two groups for all data collection observations. The following procedure was used for both the baseline and the treatment conditions. Students were observed coloring with an adapted crayon arranged in groups of four or five students. Students sat at a half circle table facing the researcher. Classroom and student assistants sat behind or next to the students. The treatment protocol consisted of the teacher passing out a plate of crayons for each child to use along with a coloring sheet. The teacher gave the direction to color to each child. The children would then begin coloring and every 15 seconds the researcher recorded levels of engagement. Use of a physical prompt within the intervals was recorded in the treatment phase to measure levels of spontaneity within a child's engagement. After five minutes, the students were told that they were done. These students then moved to another classroom activity and the second group of students came to the table and the same procedure was repeated.

Levels of engagement were reported as percentages of total intervals the students demonstrated engaged behavior for both the baseline and intervention sessions. Students were rated on a scale of one to five on overall engagement levels, and frequency of physical prompts was recorded. Both quantitative and qualitative data was recorded each session for each student. Researcher recorded each qualitative rating for each student's session. 72 sessions were available to be recorded across all nine students. There were 20 absences over the course of the 11 weeks, equaling 53 total opportunities for engagement to be recorded.

4. Data Analysis

Data were analyzed descriptively. Each sessions' levels of engagement were calculated as a percentage of intervals for each student so that results could be compared across different sessions. In addition, the percentage of occurrence of physical prompts was calculated, by dividing the number of intervals where there was a physical prompt by the total number of intervals of active or passive engagement. The small number of individuals included in the investigation was so small that any statistical analysis conducted would have little value. Therefore, results are reported descriptively.

5. Results

Overall average levels of engagement for the students in the class ranged from a low of 26% to a high of 83% (Table I). There was a difference in engagement from baseline levels compared to overall average engagement for the eight sessions for every student. Increases in engagement ranged from no increase to 60% increase. For two students, students six and seven, there was no increase in engagement between the baseline and average levels while using the assistive technology device. (Table II and Figure 1). This indicates that engagement levels were relatively stable across all data sessions and the use of the assistive technology neither improved nor weakened engagement levels for either of these students. It indicates that the specific design features of this device were not detrimental or caused a regression in skills. One can conclude that other designs may be more beneficial or preferred for these students.

A comparison of levels of physical prompts across students were analyzed from day one to day eight in the data collection sessions. Average levels of physical prompts were calculated. Day one there was an average of 10% of physical prompts performed across all students compared to day eight in which there was an average of 3.4 % of physical prompts used. This is a decrease in 6.6%.

Qualitative data from rating scales and from the teacher interview were also analyzed. When analyzing engagement using the rating scale from one to five it was found that during 83% of the total sessions students were rated as a three (engaged) or above. Classroom teacher qualitative interview answers supported the quantitative data and provided additional insight into changes in overall student performance comparing behavior before the study to the present time.

She observed positive changes and commented specifically on seven of the students' behavior during the study. Her comments related to how the shape and features of the crayons aided in the ease of use for the students, as well as the preference many students had for the crayons, which all factor into increasing engagement in a task. This interview served to obtain a level of validity for the researcher's observations and to add another piece of qualitative data to validate and triangulate the quantitative data on levels of engagement. The teacher was asked, "What are your observations of how the students performed during the entire intervention session?" The teacher provided observations on several of the students (Classroom teacher, personal communication, April 26, 2017).

> *Student #1 and Student #4 use the adapted crayons specifically. They color items a certain color, use different colors, and are detailed in their coloring. Student #4 usually gets bored with coloring and previously would not tolerate holding a name brand crayon. He only wanted to write numbers with the crayons. He actually uses the adapted crayons for its purpose, to color. He never engaged that long in a project until now. Student #3 doesn't like coloring, and with these crayons he interacts more with the task. Student #9 finds the crayons easier to hold. It is hard for him to grasp crayons, even the chunky ones. He uses the flat sides of the crayons to color and likes that. Student #8 isn't always this compliant. Art is normally difficult for her and she never fussed during any of these sessions. Student #7 likes holding them for the sensory component. Student #6 had an easier time with the crayons. With any task given to him, without support, this student would not do anything. His performance is based on focus of that moment.*

6. Discussion

Engagement is a variable that is influenced by outside factors, many of which are not under the control of the researcher or of the professionals that worked with the students in this study. Due to the nature of the applied setting, many external factors could not be controlled for, such as outside activity, changes in schedules, sickness, fatigue, change in classroom personnel, and home life. These daily temporal changes are unpredictable and may influence the student's overall engagement.

Anecdotal observations proved to provide useful information for the researcher regarding student behavior. Throughout the investigation verbal prompting as well as the level of physical prompting were important in discussing student performance. During the both the baseline and intervention phases, the para-professionals took a hands-off role unless a physical prompt was necessary. When more than six intervals had gone by with no activity from the student the paraprofessional gave a verbal prompt. Anecdotal observations noted that para-professionals used a variety of appropriate prompts during the intervention and were ones that occurred naturally, and on a regular basis within the classroom environment. These prompts did not interfere with the level of student independence. They verbally prompted the student by saying, "color", asked if they wanted a new coloring page, or requested students to try a new color.

If the student did not return to task, a paraprofessional gave a physical prompt. Physical prompts were also used if the student displayed refusal behaviors or if the student attempted to leave the table. These intervals when physical prompts were used were recorded and coded as "no engagement". A physical prompt was a hand over hand support mimicking a coloring movement for 1-5 seconds. There were some students that still required that level of prompting, however, even with that, still achieved higher levels of engagement than the baseline.

The use of physical prompts was minimal in comparison to the levels of engagement. Many students showed a decrease in the levels of physical prompts used over time. However, decrease in physical prompting did not always equate to an equal increase in engagement. It is an indication more of increased independence and an increased ability to respond to more verbal prompting and visual cues.

Analysis of anecdotal observations resulted in the following conclusions. Several environmental factors contributed to students' attention levels in this study. One environmental factor was the frequent change in para-professionals in the classroom day to day. This level of change can be difficult for any student to process, let alone a student who has autism, and who is highly affected by change. The personality and demeanor, and skill level of a paraprofessional also affected student's behavior and could have a calming or agitating affect, which would manifest itself as engagement or non-engagement during the intervention sessions.

Student sickness, tiredness, or inconsistencies from home also affected student engagement levels. A child's overall sense of health and well-being factored into his or her ability to sit and engage in a fine motor task.

6.1 Limitations

The small sample size makes it difficult to form any generalizations outside of the target population. The study used an AB baseline and intervention phase design. Even though the study included the minimum two conditions, ideally the study would benefit from using a standard ABAB design. Multiple baseline conditions as well as a longer treatment condition time may be beneficial in producing stronger evidence of change over time. The researcher was the sole observer and recorder of data. Human observation's recording of data can be influenced by a variety of factors, and therefore inter-observer agreement should be used to prevent observer bias or error. After each session, the researcher discussed the student performance with the teacher to confirm and validate observations, as well as performed a qualitative interview with the classroom teacher at the end of the study; however, the data collection would have stronger validation more if there was more than one observer for each observation session.

7. Conclusions

This study explored the use of ergonomically designed assistive technology during a fine motor task with children with autism and fine motor delays. The piece of assistive technology contained features grounded in ergonomic design principles. This study fills a gap in the research due to the lack of studies that have investigated how ergonomic assistive technology influences engagement in fine motor tasks with students with disabilities, specifically autism.

There are several recommendations for future research. The study would benefit from expanding on the population. Currently, the target population are students with autism and fine motor delays. It would be interesting to measure the engagement levels of students with sole physical or fine motor delays over time instead of students who have fine motor delays and autism. There were many variables at play within the study, and it may be beneficial to limit the variables of influence to the use of the adapted device and presence of fine motor delays.

Future longitudinal studies could also add to the literature to investigate if children's exposure and use of specific pieces of assistive technology early on and over time would give children a greater advantage over children who start using typical drawing and coloring tools. Instead of working to adjust and correct a child's grip, does the adapted crayon facilitate proper grip earlier, leading to quicker development of fine motor skills?

The addition of ergonomic features of the crayon allowed students to be more independent, facilitated increased levels of engagement, and proved to be a preference for many of the students, as indicated by teacher observations. Student engagement and assistive technology are important constructs that warrant continued research together, in not only students with autism, but other physical disabilities as well.

Table I: Percentage of Engagement and Physical Prompts Across Intervention Sessions

Student		Baseline 13-Mar	Session 1 20-Mar	Session 2 22-Mar	Session 3 29-Mar	Session 4 3-Apr	Session 5 5-Apr	Session 6 19-Apr	Session 7 24-Apr	Session 8 26-Apr
1	Engaged	21%	84%	52%	100%	80%	75%	95%	80%	A
	Physical Prompts	NR	0%	10%	0%	0%	0%	0%	0%	A
2	Engaged	57%	36%	42%	78%	90%	25%	9%	65%	57%
	Physical Prompts	NR	5%	0%	0%	0%	0%	0%	5%	5%
3	Engaged	21%	31%	A	A	60%	35%	45%	35%	42%
	Physical Prompts	NR	57%	A	A	0%	5%	0%	0%	0%
4	Engaged	68%	100%	100%	A	A	75%	85%	55%	A
	Physical Prompts	NR	0%	0%	A	A	0%	0%	0%	A
5	Engaged	5%	A	A	0%	A	52%	75%	3%	0%
	Physical Prompts	NR	A	A	100%	A	40%	15%	30%	21%
6	Engaged	52%	63%	94%	31%	95%	65%	20%	45%	47%
	Physical Prompts	NR	10%	10%	0%	0%	0%	10%	0%	5%
7	Engaged	78%	78%	68%	100%	80%	55%	75%	60%	A
	Physical Prompts	NR	5%	21%	0%	10%	10%	0%	15%	A
8	Engaged	31%	73%	78%	94%	60%	75%	85%	80%	47%
	Physical Prompts	NR	15%	0%	0%	0%	20%	0%	0%	0%
9	Engaged	63%	47%	57%	89%	65%	75%	75%	85%	68%
	Physical Prompts	NR	5%	10%	0%	0%	0%	0%	0%	0%

Note. NR denotes No Score Recorded.

Table II: Average levels of student engagement compared to baseline performance

Student	Average level of engagement	Difference between average and baseline
1	81%	60%
2	50%	-7%
3	41%	20%
4	83%	15%
5	26%	21%
6	58%	-5%
7	74%	-4%
8	74%	43%
9	70%	7%

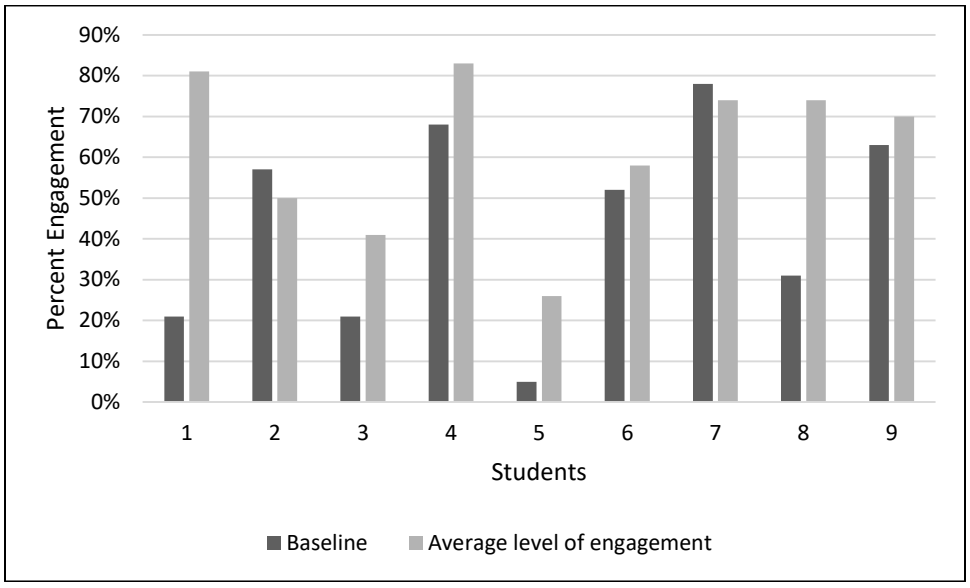

Figure 1. Baseline and Average Level of Engagement.

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