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# A CASE STUDY OF LEARNING MATHEMATICS VIA SELF-DIRECTED INTERACTIVE POWERPOINT

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***Abstract:*** *PowerPoint has been a popular presentation tool for conveying learning materials in educational institutions. While slides and points simply move on clicks, students may find presentation too quickly to absorb, digest and reflect on its contents. This study is an exploratory attempt to turn PowerPoint slides into an interactive, self-paced and self-directed learning platform (iPP) designed for learning to solve equations and inequalities involving absolute values. The purpose of the study was aimed at a quick initial assessment of the design effectiveness particularly for pedagogic improvement. The purposive sample involved an A-Level student who voluntarily sat for a pretest and interacted with the PowerPoint slides before attempting a posttest. The participant's interaction with the iPP was both observed and video-recorded, and the solutions to the pretest and posttest qualitatively compared. In particular, the fine-grained analysis of the participant's interaction with the iPP, which offers the opportunity to attempt tasks, access worked solutions, learn concepts and explore reasoning, may explain the participant's enhanced performance particularly in solving inequalities. Nonetheless, the observations on the participant-slide interactivity led to some pedagogical insights as to how interactive slides could meet a better design for more effective learning. It is concluded that interactive PowerPoint slides which contain pedagogical and resourceful contents and allow for autonomous navigation may support mathematics learning.*

***Keywords:*** *PowerPoint, Mathematics Learning, Solving Equations and Inequalities of Absolute Values*

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## Introduction

Throughout decades, PowerPoint has proliferated in the commercial and educational arenas. Past educational studies have revealed that PowerPoint use in lectures is looked upon with favor by instructors and students alike, claiming such benefits as enhanced professionalism, motivation, attention sustainability, learnability, and interest in a subject matter (Apperson, Laws, & Scepansky, 2006; Clark, 2008; Frey & Birnbaum, 2002; Susskind, 2005). However, many studies based their findings on surveys of respondents' beliefs and perceptions (e.g., Frey

& Birnbaum, 2002; James, Burke, & Hutchins, 2006), while others evaluating academic performance found no significant differences (Apperson at al., 2006; Susskind, 2005; Szabo & Hastings, 2000).

One key concern has been *how* PowerPoint is used and not merely if it is used (Bartsch & Cobern, 2003; Isseks, 2011; Jordan & Papp, 2014; Ricketts, 2018; Stryker, 2010). For instance, while slide presentation is mostly instructor-controlled, students usually serve as passive listeners. They may not favor the pace of presentation and the lack of engagement and interaction with PowerPoint (Rudow & Finck, 2015).

This study attempted to resolve this limitation with interactive, self-paced, self-directed PowerPoint slides (iPP) designed for learning to solve equations and inequalities involving absolute values, based on the Cambridge A-Level syllabus.

**Literature Review**

The use of PowerPoint for teaching and learning has prevailed rapidly since its debut in the 1880s. Its tremendous rate of expansion has indicated not only its popularity among instructors and students, but also the growing concern about its actual contribution to learning (Apperson at al., 2006; Bartsch & Cobern, 2003; Craig & Amernic, 2006; Frey & Birnbaum, 2002; Gambari, Yusuf, & Balogun, 2015; Hill, Arford, Lubitow, & Smollin, 2012; Johnson & Sharp, 2005; Levasseur & Kanan Sawyer, 2006). Due to the popularity and ubiquity of PowerPoint, a few questions have become highly relevant and significant: Why is PowerPoint favoured? How could it be used effectively? Does it significantly contribute to student learning and academic performance?

Past studies on the use of PowerPoint varied in the extents and ways PowerPoint was employed to enhance learning. At the least, some studies investigated if there was a difference in student learning with and without PowerPoint use. For instance, Chen and Lin (2008) investigated if students downloading PowerPoint slides before lessons led to better performance. Their study involved 126 students who took an intermediate microeconomics course at a public university in Taiwan. In the study, each student's access to the slides on the server was electronically tracked. The researchers were hence able to know which students downloaded the PowerPoint slides and the number of times downloading of slides occurred over a learning period of 12 three-hour face-to-face lectures. A panel data analysis was conducted to take into consideration possible individual heterogeneity with fixed effects and random effects models, in addition to the ordinary least squares model. All three models revealed statistical significance with a positive correlation between students downloading of PowerPoint and their examination performance.

In an innovative attempt, Wanner (2015) employed a just-in-time learning method, whereby students were required to answer a few conceptual questions via short PowerPoint presentation prior to lectures. The students presented their work during lectures and thus were engaged in active learning both before and during lectures. Such pedagogic use of PowerPoint was claimed to help students in structuring their thoughts and shaping learning contents with enhanced interactivity. In a similar strategy, Davies, Korte and Cornelsen (2016) made PowerPoint slides available to students outside of classroom. This way was claimed to be particularly useful for accelerated classes. In all the above studies, PowerPoint served as a 'carrier' of learning contents made available to students outside of class time.

Other studies looked into the use of PowerPoint during class time. Nam and Trinh (2012) tested the effects of PowerPoint on vocabulary retention of 68 grade 10 students using a pretest-posttest design and assessed the students' attitude towards the use of PowerPoint. The study found that the group with PowerPoint outperformed the control group in vocabulary retention and carried more positive attitude towards the use of PowerPoint in teaching and learning. Susskind (2005) compared traditional means with PowerPoint use in lectures on students' performance, self-efficacy, motivation, and attitudes. The students were found to have greater self-efficacy and more positive attitudes towards their lectures with PowerPoint use. However, no significant differences in academic performance were noticed between the two lecture styles. Similarly, the study by Apperson at al. (2006), comparing chalk-and-talk lecture style with PowerPoint use, found no difference in students' academic achievement despite their enhanced perceived effectiveness of PowerPoint in terms of organization and clarity, interest sustainability, and professional 'feel' about professors using PowerPoint.

Most studies, however, point to such generic aspects and features of PowerPoint as concise points on slides, dynamic and animated contents, slide handouts made available before, during or after lectures, attractive slide design and presentation, etc. While such generic features are certainly relevant and supportive to learning across domains, creative design of PowerPoint slides germane to the learning of a particular subject is rare. Such rare attempts may include the effort by Carmichael and Pawlina (2000), who developed animated images with PowerPoint to enhance the learning of Anatomy. The process of creating the animated presentation of a human heart was painstakingly tedious. They systematically obtained scanned images from pen-and-ink paper drawings which were intricately and repeatedly edited and refined to sufficient details. Upon laying the images onto a PowerPoint slide, animation and colours were created to saliently differentiate the various parts of the heart diagram dynamically. This dynamic nature of the course was greatly favoured by the students.

While past studies have revealed mixed results relating to the effectiveness of PowerPoint use, it clearly points to the need for greater attention to *how* PowerPoint should be designed and used, rather than simply its use and availability in teaching and learning. Johnson and Sharp (2005) argued that the use of PowerPoint as a sole presentation tool for instructors may not promote learning. Without thoughtful pedagogical considerations, PowerPoint may simply be static documents, which do not embrace change, promote open thought, and require student's active role and participation. Jones (2003) viewed PowerPoint as a very powerful and flexible teaching and learning support tool but lamented its downplay to mere information transmission which was described as very restricted pedagogy in case of inappropriate design. In addition, Szabo and Hastings (2000) cautioned that the efficacy of lectures with PowerPoint may be case specific rather than universal, implying the need for particular attention to not only the generic features of PowerPoint, but also domain-specific pedagogical strategies. This viewpoint is in line with the Standards of Excellence in Teaching Mathematics in Australian Schools which espouse the critical role of mathematics teachers in maximizing student learning by encouraging self-directed learning, mathematical thinking and reasoning, in addition to providing purposeful and timely feedback in the teaching and learning of mathematics (Galligan, Loch, McDonald, & Taylor, 2010). However, how such critical instructional ideals should blend with technology to catalyse learning requires thoughtful efforts and passion.

### Purpose of the Study

This study was an exploratory attempt at a quick, initial assessment of the effectiveness of a self-paced, self-directed, interactive PowerPoint presentation (iPP) designed for learning to solve equations and inequalities involving absolute values, based on the Cambridge A-Level syllabus. In particular, the study looked into the interactivity between a participant and the iPP, in an effort to better understand the nature of such interaction. In addition, it was also aimed at identifying possible areas for improvement, particularly on the pedagogical design of the slideware. The study thus inquired: How will the participant interact with the PowerPoint slides? How will the participant's performance in solving absolute value equations and inequalities change upon interacting with the slides?

## Method

### *Design*

This study adopted a qualitative design. The participant-slide interactivity was both observed, video-recorded, transcribed and qualitatively analyzed. In addition, the participant's solutions to a pretest and a posttest were qualitatively compared.

### *Sample*

This study involved a purposive sample of a Chinese male A-Level student, age 19, who was pursuing a Cambridge Advanced Subsidiary Humanities Program at a private college. The participant voluntarily took a pretest and interacted with the iPP before attempting a posttest. The participant's knowledge of absolute values was initially unknown. However, findings from the pretest confirmed his limited knowledge of absolute values and hence his suitability as a participant, who will be addressed as Sam hereafter.

### *Instrument*

#### *Interactive PowerPoint Presentation (iPP)*

The iPP was designed to contain five main strands, i.e. Preparation, Tasks, Worked Solutions, Concepts, and Reasoning, in consideration of such important aspects as conceptual understanding, reasoning, and the opportunity to solve problems and receive feedback (NCTM, 2000; National Research Council, 2001). The five strands are further elaborated in Table 1. A total of five absolute value equations and eleven inequalities were incorporated in the iPP in two separate files. The equations and inequalities were sequenced with gradually increasing complexity (see Table 2). The need to simplify two related conditional inequalities, such as '$x > 2$ and $x > 5$' implies $x > 5$, formed part of the solutions to the inequalities.

The first two of the eleven inequalities did not involve absolute values, i.e. $x^2 \geq 9$ and $\frac{8}{x} < 4$. They served to help the learner establish, and be familiar with, the understanding of real values and magnitudes before the concepts of modulus kicked in. In addition, an absolute value was defined in multiple ways to help the learner master the concepts of absolute values from multiple perspectives (Brumfiel, 1980). For example, $|x|$ can be ensured a non-negative value by manipulating the sign of $x$ conditionally, i.e. $|x| = x$, for $x \geq 0$ and $|x| = -x$, for $x < 0$. Alternatively, $|x|$ can be viewed as the magnitude of $x$, namely the distance of the real value $x$ from zero. Involving reverse operations, $|x|$ can be transformed into $\sqrt{x^2}$.

**Table 1: The Five Main Strands of The Interactive PowerPoint Presentation**

| Strand | Content/Purpose |
|---|---|
| 1. Preparation | Cover page, subject title, learning outcome, instructions and explanation on the overall slide design (e.g. how to navigate between slides) |
| 2. Tasks | Tasks on absolute value equations and inequalities for learner's attempt |
| 3. Worked Solutions | Solutions to the tasks revealed part by part on learner's action |
| 4. Concepts | Mathematical concepts in relation to particular tasks and solutions |
| 5. Reasoning | The reasoning explaining particular concepts or solutions |

**Table 2: Absolute Value Equations and Inequalities Incorporated In The iPP**

| Equations | Inequalities | |
|---|---|---|
| 1. $\|x\| = 5$ | 1. $x^2 \geq 9$ | 7. $\|2x - 3\| < 5x - 6$ |
| 2. $\|x - 2\| = 7$ | 2. $\frac{8}{x} < 4$ | 8. $\|2x - 3\| > 5x - 6$ |
| 3. $\|3x - 2\| = \|7 - 5x\|$ | 3. $\|x\| < 4$ | 9. $\|2x - 3\| < \|5x - 6\|$ |
| 4. $\|3x - 2\| = 7 - 5x$ | 4. $\|x\| > 4$ | 10. $\|x + 5\| \geq \|2x - 7\|$ |
| 5. $\|\|x + 2\| + \|2x - 8\| = 9$ | 5. $\|2x - 3\| < 5$ | 11. $\left\|\frac{2x+1}{x-1}\right\| \geq 3$ |
| | 6. $\|2x - 3\| > 5$ | |

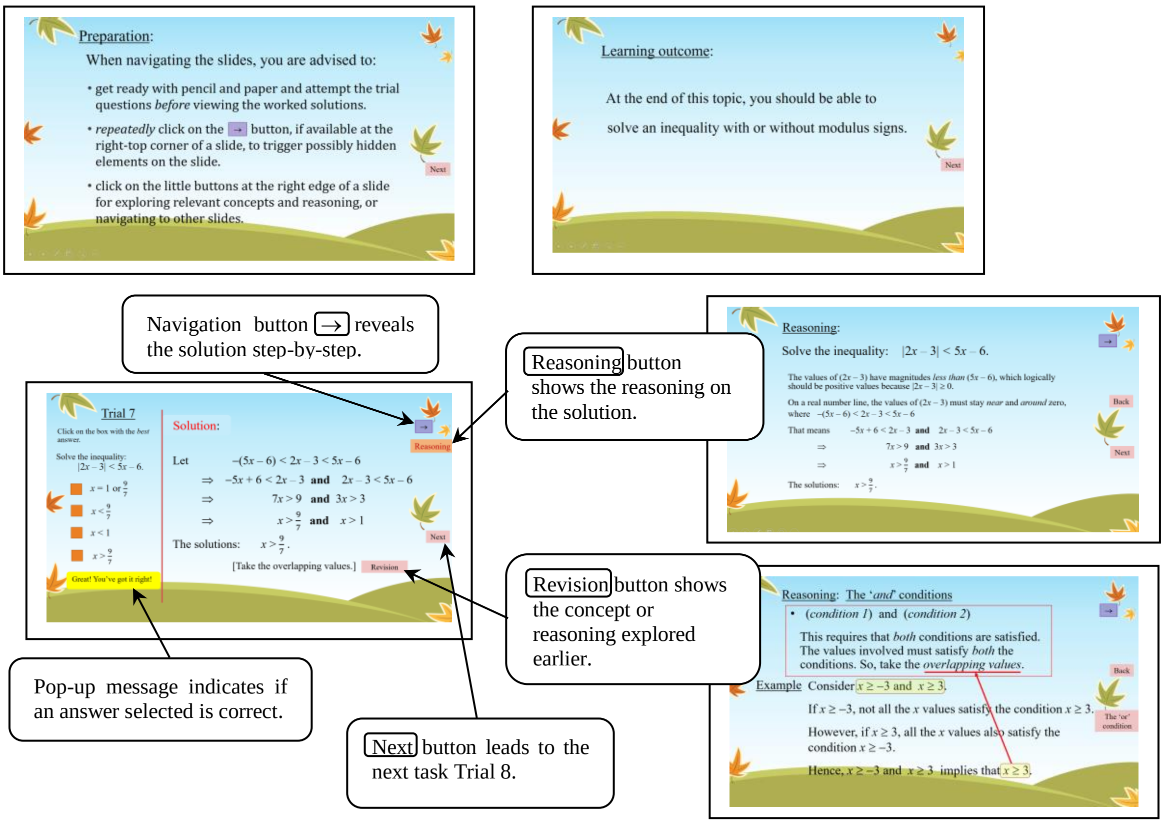


**Figure 1: Examples of Connected Slides In iPP Showing Nonlinear Paths of Learning**

One key feature of the iPP is the connected ideas which readily link a task and its solution to the related concepts and reasoning. Recursive nature and nonlinear paths of learning are made possible via the availability of buttons whereby the learner could freely attempt a task, receive feedback, view a worked solution and study the concepts and reasoning involved. For instance, when one of the optional answers to a task is clicked on, a feedback message would pop up to inform if the answer selected is correct. A few screenshots in Figure 1 illustrate how navigation between slides was made possible.

***Pretest and Posttest***

Both the pretest and posttest included the same tasks as shown in Table 3. The tasks of the Cambridge A-Level syllabus were varied in structural and logical intricacies, thus posing different levels of cognitive demand. Moreover, the tasks are amenable to multiple solutions based upon varied algebraic reasoning despite sharing the same fundamental concepts of absolute values.

This mathematical topic of solving absolute value equations and inequalities was selected in view of students' difficulties in dealing with the structural varieties and particularly the epistemological complexity involved with absolute value inequalities (Sierpinska, Bobos, & Pruncut, 2011).

***Procedure***

Two separate sessions were conducted for Sam's learning of the absolute value equations and inequalities. In the first session, two sets of pretests were administered, one on absolute value equations and the other on absolute value inequalities. Subsequently he interacted with the iPP and attempted the posttest on absolute value equations. In the second session, Sam interacted with the iPP and attempted the posttest on absolute value inequalities. Paper was provided for Sam's rough work when interacting with the iPP which formed part of the data collected. The two sessions took approximately 38 minutes and 1 hour 15 minutes, respectively.

Before Sam began interacting with the iPP, the relevant ideas pertinent to the iPP were explained to Sam, who freely navigated the slides to attempt tasks, view worked solutions, and explore the underlying mathematical concepts and reasoning. Sam's interaction with the iPP was closely observed and video-recorded. The video recorder was orientated such that the mouse movement on screen and Sam's attempts at the tasks on paper were identifiable. Relevant details on Sam's interaction with the iPP were noted during observation and the video data subsequently transcribed for qualitative analysis.

**Table 3: Equations and Inequalities of Various Structures in The Pretest and Posttest**

| Equations | Inequalities | |
|---|---|---|
| 1. $\|5x + 2\| = 8$ | 1. $\|2x + 5\| < 8$ | Simplify: |
| 2. $\|5x - 3\| = \|3 - x\|$ | 2. $\|2 - 7x\| \geq 3$ | 7. $x < 8$ and $x > -2$ |
| 3. $\|2x + 6\| = 4 - 8x$ | 3. $\|2x + 6\| \leq 4 - 8x$ | 8. $x > 8$ and $x > -2$ |
| | 4. $\|5x - 2\| > 3 - x$ | 9. $x \leq -3$ or $x \leq 5$ |
| | 5. $\|4x + 3\| < 3\|x + 1\|$ | 10. $x \geq 3$ and $x \leq 1$ |
| | 6. $\left\|\frac{3x+5}{1-2x}\right\| > 2$ | |

### *Data Analysis*

#### *Interaction with the iPP*

The observation and digital records of Sam's interaction with the iPP were coded according to the contents Sam accessed (e.g. Preparation, Tasks, Worked Solutions, Concepts and Reasoning) and the activities that took place. The digital data were viewed multiple times on a video player and headphones, with particular attention to mouse movement and sounds of click. The time at which a particular content was first accessed and later revisited was recorded. The time spent on the various contents and activities were analyzed. Any screen incidents possibly related to the iPP design quality were also analyzed. Instead of focusing on frequencies of occurrences as in most other qualitative studies, we paid close attention to any occurrences pertinent to the iPP design which might bear on the effectiveness of instruction and learning.

Five hundred points of time were randomly generated. The contents the participant accessed at these points of time were subjected to a reliability test by two independent raters. The Kappa Measure of Agreement value was .915 for $p < .0005$, indicating a very good agreement.

#### *Pretest and Posttest*

Sam's responses to the pretest and posttest were qualitatively compared. The emergent codes slightly varied from task to task. Five typical codes emerging from the solutions were *interpretation of absolute values*, *intrinsic relational properties of absolute values*, *algebraic simplification*, *conclusion of conditional inequalities* and *accuracy*. In particular, the extent to which each of these features was salient and accurately expressed was compared. Considering the interconnectedness of mathematical ideas, however, a feature was considered tacit or implied should the subsequent development imply the understanding of the feature.

Figure 2 illustrates the qualitative comparison of Sam's solutions to the Task '$|2x + 6| \leq 4 - 8x$' before and after interacting with the iPP. Besides the ostensibly accurate interpretation of the absolute values $|2x + 6|$ and correct algebraic simplification, the pretest solution showed no conditions of $x$ stated to justify the signs of $(2x + 6)$ and revealed little understanding of the intrinsic relational properties of absolute values. Furthermore, no simplification of two related conditional inequalities in a solution was observed. The posttest solution showed otherwise. The conditional inequalities being correctly concluded in the posttest solution implied Sam's understanding of the absolute value intrinsic relational properties '$x \leq -1/5$ and $x \leq 5/3$' which implies '$x \leq -1/5$'. No such simplification was observed in the pretest solution.

## Findings

### *Interaction with the iPP*

Sam was observed to have navigated the iPP freely mostly on the computer mouse and occasionally on the keyboard. Most of the time he was focusing on the slides, e.g. attempting a task, viewing a solution, or studying the relevant concepts and reasoning, at times evidenced by his line-by-line mouse movement on the screen. Other time he would be attempting the tasks on paper.

Sam spent a total of 21.7 minutes and 55.5 minutes on learning absolute value equations and inequalities respectively. Figure 3 depicts the total time spent on each of the various iPP contents. Most time was spent on reasoning (44.1%), attempting tasks (18.8%) and

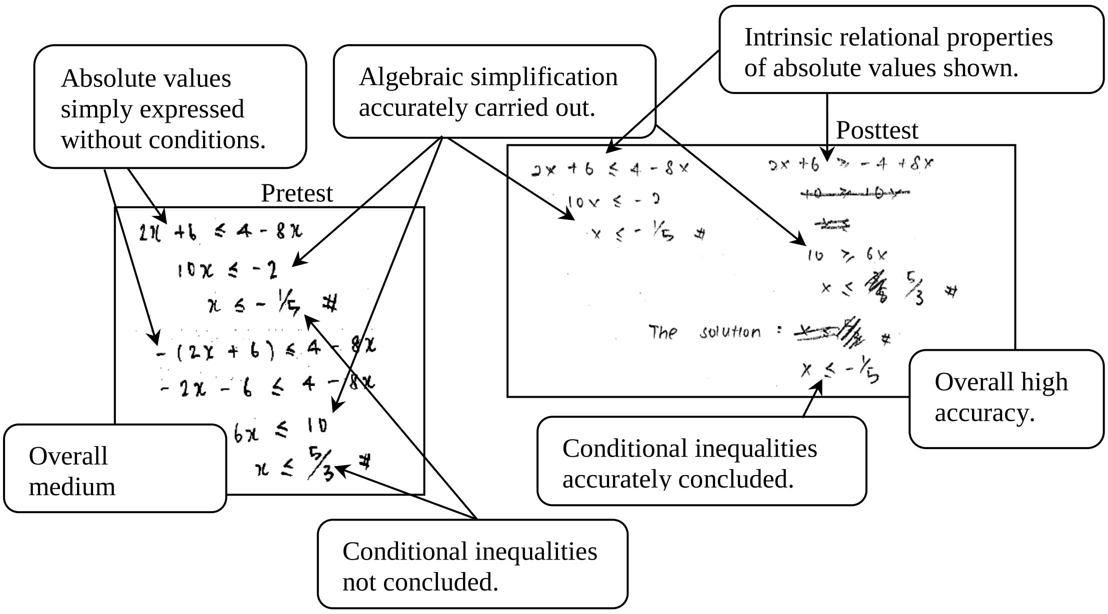


**Figure 2: Qualitative Comparison of the Pretest And Posttest Solutions to Task '$|2x+6| \leq 4 - 8x$'**

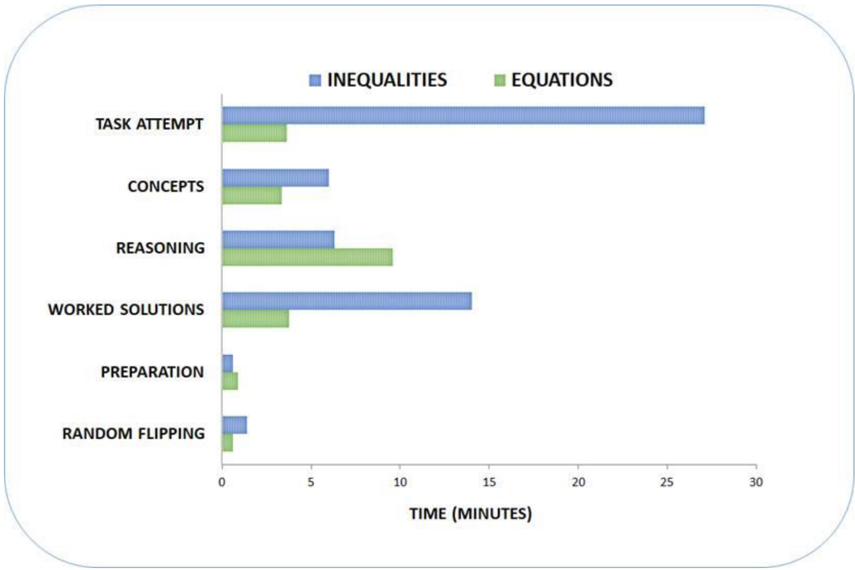


**Figure 3: Time Spent on the Various Contents During Sam's Interaction with The iPP**

studying worked solutions (16.8%) while learning equations. On the other hand, most time was spent on attempting tasks (48.9%), studying worked solutions (25.3%) and reasoning (11.4%) while learning inequalities.

Figure 4 compares the first and revised time spent on the various iPP contents for each of absolute value equations and inequalities. Sam was observed to have repeated the various contents at different points of time. The revisited contents on the nonlinear paths of

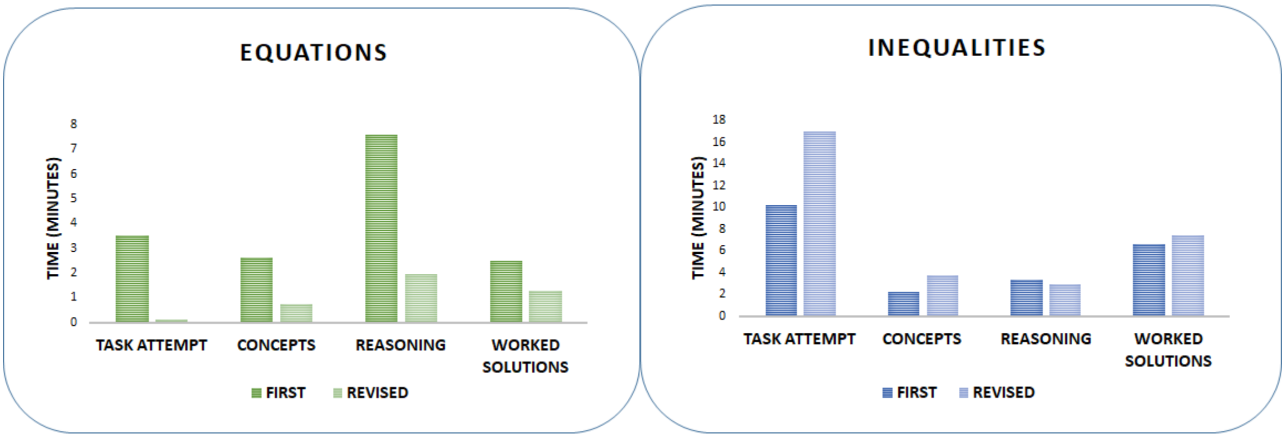


**Figure 4: The First and Revised Time Spent on The Various Contents During Sam's Interaction with the iPP**

learning confirmed the flexibility of iPP in supporting nonlinear, recursive autonomous learning.

In general, Sam spent relatively much more time on learning absolute value inequalities, understandably due to both the higher number of tasks available and the more demanding logical intricacies involved in absolute value inequalities than in equations. In particular, Sam had spent relatively more time on attempting tasks and viewing worked solutions than on concepts and reasoning related to absolute value inequalities. The instructional implications will be discussed later.

There were relatively fewer attempts at revising the various contents on absolute value equations, confirming Sam's some, albeit limited, knowledge of absolute values (i.e. also supported by the pretest results). In some cases, he apparently did not have the need to work on paper while solving the absolute value equations on the iPP. On the other hand, observation and the video data revealed that Sam was faced with greater challenges in handling inequalities even with those without modulus, presumably due to insufficient knowledge of the intrinsic properties of real values. For instance, while attempting the task '$x^2 \geq 9$' on the iPP, he clicked on the option '$x \geq 3$' without noticing that '$x \leq -3$' is equally acceptable. The same superficial attempt occurred for the task '$\frac{8}{x} < 4$', in which case Sam selected only the answer '$x > 2$' but not the equally acceptable '$x < 0$'. Sam had obviously not thought that any negative values must be less than the positive value 4. In particular, the learning process slowed down significantly when the complexity of tasks increased with seemingly little structural differences, e.g. '$|2x - 3| > 5x - 6$', '$|2x - 3| < |5x - 6|$', '$|x + 5| \geq |2x - 7|$' and '$\left|\frac{2x+1}{x-1}\right| \geq 3$'.

However, Sam patiently revised the studied contents recursively and that could have enhanced his understanding of the learning material. For instance, when Sam first attempted '$|2x - 3| < |5x - 6|$', he seemed to be perplexed by the structural nuances. He then revisited the reasoning pertinent to '|2$x$ – 3| > 5$x$ – 6' and went back to the task and re-studied its solution before reattempting '|2$x$ – 3| < |5$x$ – 6|'. He however clicked on the wrong answer '$1 < x < \frac{9}{7}$', reattempted it and insistently clicked on the same wrong answer, presumably due to the wrong interpretation of his solution. He finally worked out the right solution, clicked on the correct answer '$x < 1$ or $x > \frac{9}{7}$' and started studying the worked solution twice to confirm his solution and understanding. In addition, his later attempt at '$|x + 5| \geq |2x – 7|$' revealed a more advanced computational strategy compared with his earlier attempt at '$|2x – 3| < |5x – 6|$', as shown in Figure 5.

Sam re-attempted most of the tasks on inequalities and studied their solutions before leaving the iPP. He was found to be better able to provide correct answers to most of the tasks. He however failed to complete his solution to '$\left|\frac{2x+1}{x-1}\right| \geq 3$'and randomly clicked on the wrong answer '$x \leq 0.4$ or $x \geq 4$', even for a second time after thinking for a while. He then grabbed his pencil but not writing. He finally decided to study the worked solution on the iPP and crossed his own solution out on the paper.

While offering learning opportunity, the iPP is not without space for improvement. It was saliently observed that Sam had frequently pressed on the navigation button on a slide not knowing that he had reached the end of the slide. As a result, the slide presentation of, e.g. a worked solution, simply repeated. In addition, there was occasional confusion when random flipping of slides occurred either by pressing on the keyboard arrows or by Sam's eagerness to quickly move around to see the connected contents or what was to expect subsequently.

***Pretest and Posttest***

Sam performed equally well in solving absolute value equations in both pretest and posttest, implying the existence of some prior knowledge. However, a careful analysis of the pretest results from solving equations and inequalities confirmed Sam's mere superficial knowledge of the absolute value definition with little or no understanding of the underlying concepts and intrinsic relational properties of absolute values. The pretest solutions to both equations and inequalities indicated consistent and mechanistic operations with no relation to deeper attributes pertinent to structural variations in the inequalities. Apparently, Sam had simply replaced any expression of the form $|x|$ by $x$ and $–x$ without considering the nature of $x$ values that validate $|x| = x$ and $|x| = –x$. The expressions of relational logic such as 'and' (i.e. $|A| \leq B \Rightarrow -B \leq A \leq B$) or 'or' (i.e. $|A| \geq B \Rightarrow A \leq -B$ or $A \geq B$) were completely absent in Sam's pre-test solutions. As a result, he did not simplify nor conclude the final answers correctly in most cases. While such superficial knowledge structure seemed to be enough for tackling absolute value equations, it was far from sufficient for handling absolute value inequalities, especially when the structural complexity increases. Figure 6 illustrates a couple of such examples, which are more likely to imply procedural thinking than conceptual understanding.

Nonetheless, the comparison between the pretest and posttest solutions to absolute value inequalities showed significant improvement in conceptual understanding and reasoning (see Figure 2). The posttest solutions to the inequalities revealed not only a change in reasoning but also enhanced accuracy particularly in communicating the intricate ideas of simplifying related conditional inequalities (e.g. '$x > 2$ or $x > 5$' $\Rightarrow$ '$x > 2$', but '$x > 2$ and $x > 5$' $\Rightarrow$ '$x > 5$'). Figure 7 illustrates a few more examples of enhanced solutions.

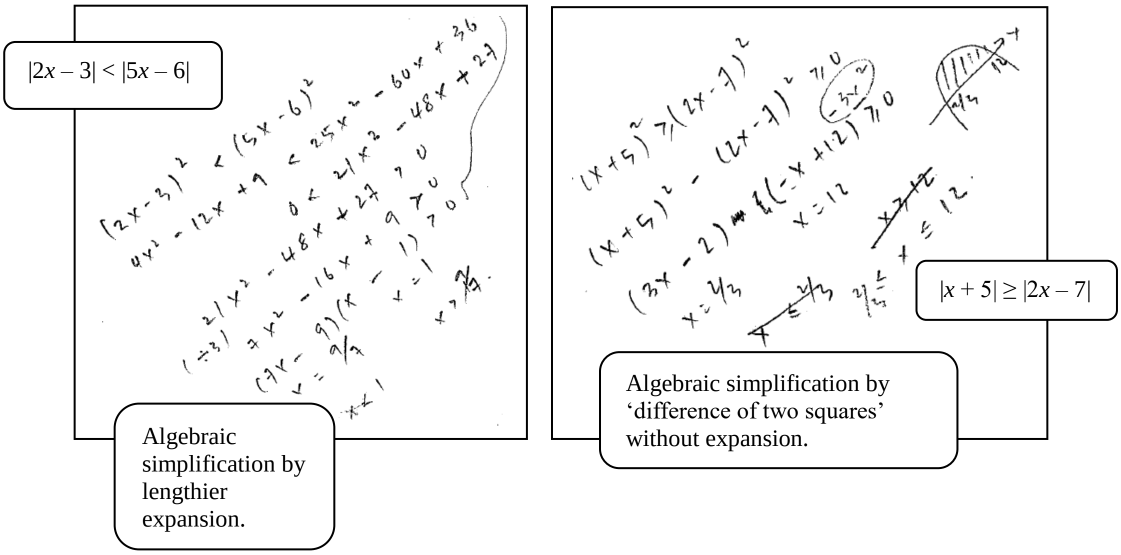


**Figure 5: Different Computational Strategies Applied by Sam While Learning On The iPP**

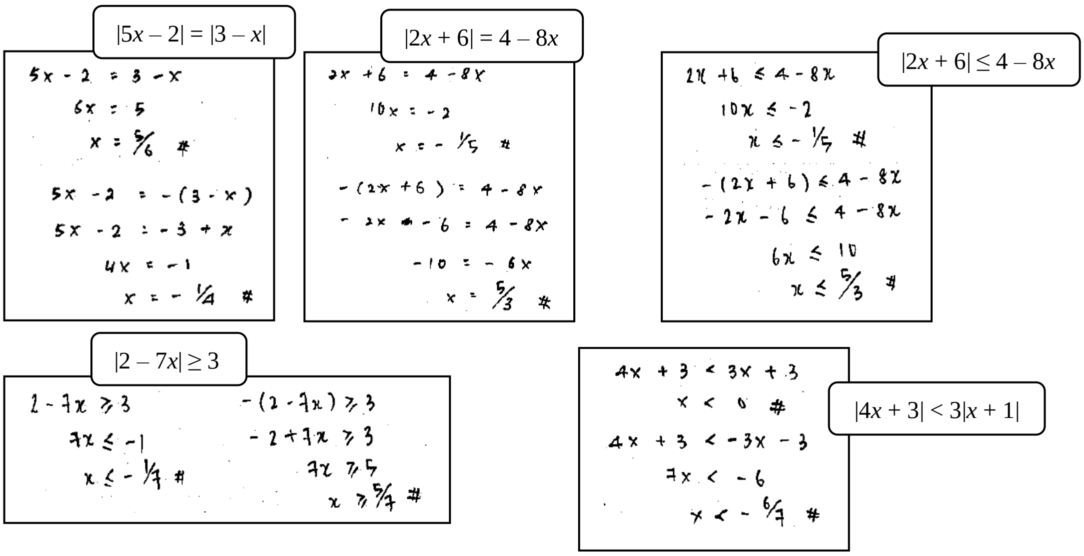


**Figure 6: A Monotonous, Mechanistic Operation Applied to All Solutions to Pretest**

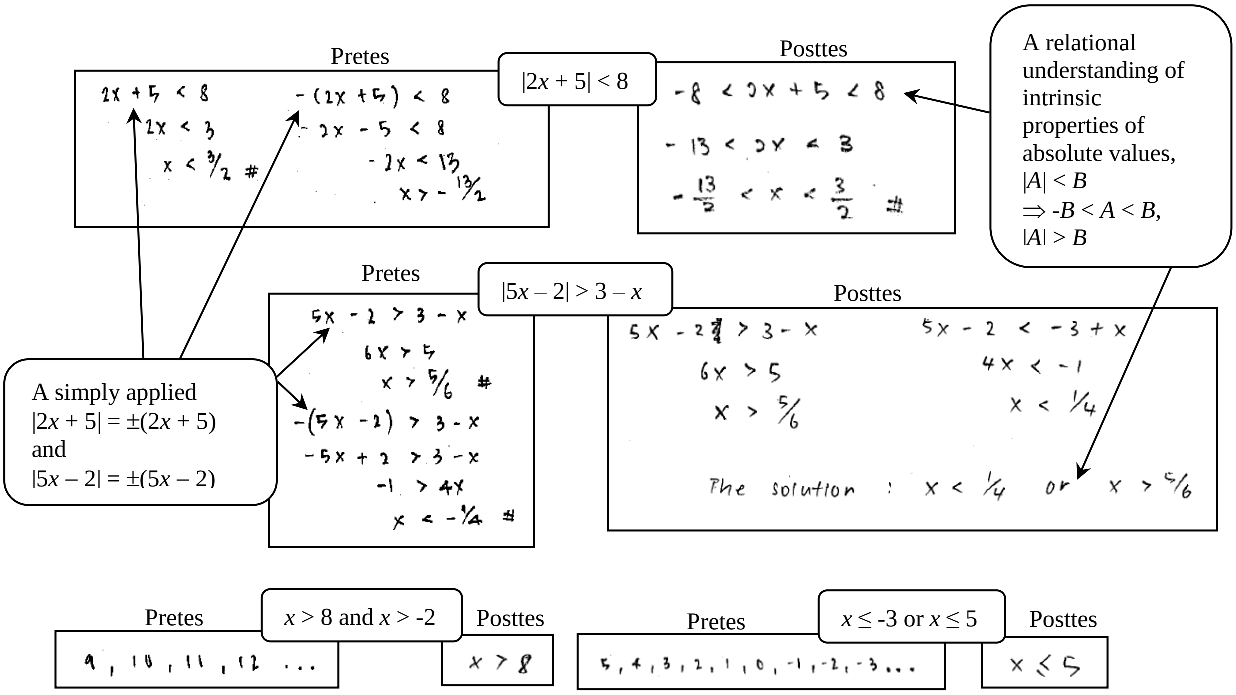


**Figure 7: Improved Conceptual Understanding and Reasoning Shown In the Solutions to Posttest**

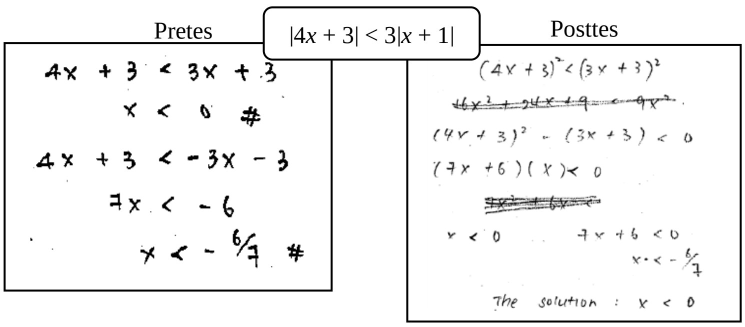


**Figure 8: The Only Failed Solution To $|4x + 3| < 3|x + 1|$ In the Posttest**

The only exception was the solution to $|4x + 3| < 3|x + 1|$, which started well conceptually but failed with an inaccurate conclusion (see Figure 8). The final answers required the solving of a quadratic inequality.

In summary, Sam was found to have interpreted any expression in the form $|x|$ as possibly $x$ and $-x$ across tasks in the pretest, without specifying the conditions that warrant his interpretations. Such understanding seemed to be enough in obtaining the correct answers to simple equations, but that is far from being sufficient for solving absolute value inequalities that require more sophisticated reasoning and understanding.

## Discussion

### *The Overall Efficacy and Design of the iPP*

PowerPoint has commonly been employed according to its original intent, i.e. be supportive of a presenter in engaging an audience with dynamic information. This study, however, showed that it may also work well without the presence of a presenter in an educational context. This study echoed the findings of other studies that the use of PowerPoint enhances learning (Davies et al., 2016; Nam and Trinh, 2012; Wanner, 2015). Given the freedom to navigate the presentation on a self-paced, self-directed path of learning, a learner may flexibly access and learn a content (e.g. concepts and reasoning) and assess his understanding by attempting tasks repeatedly. We surmise that such interactivity and the freedom and autonomy in learning could expand the learner's attention span (Geri, Winer, & Zaks, 2017) and be motivating and engaging (Reeve, 1999).

Besides the peripheral design supports, e.g. pace of presentation, font types and sizes, animation, etc., the contents and substance on the slides are no less important. In particular, mathematics is philosophically a 'language'. Every mathematical statement conveys some information, which could only be sensible with sufficient conceptual understanding, reasoning and the power to explain. Such belief was a key consideration for the slide design. Without the essential substance to promote conceptual understanding, reasoning and mathematical thinking, even an attractive presentation is of little value. The emphasis on concepts and reasoning (Brodie, 2009), with the opportunity to attempt tasks and learn from the worked solutions with reasoning on the iPP (Renkl, 2002), is believed to be a strategic synergy between pedagogy and technology.

### *Observation of The Participant's Interaction with the iPP*

It is also worth mentioning that the qualitative observation adopted in this study has unraveled aspects that are not immediately apparent. Such method of analysis is deemed to be effective in unraveling tacit nuances and details critical for continuous improvement, particularly in the design aspects. For instance, there is obviously a need to include in the iPP an end-of-slide indicator to signal all elements on a slide have appeared, such as by changing the color of the navigation button. Obviously, Sam, when navigating on a slide, was not quite sure if the hidden elements in the slide had all appeared. That explained the repeated pressing on the navigation button. Adding an end-of-slide indicator would inform the learner of his end of navigation on a slide so that he will not expect any more hidden elements to appear subsequently.

### *Instructional Implications for Pedagogic Design*

A casual inquiry into Sam's occasional random flipping between slides suggested that navigation from slide to slide could be made more efficient and convenient if content pages are created to lay explicitly all available tasks, concepts, and pieces of reasoning with hyperlinks to the relevant slides for further details or action. While the navigation buttons for linking to the tasks on the right edge of an existing slide were merely numbered (e.g. Trial 1, Trial 2, etc.), they did not explicitly reveal in detail what tasks, for instance, Sam had just attempted. Similarly, clicking on the buttons to navigate to other slides, a learner may move further and further away from the original slide, causing great inconvenience in returning to the original slide of focus. That partly explained the random flipping between slides which could have unnecessarily reduced learning efficiency. Incorporating content pages with explicit information may facilitate moving to the intended slides more efficiently. In addition, content pages explicitly reveal the contents and better inform a learner of what to expect.

Furthermore, some other occasional flipping of slides forward may imply sign of impatience. Learning could be made more enjoyable yet effective with fewer content elements and shorter learning sessions. This is particularly critical in view of the shorter attention spans among learners in this technological era (Rothman, 2016). As the data imply (see Figure 3), the content density of inequalities on the iPP had appeared to be overwhelming. Sam could have experienced some pressure of time tackling the inequalities. He spent relatively more time working on the inequality tasks and worked solutions than on learning the relevant concepts and reasoning. Reducing the amount of contents and the time for a learning session would hopefully make learning less overwhelming and more balanced in learning the various elements.

### *Expectation and Requirement*

Finally, teachers need to be familiar with the use of technology in instructions. As such, training on how technology (e.g. PowerPoint and the Internet facilities) can best support instruction is no less significant especially for young and inexperienced teachers (Hartsell, Herron, Fang, & Rathod, 2009). Without proper training for educators, the inappropriate use of PowerPoint could be greatly detrimental to student learning (Young, 2004). Nonetheless, technology can never completely replace human educators for its lack of human and social elements (Joseph, 2012). As in the case of this study, the iPP would best take on a supplementary role. The instructor will still have a vital role to play, particularly in the assessment of the learning outcomes and the provision of constructive feedback.

## Conclusion

It is concluded that interactive PowerPoint slides which contain pedagogical and resourceful contents that are accessible by autonomous navigation may support mathematics learning. However, any attempt to generalize the findings is strictly inappropriate until further investigation was carried out with a reasonably larger sample of participants.

Turning PowerPoint into an interactive, self-paced, self-directed presentation for the learning of mathematics is a rare attempt. Such attempt is indubitably time-consuming. However, considering a one-time design with subsequent fine-tuning only when needs arise, the opportunity for students to freely attempt tasks, reflect on worked and own solutions and access relevant concepts, explanations and reasoning, it could be worth the effort particularly in supporting weaker learners.

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