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# Insights regarding the usefulness of partial notes in mathematics courses

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*Abstract: Note-taking is a widespread practice used by college students to record information from lectures. Unfortunately, even successful students' notes are incomplete and, therefore, may lack the potential to positively impact their academic performance. Research suggests that instructors can help students improve their note-taking skills by using partial notes in their classes. The purpose of this exploratory study was to understand the potential usefulness of partial notes in mathematics courses. Findings showed that students perceived partial notes as beneficial to their learning. Course examination scores further confirmed that partial notes related strongly to high academic performance.*

*Keywords: note-taking, partial notes, mathematics, instructional strategy*

## I. Introduction.

Note-taking is a widespread practice used to record information in written form. This practice is very common among college students; in fact; Palmatier and Bennett (1974) found that 99% of the students they surveyed took notes during an instructor's lecture.

The practice of note-taking has been the subject of educational studies for over 75 years. In his seminal work of 1925, Crawford analyzed the benefits of taking notes during a lecture versus listening without taking notes and concluded that note-taking itself enhances students' examination performance. More recently, Einstein, Morris, and Smith (1985) analyzed students' notes and found that students could recall 40% of the material in their notes but only 7% of the material that was not in their notes. They also compared notes of successful and less successful college students and concluded that successful students included more of the main ideas in their notes than did less successful students.

Unfortunately, even successful students' notes are incomplete and, therefore, may lack the potential to improve their academic performance. Indeed, successful junior students record, at most, 70% of the critical ideas that are presented in lectures (Kiewra, 1984), and first-year students include only 11% of such ideas in their notes (Hartley and Marshal, 1974). Researchers have suggested several ways in which instructors can help students improve students' note-taking skills, such as: lecturing at slower rates (Peters, 1972); using verbal cues (Titsworth and Kiewra, 2004); providing students with lecture notes (Kiewra, 1985a). Kiewra encourages instructors to address directly the problem of students' poor note-taking skills. He states, "Teachers should be aware of students' relatively incomplete note-taking behaviors, and, therefore, [should be] encouraged to provide learners with adequate notes for review" (Kiewra, 1985a, p.77). This proviso applies to mathematics instructors as well as others, since note-taking directly affects students' ability to follow and understand mathematics lectures. In this article, we

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focus on assisting students by providing them with a specific format of partial rather than complete lecture notes. The present work constitutes the first step towards understanding the full potential of partial notes in fostering significant learning in mathematics courses.

## II. Framework.

The literature cited above suggests that instructors should be proactive in student note-taking efforts, for example, by providing lecture notes. Studies have shown that when students receive complete lecture notes from their instructors, they achieve higher test scores than when they rely only on their own notes (Kiewra, 1985c; Maqsud, 1980). It may seem natural, then, to think that instructors can help their students by making copies of lecture notes available to them. However, there are some caveats regarding providing students with complete lecture notes. Students may feel that when they receive the notes they do not need to take notes themselves or be attentive in class (Pardini, Domizi, Forbis, and Pettis, 2005). In some extreme cases, if students receive complete notes, they may not feel the need to attend lectures at all, thus promoting absenteeism (Potts, 1993; Russell, Caris, Harris, and Hendricson, 1983). To address these caveats, instructors can provide partial notes instead of full notes, thus requiring students to be present in class to complete their notes; moreover, students have to be attentive to complete their notes correctly, which gives them a reason to attend classes. These partial notes generated by the instructor can take the form of outlines or graphic organizers which, depending on the amount of information they contain, can be categorized as complete, partial, or skeletal notes (Katayama and Robinson, 2000).

Several studies have been conducted to compare the effects of partial notes and full notes on students' achievement. For example, Annis (1981) compared examination performance amongst students using their own personal notes, the instructor's complete notes, or partial notes prepared by the instructor. Annis found that students using personal or partial notes scored significantly higher on the essay items of the examination than did students using complete notes. In another study, Russell, Caris, Harris, and Hendricson (1983) analyzed the performance of medical students on multiple-choice questions and on critical-thinking questions. Students were provided with complete notes, or partial notes, or skeletal notes. Russell et al. found that the group of students using partial notes scored significantly higher than the other two groups did, particularly on the critical thinking questions. They concluded that " the partial handout was the best compromise between the skeletal handout, which promotes alertness during the lecture but may be less valuable for review several months later, and the comprehensive handout, which encourages passivity in class" (Russell *et al.*, 1983, p. 636). In a more recent study, Cornelius and Owen-DeSchryver (2008) examined the impact of partial and full notes on students' learning outcomes. Students using partial notes performed significantly better than students using full notes on examinations taken towards the end of the semester and on the cumulative final examination. In particular, students using partial notes performed better on cumulative conceptual questions (i.e., questions that demand understanding beyond just the definition of a concept and that require the elaboration of information). These studies suggest that students benefit from the use of partial notes, especially for courses that emphasize problem-solving and critical thinking.

Reliable lecture notes are especially important in mathematics classes because of the large amount of challenging content that is covered in each class and the cumulative nature of mathematics that requires full understanding of an idea before moving on to the next. In addition,

course examination questions consist primarily of critical thinking questions that require a solid understanding of the concepts covered and the relationships among them. While the studies previously reviewed were conducted in fields such as psychology, medicine, and education, our review of the literature revealed no studies about partial notes in mathematics classes. However, the literature does suggest that partial notes could benefit students in mathematics courses, and we did find two studies about teaching foundational skills that would prepare math students to deal effectively with partial notes. One of those studies (Backman, 1994) was an action research project by a high school mathematics teacher, designed to help students learn effective note-taking for studying, organizing, and remembering information. As a result of this project, students were able to refine their note-taking skills. The other study (Eades and Moore, 2007) examined the benefits of a systematic note-taking procedure in a developmental mathematics course. Results from surveys and instructors' observations revealed that the system increased student understanding and motivation.

The present article attempts to further the understanding of this instructional strategy in mathematics courses. Specifically, this work explores the potential usefulness of partial notes in mathematics courses. We base our findings on the analysis of students' perceptions regarding the use of partial notes and on students' performance on course examinations. The article concludes with a discussion of the findings, a summary of key recommendations for practice, limitations and future research aimed at learning more about the effectiveness of this instructional technique.

## III. Method.

### *A. Context and Sample.*

One of the authors of this paper taught a calculus course at a large northeastern public university in the United States of America. The framework of the instructor's lectures was based on her typed personal notes. These notes consisted of complete statements of theorems, explanations, and full solutions of examples. In the Fall, 2007 semester, the instructor decided to try a different instructional strategy that would promote active engagement of students with the material. To that effect, she introduced partial notes that she handed out to students at the beginning of every class.

Partial notes (PN) are typed versions of the instructor's personal notes. They are called *partial* because the solutions to examples are omitted and blank spaces are left, so that the students can add their own solution to each of the examples within the PN. The instructor followed this format of PN for her classes because she felt this would be beneficial to her students. Certainly, other PN formats are also possible (e.g., leave blanks for definitions, names of properties, etc.) An example of a four pages long PN is provided in Figure 1. Since partial notes saved the instructor some lecture time because she did not have to write examples or problems on the board, she used the extra time to engage students in interactive in-class activities without sacrificing the amount of material she had to cover. For example, once the instructor had worked through enough examples on the board, students were asked to solve a few extra examples on the partial notes on their own. The instructor also asked volunteers to solve each problem on the board. These volunteers were given extra credit points that counted towards the

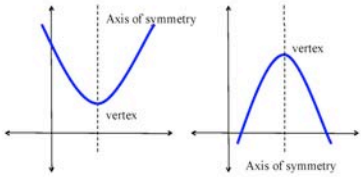
A7: Quadratic Functions

**Disclaimer:** This is MY attempt to help you study for the material. Don't use this as your main study tool. There might be some typos and/or mistakes. This material is adapted from our textbook *Calculus: Applications and Technology* ($3^{rd}$ edition) by Edmond Tomastik.

Quadratic functions are of the form

$$f(x) = ax^2 + bx + c, a \neq 0,$$

where $a, b$ and $c$ are constants and $a$ is not zero. The graph of any quadratic function is a curve called parabola and is similar in shape to the graph of $y = x^2$.




The turning point on the parabola is called the **vertex**. The **axis of symmetry** of the parabola is the vertical line passing through the vertex.

**Example 1.** *Sketch the graph of the function* $y = x^2 - 2x + 3$.

Solution

1

The following procedure can be used for any quadratic function $f(x) = ax^2+bx+c$ with $a \neq 0$ to complete the square and arrive at the standard form of the function.

$$\begin{aligned} f(x) &= ax^2 + bx + c \\ &= a\left(x^2 + \frac{b}{a}x + \frac{c}{a}\right) \text{ Factor out } a \\ &= a\left(\left[x^2 + \frac{b}{a}x + \frac{b^2}{4a^2}\right] - \frac{b^2}{4a^2} + \frac{c}{a}\right) \text{ add and subtract } \frac{b^2}{4a^2} \\ &= a\left(\left[x + \frac{b}{2a}\right]^2 - \frac{b^2}{4a^2} + \frac{c}{a}\right) \text{ Complete the square} \\ &= a\left(x + \frac{b}{2a}\right)^2 + \left(c - \frac{b^2}{4a}\right) \text{ Multiply by } a \end{aligned}$$

If we set

$$h = -\frac{b}{2a} \text{ and } k = c - \frac{b^2}{4a}$$

the quadratic function can be written in standard form

$$f(x) = a(x - h)^2 + k$$

**Properties of the graph of** $y = ax^2 + bx + c$

By completing the square, the equation of a parabola $y = ax^2 + bx + c$ can be rewritten in the form

$$y = a(x - h)^2 + k,$$

where

$$h = -\frac{b}{2a} \text{ and } k = c - \frac{b^2}{4a}$$

In this form, the vertex of the parabola is $(h, k)$ and the axis of symmetry is the line $x = h$. The parabola opens upward, if $a > 0$; and opens downward, if $a < 0$.

2

**Example 2.** *Sketch the graph of the function* $f(x) = -2x^2 + 4x + 6$ *and specify the vertex, axis of symmetry, and maximum or minimum value of* $f$.

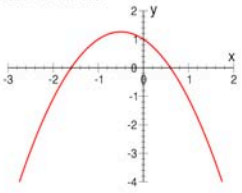
Solution:

**The Quadratic Formula**

The zeros of the quadratic $y = ax^2 + bx + c$ are given by

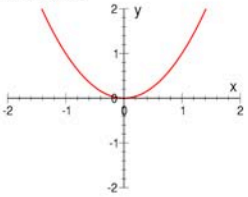
$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

- If $b^2 - 4ac > 0$, there are two zeros.

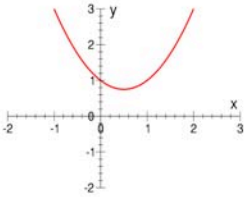



3

- If $b^2 - 4ac = 0$, there is one zero.




- If $b^2 - 4ac < 0$, there are no zeros.




Note that the zeros of the quadratic are the same as the $x$-intercept (where the graph meets the $x$-axis.)

**Example 3.** *Find the zeros of the quadratic* $y = x^2 - 2x - 1$.

Solution:

4

**Figure 1. Example of a four-page long partial note.**

weekly quiz score for the course. The students' perception of this instructional strategy (use of PN) became apparent to the instructor when she read the students' feedback on the mid-semester and end-of-semester open-ended questionnaires of Fall 2007. This feedback was gathered as part of standard educational practices for the course. Later on, these preexisting aggregated data became the basis of the inquiry that drove this exploratory study.

The instructor had taught the same course in the Fall, 2006 semester. That year she used her full personal notes to guide her instruction but did not provide students with either full or partial notes. In the 2007 semester the instructor used the same personal notes to guide her teaching and to prepare PN. Thus the material covered in the 2006 semester and the 2007 semester was identical. Other aspects that were identical to both courses, in addition to the material and the term of the year, were the days and times of the week in which the lecture took place, the length of each class meeting, and the total number of weeks in the semester. Furthermore, there was diversity of ethnic backgrounds with a predominance of Caucasian students in both semesters. The main difference between the courses was that in 2007 the students had access to partial notes.

*B. Research Questions and Data Collection.*

The aim of this exploratory study was to assess the potential usefulness of partial notes in a mathematics course. Specifically, the research questions were:

1. Among students in the Fall 2007 course, what themes characterized their perceptions of the instructor-generated partial notes?
2. To what extent did course examination scores differ between students who did not have access to partial notes and students who did have access?

Qualitative data were used to answer the first research question. These data were collected anonymously from questionnaires that students completed in the middle and end of the semester in the Fall 2007. Further details about these questionnaires can be found below.

Quantitative data were collected from the students' course examination scores to address the second research question. We compared the examination scores from Fall 2006 and Fall 2007. For the purposes of this study, scores were imported from the grade books to a separate file, students' names were removed, and scores were recorded in increasing order for each semester. Thus all the quantitative data were analyzed anonymously and in aggregate. Further details about the examinations can be found below.

*Mid-semester Questionnaire.* Seven weeks into the semester and 2 weeks after the first examination, students completed an anonymous mid-semester questionnaire. The mid-semester questionnaire was a short, open-ended questionnaire developed by the instructor. Its purpose was to obtain anonymous feedback from the students that would help improve their learning experience in the remaining weeks of the semester and to obtain feedback about her teaching effectiveness. Students completed the questionnaires in the first 15 minutes of the lecture while the instructor was out of the room. The items on the mid-semester questionnaire were as follows:

1. What is going well for you in lectures?
2. What is not going well for you in lectures?
3. What can I do to further help your learning in this class?
4. What can you do to make the lectures more productive for yourself?
5. Other comments/concerns/suggestions.

*End-of-Semester Questionnaire.* As is customary in many institutions, at the completion of each semester students were asked to complete an anonymous official student evaluation of faculty. At our institution this evaluation takes place each spring and fall semester. This evaluation consists of two pages: the first page is a 10-point-scale quantitative form to numerically rate the instructor's effectiveness; the second page is an open-ended questionnaire wherein students can provide a short narrative of the instructor's performance. For the purposes of this study, we focused on the second page questionnaire that consisted of the following items:

1. What was the most positive aspect of the way in which this instructor taught this course?
2. What can this instructor do to improve teaching effectiveness in the classroom?

The results are used by the instructor for improving teaching performance and for promotion, tenure, and reappointment of the instructor. Each instructor receives the results after the semester has ended and grades have been distributed.

*Examinations.* Three examinations were administered in-class in both the Fall 2006 and the Fall 2007 semesters. In each semester, the first examination took place during the sixth week of classes, the second examination during the eleventh week of classes, and the cumulative final examination during the official Finals Week at the end of the term. The examinations consisted of computational questions as well as conceptual questions. Only the final examination was cumulative. In 2007, these questions were only slightly modified in content to avoid concerns of contamination across years. Additionally, we compared the scores of the two groups on the mathematics section of the Scholastic Aptitude Test (SAT) to control for general mathematical ability prior to taking the course.

*C. Data Analysis.*

*Mid- and End-of-semester Questionnaires.* Data analysis consisted of several steps. First, each of the authors coded the data separately following the constant comparative method (Corbin and Strauss, 2008) without seeking to build theory. The constant comparative method "involves continually comparing one unit of data with another in order to derive conceptual elements" (Merrian, 2002, p. 8). Next, we met, compared, and refined codes. Patterns that repeated were collapsed or enhanced to form categories until we identified emerging themes (Miles and Huberman, 1994).

To add rigor to our work, we generated individual analyses, and met periodically to discuss our findings. Disagreements about codes, categories, and themes were resolved during our meetings, creating an iterative process of dialogic collaboration (Paulus, Woodside, and Ziegler, 2008).

*Examinations.* Examination scores of the different groups were compared to determine if significant statistical differences existed. Ideally, the authors would have preferred to carry out an ANCOVA with the SAT score as the covariate, but this was not possible because the data were only available in aggregate. In lieu of such analysis, tests of equal variances, homogeneity, and skewness were performed to justify application of a t-test that measured examination scores differences. Finally, we also performed a t-test to determine if significant statistical differences existed between students' SAT scores.

## IV. Findings.

### *A. Qualitative data from open-ended questionnaires.*

The analysis of the responses to open-ended questionnaires was performed to understand students' perceptions of partial notes. Four themes emerged from the analysis: *(1) Students defined partial notes in their own words. (2) Partial notes allowed students to follow the lecture attentively. (3) Students perceived the lecture structure as beneficial. (4) Students perceived partial notes as a helpful aid for studying.* Each of these themes is described in detail below.

*Students defined partial notes in their own words.* The instructor made no attempt to call students' attention to partial notes because the objective of the course was to help students learn the fundamental mathematical concepts of the course. Consequently, students were never given a specific name for the partial notes. In spite of that, students found ways to define partial notes, using their own words to comment on the course strength both in the middle of the semester and again at the end of the semester when they responded to the questionnaires. For example, many students referred to partial notes as "handouts," or "packets." A lower number of students referred to them as "notes." Among the comments made were the following, "The handouts are extremely helpful," "The packets are a good way of presenting the material…," and "I really liked how we got a handout every class with all the notes and examples. It really helped me." Overall, the students used their own words to refer to partial notes in their comments.

*Partial notes allowed students to follow the lecture attentively.* A key benefit of partial notes is that it allowed students to follow along with the lectures. When students did not need to take notes feverishly, they could concentrate on the highlights of the lecture and devote their efforts to listening attentively to the instructor's explanations. Many students referred to this aspect of partial notes. For example, one student mentioned that the partial notes were effective in keeping up with the instructor: "I like following along in the lesson through the packets. It is quite effective." Another student explained the effect that having the definitions and examples already in written form had on listening to the lecture: "I like how you give us everything (definitions and examples). It makes it easier to follow along and listen to your examples." When students had to take full lecture notes on their own, their attention was divided between listening, processing information, and note-taking. On the other hand, with the aid of partial notes, students' attention was focused on what the instructor was saying at the moment, allowing for meaningful processing to take place.

Students followed the lecture attentively in two distinct ways. Some students liked partial notes because they could listen to the lecture attentively without the distraction of taking notes, as the following student explained, "I really like that you give us handouts of class in a worksheet so that we can concentrate more than trying to scribble every word down." Some of these students also commented on the fact that critical lecture ideas were readily available on the partial notes, "The handouts were a big help because they allowed students to focus on the main points of the lecture rather than waste time doing extra writing." Other students liked using partial notes to follow the lecture because they could rephrase the instructors' comments or explanations in their own words to complement the content of the provided notes, "The handouts are very useful. It helps to write down notes on the papers because I can add my own notes, if needed. But I am not worrying about writing down definitions." Similarly, another student mentioned, "I like the fact that we get a handout for each class that we can follow along with but still fill in the examples." Using partial notes, students were able to either put down their pencils

and focus on listening to the instructor's explanation, or they were able to combine attentive listening with meaningful note-taking.

*Students perceived the lecture structure as beneficial.* A few students did not refer to partial notes explicitly but alluded to the structure of the class when they reflected upon the positive aspects of the course. For example, one student liked having the opportunity to independently attempt problems before seeing the instructor's explanation, "Dr K. provides thorough explanations in class and also allows us to work at problems prior to explaining them on the board for practice." Another student reflected upon the uncluttered nature of partial notes and on the structure of the class; and in particular alluded to the extra points quiz policy described in the Context section above, "Gave good explanation of problems without cluttering examples with unneeded information. Also gave great quiz opportunities such as examples on the board." The use of partial notes allowed the instructor to structure the lecture in such a way that all of the above was possible (i.e., clear presentation of topics, extra time to solve problems, etc.), so that she could incorporate extra activities within the allocated time.

*Students perceived partial notes as a helpful aid for learning and studying.* Some students pointed out that learning the lecture material was facilitated by partial notes. For these students, partial notes helped them learn the concepts covered, "Going through the section of focus with the printed out guide is very helpful for me to learn the material." Students also found partial notes useful in the reviewing process after the lecture, when they were studying for examinations, "The handouts each week were very helpful because they are easy to review for test time." Students also mentioned another key skill for learning and studying: organization, "Handout materials were wonderful. Kept me organized." Overall, students used partial notes as an aid in the cognitive processing stages (learning) and in the review or product function of note-taking (studying) (Suritsky and Hughes, 1991).

*B. Quantitative data from examinations.*

For the analysis of the scores, the alpha level was set at .05. Effects that produced $p$ values between .05 and .10 are reported as marginally significant effects.

First, we looked at the differences between the two groups (2006 and 2007), comparing the mean scores on the course examinations. Table 1 shows the descriptive statistics for all examination scores across the two groups. Students using partial notes scored significantly higher ($M$=41.43, $SD$=6.64) on the first examination than did those without access to partial notes ($M$=34.67, $SD$=7.94), $t(52)=3.50$, $p<0.001$. The standardized mean difference effect size[4] ($ES_{sm}$) between the two groups on the first examination was very large ($ES_{sm}$=0.90). The analysis of the scores on the second examination indicated that the students using partial notes scored marginally higher ($M$=38.86, $SD$=9.13) than did those students with no access to partial notes ($M$=34.59, $SD$=7.98), $t(54)=1.61$, $p$=0.056. The standardized mean difference effect size between the two groups on the second examination was moderately small ($ES_{sm}$=0.41). Finally, the results indicated that students using partial notes scored significantly higher on the final examination ($M$=58.83, $SD$=14.52) than did those without access to partial notes ($M$=34.59, $SD$=7.98), $t(55)=2.62$, $p$=0.014. For the final examination scores, the standardized mean difference effect size between the two groups was moderately large ($ES_{sm}$=0.67).

[4] Notation for effect size index ($ES_{sm}$) from *Practical meta-analysis*, by M.W. Lipsey and D.B. Wilson, 2001, Thousands Oaks, CA: Sage.

Second, we assessed the statistical significance of differences in the mean score of the mathematics section of the SAT between the two groups. The results of the t-test indicated that the group using partial notes scored significantly lower ($M$=572.67, $SD$=76.15) than the group that did not have access to partial notes ($M$=606.45, $SD$=73.19), $t(59)=1.77$, $p=0.04$. There was a medium standardized mean difference effect size in SAT scores between the two groups ($ES_{sm}$=0.45).

**Table 1. Descriptive Statistics for Examination Scores Across Groups.**

| | Without partial notes[a] | | With partial notes[b] | |
|---|---|---|---|---|
| Examination | M | SD | M | SD |
| Examination 1* | 34.67 | 7.94 | 41.43 | 6.64 |
| Examination 2[c]* | 34.59 | 7.98 | 38.86 | 9.13 |
| Final Examination * | 49.7 | 14.53 | 58.83 | 14.52 |

[a] n=30. [b] n=29.
[c] Two students and one student were absent from each group respectively.
*$p \leq 0.05$

## V. Discussion.

The analysis of the students' comments on the questionnaires illuminated how students reacted to instructor-generated partial notes. In fact, the qualitative analysis showed that students identified partial notes as a key factor to aid their learning.

The instructor did not formally introduce the concept of partial notes to her students. She used partial notes as a way of presenting the material and making sure that students would be engaged with it. What became surprising to her was that students perceived she was using an instructional technique that was making a difference in their learning. Thus, students indicated they had noticed this instructional technique by using a variety of names to describe partial notes in the questionnaires they completed in the middle and at the end of the semester.

The findings highlighted the importance students attributed to follow along with the lecture. As Williams and Eggert (2002) pointed out " attempting to record all the details could detract from one's understanding of the main idea(s). Notetakers can miss main points while recording minutia." (p.177). Partial notes address students' preferences to process information by listening attentively to the instructor's presentation without worrying about recording every detail and instead focusing on the information being presented.

The evidence also revealed that students perceived the opportunity to explore the concepts in class on their own as beneficial to their learning. Research consistently supports the effectiveness of student engagement on a broad range of learning outcomes. Astin (1993) reported that student involvement is one of the most important predictors of success in college. Using partial notes, the instructor gains considerable time by not having to write everything on the board (e.g., all the definitions, examples, or statements). That time can be used to engage students in other activities like having students work on problems independently or showing their solutions on the board. Such activities promote student engagement and involvement with their own learning (Smart and Csapo, 2007).

The final point that the findings suggested is that students also relied on partial notes to learn the material and to review for examinations. We speculated that students' familiarity with partial notes increased the efficiency of the review process. These conclusions are consistent with results from research studies that confirm the significant correlations between reviewing

notes and academic achievement (Hartley, 1983; Kiewra, 1985b). Therefore, an effort should be made to make students aware of the benefits of reviewing the notes in preparation for examinations.

To summarize, the themes that emerged from the analysis of the qualitative aggregate data are taken as an indication that partial notes may have played a role in students' improvement of learning. This evidence was further confirmed with the analysis from the quantitative data.

Results from the comparison of the quantitative data helped us assess differences between the students who did not have access to partial notes (Fall 2006) and students who did have access (Fall 2007). The mean scores for all the examinations in the course were consistently higher for the group using partial notes. Statistical analysis of the first examination scores revealed that the students using partial notes outperformed the group that did not use partial notes. Results were not as promising for the second examination, for which the higher mean in the scores of the partial notes group was only marginally significant compared to the group that did not use partial notes. Although we do not have a specific explanation for this result based on the available data, we speculated that overconfidence, because of the very high scores on the first examination, may have been somewhat counterproductive in the students' preparation for the second examination. Nonetheless, by the end of the semester, the partial notes group outperformed the group that did not use partial notes in the final examination. Given the cumulative nature of the final examination, this evidence suggested that the partial notes group overall performed significantly better academically. These results suggested that the use of partial notes might be a factor in improving student academic performance.

Finally, analysis of students' prior mathematical knowledge based on scores on the mathematics section of the SAT showed that students using partial notes performed significantly lower than the other group. Therefore, high academic performance of the partial notes group cannot be attributed to superior mathematical ability. We concluded that participation in the course using partial notes related strongly to higher academic performance.

## VI. Conclusion.

The results of this exploratory study suggest that providing students in mathematics classes with partial notes is beneficial to their learning. The students' voluntary comments about partial notes indicated that they appreciated the strategy. Students emphasized that partial notes were beneficial for keeping them engaged with the lecture, providing opportunities to participate actively in class, and to effectively review for examinations. In addition, the comparison of the examination scores suggests that partial notes might have been a factor contributing to the improved student performance.

### *A. Implications for Practice.*

In this work we presented some of the benefits of providing students with one format of instructor-generated partial notes in mathematics courses. For the instructor who ordinarily types the lecture notes, this strategy could be easily implemented in his/her classes. For the skeptical instructor, the results of this exploratory study should be a starting point to show that the benefits might be worth the extra effort involved.

The benefits of partial notes go beyond the specifics addressed in this study. Partial notes may have the same benefits, detailed in the previous section, in other mathematics courses and in

many science courses. Instructors can adjust the format of the notes to the students' levels and experience and they may find outlines to be more appropriate for upper-level courses than partial notes as described in this article. Partial notes may be particularly beneficial for coordinators of multi-section courses, ensuring uniform coverage of the material across all sections. Coordinators can use partial notes to help new teaching assistants and foreign instructors who might not be familiar with a particular educational system.

Partial notes can also enhance the learning experience of learners whose native language may be different from the language of instructors, and of students with disabilities who are easily distracted and might miss important lecture ideas. Students who find the pace of the class too fast and students with bad handwriting may also benefit from the use of partial notes.

*B. Limitations and Future Research.*

As an exploratory study, this work offered valuable insights regarding partial notes, but its limitations need to be addressed. One major limitation of this study was that we worked with aggregated data that were analyzed after the semester concluded. Therefore, there were no follow-up questions or interviews that could allow for a deeper understanding of what students meant on the open-ended questionnaires. While partial notes were the only instructional difference the instructor introduced in the Fall 2007 semester (compared to Fall 2006), the researchers could not entirely attribute students' improvement of their performance solely to the presence of partial notes. Therefore, the researchers are cautiously optimistic about the success reported here because of the exploratory nature of this study.

The findings of this exploratory study revealed only the tip of the iceberg of this promising strategy in mathematics courses. Further research should delve deeper into the students' PN preferences in mathematics classes as well as examine other formats of partial notes that would eventually lead students to take their own efficient notes. Since this instructional strategy is not content-dependent but cognitive-dependent, we feel confident that readers teaching other disciplines will find this article relevant to their contexts.

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