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EXPLORING STUDENTS' PERCEPTIONS OF THEIR NOTE-TAKING PRACTICES

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by

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ABSTRACT

The purpose of this study was to explore the note-taking preferences of students enrolled in an undergraduate general chemistry course. Note-taking is known to have positive effects on learning, and the age of technology presents new avenues by which students may choose to take notes. In addition, chemistry is a domain that uses a variety of symbols and non-verbal representations, which may make note-taking a challenge for students. This was a three-phase study, where focus groups, individual interviews, and a survey were used to understand how students take notes, decide what information to record, use instructional supports during note-taking, and incorporate representations into their notes. The results indicate that students make purposeful decisions about their note-taking that they believe will help them reach their goal(s) of learning the material and/or passing the course. The results are framed in a self-regulatory framework through which note-taking preferences can be further explored.

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Chapter 1

Introduction

It is well known that undergraduates struggle to learn chemistry, but little is known about what students do when trying to learn chemistry. Previous studies have suggested that students' understanding of chemistry is poor because the nature of chemistry is abstract and because assumptions are often made about the level of students' prior knowledge (Carter & Brickhouse, 1989; Corradi, Elen, Schraepen, & Clarebout, 2013; Carson & Watson, 1999; Johnson, 2000). Most studies addressing this issue have focused on strategies instructors can use to help students successfully learn chemistry (e.g. Carroll, 2013; Cook, Kennedy, & McGuire, 2013), but it may also be important to consider student perceptions about learning strategies. Students may have their own ideas about what constitutes an effective learning strategy, and hence this study will focus on note-taking as a strategy through which students' perceptions about effective learning strategies can be understood. Note-taking is a learning strategy known to lead to higher learning gains and improved understanding of course material, but there is little understanding of how content-specific information, such as complex chemistry topics, may impact note-taking.

Note-Taking

There has been a considerable amount of work done to understand how note-taking impacts student learning. Students who take notes in class learn more and are more successful on far-transfer tasks than students who choose not to take notes (Crawford, 1925; Kiewra, Benton, & Lewis, 1987). However, the nature of the notes and method through which the notes were taken plays a critical role in the learning process. Students who record complete notes perform better on exams, and the way students organize their notes has been found to lead to higher academic achievement (Kiewra, 1984; Einstein, Morris, & Smith, 1985). Therefore, it is not only

important that students take notes, but also that we better understand *how* students take notes and what information they choose to record. Some factors to consider in understanding students' note-taking preferences are cognitive load, the use of technology, and the use of non-verbal representations.

Cognitive Load. The cognitive processes associated with note-taking are not well understood, but are important because note-taking is a strategy that many students use across various courses. Note-taking requires students to select, comprehend, and write information simultaneously, which is cognitively demanding. In chemistry, where most of the material is analogous to learning a new language, cognitive load being at its maximum is potentially an issue for many students while note-taking.

Due to the time constraints that students often face when trying to take notes in class, note-taking has been found to demand more effort than learning or reading (Piolat, Olive, & Kellogg, 2005). However, note-taking does have some storage benefits because it relieves the working memory of some of the information that needs to eventually move to long-term memory (DiVesta & Gray, 1972). Therefore, there is some debate regarding the demand note-taking has on working memory. Yet, as Bui & Myerson (2014) point out, differences in working memory capacity, individual differences, and use of note-taking strategies all play a role in the demands in effective note-taking, so it is difficult to draw conclusions on how working memory alone is related to note-taking.

One major way in which cognitive load is thought to be related to note-taking is through the encoding function of note-taking. The encoding hypothesis says that just the act of taking notes helps students learn and/or remember more information than they would if they did not take notes, but as pointed out by Kobayashi (2005), this hypothesis is not supported in many

note-taking studies. Kobayashi (2005) found that it is common for encoding to only support factual recall and it does not typically support high-order thinking skills. The encoding function of note-taking, along with cognitive load demands, are of interest when thinking about how science students take notes because the abstract nature of science lends itself towards requiring students to use large portions of their working memory to keep track of the abstract concepts.

Technology. As technology continues to advance, note-taking preferences must be reevaluated. There are constantly new tools students can use while taking notes, and their use during note-taking is not well understood. For example, changes have been put in place by professors in most college courses to utilize technology such as PowerPoints, online textbooks, and YouTube videos while teaching. Also, many professors now post online notes before and/or after class through PowerPoint or other software, which could drastically change the way in which students take notes. In addition, many students may choose to take notes on personal laptops or tablets, which raises questions regarding the difference between taking notes on paper versus on the computer. In chemistry, the use of technology during note-taking is particularly interesting because there are a multitude of non-verbal representations that students may want to include in their notes, but the use of a computer may create obstacles for students. In addition, technology creates distractions for students and most students underestimate how often they check e-mail or use instant messaging on these devices during class (Kraushaar & Novak, 2010).

Many students have admitted to using their laptops for purposes not related to the course while a lecture was going on, are likely to be multitasking by completing assignments for other courses, and typically have a poor perception about how well they understand course material when taking notes on personal computers (Fried, 2008; Skolnik & Puzo, 2008). Even while controlling for distractions on personal computers, those who used took notes longhand instead

of on a computer performed significantly better when tested on conceptual material (Mueller & Oppenheimer, 2014). In addition, longhand note-taking has been found to support the encoding hypothesis and improve factual and conceptual knowledge because students must paraphrase and reword information (Piolat et al., 2005; Peper & Mayer, 1986), while those who take notes on laptops only tend to record information verbatim (Mueller & Oppenheimer, 2014).

The idea that longhand note-taking may be more effective than taking notes on a computer is interesting to consider in the context of introductory chemistry because (1) students are often new to college and may not know the best way to take notes and (2) the non-verbal representations are not intuitive to type into a computer.

Multiple External Representations. Multiple external representations (MERs) can include text, diagrams, equations, graphs, and other non-verbal information. MERs are common in chemistry, and when prompted to pay attention to certain representations, conceptual knowledge increased in chemistry (Corradi et al., 2013). Corradi et al. (2013) found, however, that when no prompts were given, there was no difference in learning gains. This points to the idea that students need assistance with focusing their attention to certain representations if they are going to incorporate them into their mental representations.

To construct mental representations, students must organize and analyze the representations they are being presented with. When students are presented representations that are not relevant to what they are learning, it often hinders their ability to construct a mental representation (Schnotz & Bannert, 2003). In addition, students are often trying to construct multiple mental representations at one time (Schnotz & Bannert, 2003) and it is difficult for students to translate across representations (Ainsworth, Bibby, & Wood, 2002). When putting this in the context of note-taking and cognitive load, there could be issues with writing and/or

processing representations while note-taking because of the complexity of the representations and students' inability to translate between them. There is little evidence at this time to support or disprove this idea, though.

Kozma & Russell (1997) found that experts more easily translate between representations than novices. In addition, they found that novices tend to group ideas based on surface features and struggle to produce verbal explanations of chemical concepts (Kozma & Russell, 1997). This is relevant because if learners could learn to group representations in a more expert-like way, it is possible that their learning would be improved since it has been found that when learners can properly integrate representations, their conceptual knowledge is more coherent (Ainsworth, 2006; Schnotz & Bannert, 2003). However, due to the expert-novice differences between students and instructors, an instructor may not realize how much students are struggling to integrate and translate between representations. This idea could greatly impact note-taking since students may not know what representations are important to include in their notes or how different representations are related.

Current Study

The current study aims to understand students' perceptions of note-taking in chemistry. Ultimately, investigating note-taking interventions for college chemistry students would be ideal, but without knowledge of students' current practices, it would be difficult to design an effective intervention. Therefore, the purpose of this study was to better understand the current note-taking practices of chemistry students and why they prefer to take notes the way that they do.

No theoretical framework was used in this study because it is exploratory in nature. However, factors such as cognitive load, the use of technology, and available instructional supports were of interest because we already know some information about these topics in

relation to note-taking. Representations were also of interest because, in general, students do not use representations effectively. The understanding of these factors in specific contexts (such as chemistry) is not well understood and is the major focus of this research.

We sought this understanding of students' current note-taking preferences through the following research questions:

1. How do students take notes and decide what information to record in chemistry?
2. Are chemistry students' note-taking preferences based on course content and/or instructional supports?
3. How do chemistry students utilize their notes and their instructor's notes?
4. Do non-verbal representations play a role in student note-taking choices in chemistry?

As this study was intended to be exploratory, there were no hypotheses following the research questions. The intention was not to support or disprove a certain hypothesis, but instead the intention was to understand more about note-taking. To do so, we first needed to establish the legitimacy of the questions being asked of participants because there was little previous work to build questions from. Following this, the research design was intended to continuously refine and improve the questions being asked while simultaneously addressing the research questions. This approach will be further discussed in the methods.

Chapter 2

Methods

Participants & Design

A total of 195 students participated in the study and all participants earned extra credit in their chemistry course for participating. Of the 195 participants, 49.7% of participants were female, 48.7% were male, and 1.5% did not identify. The course had a total enrollment of 334 students at the start of the semester, and 301 students completed the course. Many of the study participants were in their first or second semester of college (88.7%) and the average final grade in general chemistry for 175 of the 195 participants was 76.9 ± 10.4%, which was designated a C+ letter grade. There were 20 participants who did not provide final course grades; 16 participants did not release their final grade to the researchers and 4 participants dropped the course after participation in study data collection. Data for these 20 participants is included in all aspects of the study, with the exception of analyses tied to final grades. The breakdown of academic major and ethnicity for all participants can be found in Tables 1 and 2.

Table 1
Academic Majors

Major	N=195	%
Engineering	97	49.7
Pre-Med	16	8.2
Natural Sciences	35	18.0
Agricultural Sciences	13	6.7
Health & Human Development	12	6.2
Computer Science/IST	6	3.1
College of Business	5	2.6
Liberal Arts	1	0.5
Undecided	10	5.1

Table 2
Ethnicity

Ethnicity	N=195	%
Caucasian	137	70.3
Asian	25	12.8
Hispanic	10	5.1
African-American	6	3.1
Blended (identified as more than 1)	10	5.1
Other	7	3.6

The study included three phases. The first phase was a series of focus groups designed to pilot and refine potential interview questions. The refined interview questions developed through phase 1 were then employed in phase 2. Phase 2 was comprised of a series of individual interviews used to more deeply understand the note-taking habits of students enrolled in general chemistry. The information obtained from these individual interviews informed the design of the third phase. The third phase consisted of a survey that tasked participants with answering questions related to the research questions. The purpose of this survey was to gain more information from a larger population than was elucidated in phase 2. Although focus group data was used to inform later stages, these interviews are not included in the analyses reported here. Methods associated with this phase are reported in order to clarify how interview questions were generated.

Focus Group Participants. Of the 195 total participants, 52 participated in 1 of 5 focus group interviews. As is the case with the overall participant population, engineering was the most common academic major (46.2%), the majority of participants identified as Caucasian (75.0%), most participants were in their first or second semester of college (82.7%). Unlike the overall participant population, focus group participants were majority female (65.4%).

Final grades in the chemistry course were only available for 41 of the focus group participants. The average overall grade in chemistry for these participants was 79.8 ± 9.2%, which is a B letter grade and is slightly higher than the average of all participants in the study. The range of final grades for focus group participants was 99.6% to 58.6%. Of the 11 final grades not reported, seven participants did not release their grade and four participants withdrew from the course.

Individual Interview Participants. There were 17 individual interviews and all 17 interview participants were in their first or second semester of college. Like the focus groups, the majority of interview participants were female (70.6%). While engineering was still the most common academic major (35.3%), it was closely followed by the natural sciences (23.5%). The most commonly identified ethnicity was still Caucasian (58.8%), but there was also a substantial number of participants who identified as Asian (23.5%).

The final grade in chemistry was only available for 15 interview participants. The average final grade for these participants was 78.0 ± 14.0%, which is a B- letter grade and is above the average grade of all participants combined. The two participants who were not included in the average chose not to release their final grade, and the range of final grades was 99.4% to 54.0%.

Survey Participants. There were 129 survey responses, but three responses were eliminated because the participants answered fewer than 30% of the questions. In addition, there were two participants who only responded to 71% and 76% of the questions, but these participants were retained. Therefore, the final number of survey participants used in the data analysis was 126 participants. Most survey participants were in their first or second semester of college (89.7%), 53.2% were engineering majors, 17.5% were natural science majors, and the

majority of participants were Caucasian (69.8%). Unlike the focus groups and interviews, most survey participants were male (59.2%).

Final grades in the chemistry course were available for 119 of survey participants. The average final grade in chemistry for these participants was 75.7 ± 10.2%, which is a C letter grade and is slightly below the overall average of all 195 participants in the study. There were 7 participants who did not release their final grade, and the range of final grades was 95.9% to 44.6%.

Course Setting. The study took place during the Fall 2016 semester at a large research university in the mid-Atlantic portion of the United States and participants were recruited from one section of an introductory general chemistry course. The general chemistry course is the first half of a two-semester sequence of general chemistry, meaning most students enroll during the fall semester. The course is intended for first-year college students and consists of three 50-minute lectures every week. In addition, students are required to attend one 50-minute recitation section each week, which is run by a teaching assistant. Each recitation has a maximum of 30 students and attendance and participation in recitation is part of students' final grade in the course. The recitation sessions give students an additional opportunity to work on problem-solving.

The teaching assistants who hold the recitations are typically graduate students who also hold office hours and attend the three lectures each week. Teaching assistants are often paired with an undergraduate 'learning assistant' to help them with their duties. A learning assistant is an undergraduate student who performed well in chemistry and helps with the chemistry course for course-credit. These teaching and learning assistants work closely with the professor to create a 'learning team' for the students to reach out to because the class size is so large.

In addition to regular chemistry recitation sections, there is a one-credit optional course students may choose to enroll in (identified as "CHEM 108") where sections of 30 students meet with a teaching assistant once a week for 75 minutes to work on problem solving skills. CHEM 108 requires that all enrolled students are concurrently registered for the first-semester general chemistry course. It is recommended that students enroll in CHEM 108 if they have a weak chemistry background or have not taken chemistry in while. Of the 195 participants in this study, 23 of them (11.8%) were enrolled in CHEM 108.

It is important to note that there is an electronic textbook used in the course. The textbook was created in-house at the university and contains readings, homework problems and solutions, and video demonstrations. In several phases of the study, the 'eBook' is mentioned, and that is referring to the electronic textbook. The professor for this section of general chemistry also chooses to post annotated notes on PowerPoint slides after class each day for the students to refer to as needed. Finally, any questions or comments throughout the study about 'demos' are referring to the chemistry demonstrations the professor often does in lecture. These demonstrations are usually chemical reactions that display the concepts being taught. Demonstrations are done most days in lecture, or at a minimum of once per week.

Materials & Procedures

Participants in all phases of the study were recruited from the same section of general chemistry. As stated earlier, all participants received extra credit in their chemistry course for participating in this study. All students enrolled in the chemistry course were given the option of signing up to participate in either a focus group or individual interview, with a maximum of 20 participants per focus group. Students were informed that there would be a third phase available later in the semester, but were not told what the third phase would consist of. When the survey

phase was available, a second round of recruitment was done to obtain participants for the survey. Consequently, all participants chose which phase (if any) to participate in. In addition, students were only permitted to participate in one phase of the study.

Phase 1: Focus groups. Six focus groups were conducted over a three-day period at the mid-way point in the semester. One of these focus groups was eliminated, though, due to a participant being under the age of 18 years old and therefore violating the IRB protocol. The data from the 9 participants that were a part of that focus group were destroyed and were not included in any of the demographics or data reporting. The remaining five focus groups ranged in size from seven to 15 participants, lasted an average of approximately 45 minutes each, and were audio recorded. Given that the focus groups were being used to refine interview questions, the focus group interviews were semi-structured and the questions were adjusted after each focus group. The semi-structured nature of the focus groups allowed the interviewer to ask participants to expand on certain ideas or to ask follow-up questions when ideas were brought up that were relevant to the research question.

The initial set of focus group questions was developed based on both the current note-taking literature and experiences the researcher has had when previously serving as a teaching assistant in this chemistry course and when working with members of the College of Science on course revisions and academic support. As noted earlier, there has not been extensive work done on how the content in a course can affect students' note-taking preferences or on how representations are used in students' notes. Therefore, questions were developed to see if students use multiple representations in their notes, how/when they use representations, if they take notes differently in other courses, and if their note-taking habits have changed at all throughout the semester. In addition, students were asked about how real-world examples and

demonstrations are used in their notes because these are course specific. Questions about general note-taking habits (such as when, how, and why they take notes) were also developed to understand more about why students take notes the way that they do and the decision-making process these students go through when deciding what information is or is not important to record.

The demographic and focus group questions can be found in Appendices A and B, respectively. The demographic questions were administered to all participants on paper at the beginning of the focus group session and before session taping began. Appendix B addresses how questions varied between the five focus groups. If a question was left out during a focus group, it was typically because of time constraints. In addition, participants in the focus groups were asked to elaborate when they simply gave a yes/no response to a question. As noted in Appendix B, if a question was deemed irrelevant to the research question, it was eliminated.

Given that the purpose of the focus groups was to pilot interview questions, transcriptions were not needed. Instead, memoing was used to record the main ideas discussed in the focus groups (Corbin & Strauss, 2015; Creswell & Poth, 2018). The constant-comparative method was employed when comparing memo notes from each focus group (Corbin & Strauss, 2015; Creswell & Poth, 2018). Trends among focus groups were identified and used to inform the design of interview questions for phase 2 of the study. This memoing process resulted in the same questions being used in the interview phase because they were informing the research questions in a meaningful way, but a few questions were added to obtain even more information from participants.

One question that was added to the list of interview questions included asking participants about ‘real-world’ examples instead of just about demonstrations. In the focus

groups, participants were only asked about how they incorporate demonstrations into their notes because demonstrations are a form of real-world example. However, the focus group participants did not seem to see the connection between demonstrations and the real-world, so a question about real-world examples was asked in the interviews, in addition to the question about demonstration. Other questions added included asking participants what they do when they do not know how to do a problem in chemistry and what kind of information they need to know for the exams. These two questions were designed in an effort to elicit more information about how students use the notes or other resources in their chemistry course. In some cases, participants were explicitly asked where they find information for difficult problems or when studying for exams.

Another change for the interviews was explaining to the students what the difference is between conceptual and procedural knowledge before asking about whether they take notes on more conceptual or procedural information. This was done because there was confusion in the focus groups about the difference between these two types of knowledge. Finally, two questions about representations were added to the interviews to attempt to obtain more information about the use of representations in note-taking. First, participants were specifically asked about graphs because the focus group responses seemed to separate graphs from other types of non-verbal representations. The second new question was only asked of participants who indicated that they do include non-verbal representations in their notes. This new follow-up question asked these participants why they include the representations in their notes and if they ever look back at them. The purpose of this question was to understand if students see the usefulness of representations, or if they just write them because they think they are supposed to. This distinction was not clear in the focus groups.

Phase 2: Individual interviews. Beginning a week after the conclusion of the focus groups, a total of 17 individual interviews were conducted over a three-week span. Each interview lasted an average of just under 18 minutes. The approach taken to the individual interviews was similar to the focus groups; all interviews were audio recorded and the questions were semi-structured (interview questions are listed in Appendix C). Any missed questions during an interview was either because the interviewer overlooked it, or because the question was eliminated altogether if the responses being provided were not addressing the research question(s). Participants in the interviews were asked to elaborate when they simply gave a yes/no response to a question. In addition, the same demographic questions used in the focus group were also used in the individual interviews (see Appendix A). The demographic questions were administered on paper before the start of the interview.

Memoing was not used in the interviews in the way it was for the focus groups (Corbin & Strauss, 2015; Creswell & Poth, 2018). The purpose of the interviews was to obtain more detailed information to inform the research questions, so all interview questions and responses were typed after the interview. The interviews were not directly transcribed, but all comments were summarized and recorded and any notable quotes were recorded word-for-word.

After the comments and quotes from all 17 interviews were recorded and typed, the constant-comparative method was as used to identify common themes across participants' responses to each individual question (Corbin & Strauss, 2015; Creswell & Poth, 2018). The constant-comparative method included comparing responses for each question to find similarities in the way interviewees responded. Any disconfirming evidence that was present in the interview responses was also noted during the comparisons.

Phase 3: Survey. The survey was distributed during the last week of the semester, about five weeks after the conclusion of the last interview. In the time between the interviews and the survey, the information shared during all focus groups and interviews was used to inform the design of the survey. Any questions asked in the focus groups or interviews that did not elicit responses that informed the research question(s) were eliminated. In addition, to create a more user-friendly survey, radio buttons were developed for some of the survey questions. These buttons were based on primary themes from the interview responses to allow participants to answer the survey questions in a quicker and more concise way than providing only an open textbox for responses. However, all survey questions with radio buttons also had an 'other' option with a textbox. This was added to provide opportunities for survey participants to elaborate on their responses, in a similar way to the focus group and interview participants, if they chose to.

The survey was distributed on Qualtrics and was open for one-week. All demographic and survey questions can be found in Appendices A (demographics survey) and D (survey questions), respectively. There were changes made to the demographic questions after the individual interviews, which are noted and justified in Appendix A. Survey question 19 (Appendix D) was not used in the evaluation of the survey data because it was beyond the scope of this study.

The open-ended responses from the survey were coded into major themes. Each question varied in the number of themes produced, and any comment mentioned by only one participant was not included in the results. The major themes were identified by first summarizing and grouping each response, and then each group was compared to see if there was an overarching theme connecting two or more groups. An example of this process was when students were

asked about how their note-taking habits in chemistry compare to their other courses, two of the ideas found in the summarizing process were (1) having the same method across all courses helps with understanding and studying, and (2) having the same method across all courses makes it easier to find information. These two groups were connected by the idea that students are discussing organizational components to their notes that help them stay consistent across courses. Therefore, these two summarized points were collapsed into one single idea about the organization of notes.

Given the open-ended nature of most of the survey questions, some responses made 2 (or more) points. Therefore, survey responses could be coded into more than one idea, as some participants listed multiple reasons in their responses. The final data analysis compared these survey ideas to the interview themes to find any discrepancies or similarities. These similarities and differences are reported in the results section.[1]

Finally, all Likert-scale items from the survey were summarized using averages and percentages. Tests of statistical differences are not conducted because research questions did not address any group comparisons.

[1] Analysis of course grades in relation to these responses was not considered because there are many other factors that influence course grades, such as prior knowledge, ability, and motivation.

Chapter 3

Results

The focus groups resulted in the identification of themes for the individual interviews that would best address the research questions. These themes were the emphasis of the individual interviews and subsequent survey, and these themes are used to organize the data analysis and interpretation presented in the remainder of this section. The major finding from the entirety of the data set is that students engage in thoughtful decision-making regarding how to take and use notes, and that this decision-making is often guided by their understanding of how learning is best supported. This finding emerged within and across multiple themes that can be located in participant responses. The remainder of this section presents the following themes and the specific data that supports this conclusion:

Theme 1: How chemistry students take notes

Theme 2: When chemistry students take & use notes

Theme 3: How students determine what is important to record

Theme 4: Why students take notes

Theme 5: Changes in note-taking habits

Theme 6: Comparing notes with friends and/or classmates

Theme 7: Note-taking habits in other courses

Theme 8: Use of representations in note-taking

This data presentation collapses across individual interview and survey data in order to derive general patterns that address the research questions. Each thematic section is organized in the following manner: a purpose and claim is presented, evidence supporting the claim is

discussed, and the section concludes with a brief summary and the reporting of any disconfirming evidence.

Any difference in questions and/or topics between the interviews and survey are addressed and distinctions between the data sets are drawn. Where specific participant responses are quoted, the participant is identified by a Participant ID number. These numbers were assigned sequentially beginning with the focus group participants; i.e. participant IDs #1-61 were focus group participants, #62-78 were interview participants, and #79-204 were survey participants.

Theme 1: How Chemistry Students Take Notes

Purpose & Claim. To begin the survey and interviews, all participants were asked how they take notes in chemistry. This question was designed to allow the researcher to gain a better understanding of the methods participants use to take notes before continuing to question the participants.

Overall, responses from both the interviews and survey indicate that the majority of participants take notes by hand in Chem 110, but there are other ways in which some students choose to take notes. In addition, the data indicates that participants are making purposeful decisions about the way in which they choose to take notes. These decisions are driven by factors such as the encoding function of note-taking, obstacles created by the use of computers during note-taking, the nature of the material taught in chemistry, and students' preferred organization of their notes.

Evidence. Evidence supporting the claim that the majority of students take notes by hand in chemistry was evident in the interviews when all participants indicated they take notes by hand (N=17, 100.0%). The survey results further support the claim and are presented in Table 3

[Note: due to the lack of variation in interview responses, they were not included in Table 3]. As Table 3 displays, survey participants reported a greater variety in how they take notes than interview participants, but the preferred method for most survey participants was taking notes by hand.

Table 3
How Students Take Notes in CHEM 110

Method	N=126	%
By hand on blank paper	113	89.7
By hand on printed PowerPoint slides	4	3.2
Typed on my computer	10	7.9
Typed on provided PowerPoint slides	2	1.6
On my tablet	3	2.4
On my phone	1	0.8
I do not take notes	11	8.7
Other	0	0.0

Note. Percentages add to over 100% because participants could select more than one method.

As stated in the claim, there are some students who prefer note-taking methods other than taking notes by hand. To expand on the data presented in Table 3 that support this claim, of the 113 survey participants who selected 'by hand on blank paper' as one of their methods, 96 chose it as their *only* method of note-taking (76.2%). The other 17 participants who selected 'by hand on blank paper' chose it as one of 2 options. There were only 18 total participants who chose 2 options (14.3%), and no participant chose 3 or more options.

Moving towards the second piece of the claim, which claims that students make purposeful decisions about the way they take notes, the interview and survey data regarding *why* participants take notes the way they do will be presented. As stated in the claim, students' decisions are driven by the encoding function of notes, obstacles created by computers, the nature of the material in chemistry, and how they prefer to organize their notes. These driving factors will be used as subheadings in the following presentation of the data.

Encoding. The encoding function of notes was address by 10 interview (62.5%) and 43 survey participants (34.1%). Some participants who mentioned this idea mentioned it in conjunction with other reasons (e.g. computers are distracting or it is difficult to type symbols). Some examples of participant comments include:

> It's easier to remember the information if you write it down. Well, I find it's easier. Plus, with computer I get distracted and I'll have my messages pop up, or my e-mail, and it's just easier if I write it by hand (interview, participant #73)
>
> I chose this method of note-taking because I feel that I retain the information better if I hand-write it. (survey, participant #85)
>
> I noticed whenever I type notes (like sometimes I did in high school) that I would not retain the [information] as well as if I had written it down on paper. It also makes me think about what I am [writing] because I can just [aimlessly] type. Lastly, for the format that chemistry (equation/math), it makes it easier to write what I want and draw diagrams. (survey, participant #200)

Altogether, these responses show that participants are aware that how they take notes affects their learning and that they make decisions about note-taking that are intended to support this learning. In particular, the participants seem to be aware of the encoding function of notes, believe that hand-writing best supports this function, and that these college students are able to make decisions about effective note-taking strategies.

Computers & Nature of the Material. The point about encoding is elaborated by participants who indicated that using their computers to take notes can be distracting. There were 4 interview participants (25.0%) and 9 survey (7.1%) participants who mentioned this point specifically, and 2 interview (12.5%) and 6 survey (4.8%) participants who mentioned that they

type slowly or dislike technology in general. There were also 4 interview (25.0%) and 36 survey (28.6%) participants who mentioned that the symbols in chemistry make it too difficult to type on a computer (e.g. graphs, equations, chemical notation). These comments are related to obstacles created by the use of computers for note-taking, and indicate students' decision-making ability regarding ineffective note-taking methods. Survey participants' comments about typing symbols in chemistry included:

> With chemistry, it's a lot easier [to take notes by hand]- drawing a figure or writing down formulas - and usually trying to do that with a laptop or something else isn't really that convenient, so I usually hand write them (interview, participant #76)
>
> A lot of chemistry there is math involved and formulas and typing on a computer. I feel like a computer is more like words rather than formulas and numbers (interview, participant #78)
>
> It would be too hard to type the notes on my laptop because there is a lot of symbols and mathematical operations I would not be able to use (survey, participant #133)
>
> It's the simplest and easiest method to keep up with the professor. Try writing chemical equations on Microsoft word. Good Luck [with] that. (survey, participant #83)

These participants' responses show that they are aware of potential limitations caused using a computer for note-taking in chemistry. The comments about computers indicate that students do not find computers effective for note-taking because of obstacles the computers create (e.g. attentional issues and the nature of chemistry material makes the use of computers difficult). The idea of symbols creating obstacles in chemistry note-taking also emerged as a significant factor in students' note-taking decisions and thus, the theme 'nature of the content in

chemistry' was identified as a specific theme for the data analysis. More information on this point is included in a later section of the results that addresses this theme in more detail.

Organization. The final way in which student decision-making seems to drive their note-taking choices was through comments about the organization of their notes. There were 18 survey participants (14.3%) who mentioned organization, eight of which described hand-writing notes because it makes it easier to organize and add information during note-taking. The other 10 participants who mentioned organization said that hand writing makes it easier to find what you are looking for when you look back at your notes and/or they are easier to study from. Some participant responses regarding organization are:

> I like being able to use the margins, and format my notes how I like to (survey, participant #103)

> In all previous science classes I took in high school I took notes by hand in notebooks. I have tried using other methods such as typing on a laptop or writing on printed slides but I feel studying for exams and reviewing material is simpler for me if I organize my own notes. (survey, participant #112)

These participants feel that the organization of their notes is more logical if they hand-write their notes, so they are making a purposeful decision to do so. In addition, the organization helps students when studying from their notes after class, supporting the idea of students making purposeful decisions about their note-taking methods.

Summary & Disconfirming Evidence. Overall, participants' responses indicated that they are aware that note-taking influences their learning and that their decisions about how to take notes are at least partially guided by this awareness. Of course, this was not true of all study participants. Indeed, some participants' responses indicate that their note-taking choices are

based on factors other than those that directly support learning. For example, there were 24 survey responses (19.0%) that mentioned choosing their note-taking method because it is easier/simpler, more efficient, and/or more effective. These participants did not always give a clear reason why their method is easiest or most effective for them, which makes these comments difficult to align with the claim that students are making purposeful decisions.

Other evidence that does not align directly with the claim includes 12 survey participants (9.5%) who take notes by hand because they always have or because it is 'traditional.' These participants may not have reflected on how note-taking is helping them learn in the course. Instead, these participants are just doing what comes naturally to them. There were also two interview (11.8%) and two survey participants (1.6%) who said they take notes by hand because the professor recommended it, which is another indication that not all students reflect on the way they take notes. Despite these inconsistencies, most participants in the study support the claim that most students take notes by hand in chemistry and make purposeful decisions regarding how they take notes.

Theme 2: When Chemistry Students Take & Use Notes

Purpose & Claim. Chemistry students are provided with many instructional materials such as the online textbook, problem sets, and the PowerPoint slides used in lecture. Questions related to how students take notes when studying from these materials were added to the interviews and surveys because focus group participants indicated that they do not only take notes during chemistry lectures, and they often take notes when studying from these other materials. To address the use of these notes, participants in the interviews and survey were also asked how they use their own personal notes and the professor's notes. This was added to the interviews and survey because the focus group participants indicated that they use these two sets

of notes in different ways. Therefore, this thematic section will focus on interview and survey participants' explanations regarding when they take and use their chemistry notes.

The major claim that arises from this portion of the data set is that, for the majority of students, note-taking practices affect not only their behavior during lectures, but also how they study the other course materials. The participants indicated that note-taking does not only occur during lecture, even though that is the most common time to take notes. In addition, in general, participants use their personal notes more often than their professor's notes. However, the variations in responses in both the interviews and survey did not allow a claim to be made regarding the notes students tend to use when studying for exams, or how they use their notes in general.

Evidence.

When Students Take Notes. The claim above, regarding when students take notes, is supported by evidence showing that students take notes while also engaged in other course activities. Table 4 shows both interview and survey participants' responses to the question of when they take notes. As this table shows, a large majority of students report taking notes during lecture, but this is clearly not the only time that note-taking is used in Chem 110 because many participants selected more than one answer.

Table 4
When Students Take Notes in CHEM 110

	Interview		Survey	
Time	N=17	%	N=126	%
During lecture	16	94.1	113	89.7
Before lecture	4	23.5	13	10.3
After lecture	2	11.8	43	34.1
During recitation	0	0.0	39	31.0
Other	2	11.8	6	4.8

Note. Percentages add to over 100% because participants could select more than one method.

To further expand on the evidence presented in Table 4 that support the claim; 6 of the interview participants (35.3%) and 66 of the survey participants (52.4%) who said they take notes in lecture also reported taking notes at least one other time (e.g. before lecture, after lecture, or occasionally/randomly). There was only one interview participant who does not take any notes in lecture, and that participant takes notes before class using the online textbook. Additionally, two survey participants who selected 'other' wrote that they take notes while doing homework or before an exam in addition to taking notes in lecture. The other four survey participants who selected 'other' do not take notes at all. Therefore, the data supports the claim that students do not take all of their notes in lecture and do use other course materials to take notes outside of class.

When Students Use Notes. Evidence to support the claim that students use their own notes more often than the professor's notes is supported by Tables 5 and 6. As these tables show, participants use the professor's notes 'a few times per semester' or 'never' more frequently than their personal notes. In addition, they more frequently use their personal notes during the week.

Table 5
How Often Students use Personal Notes

	Interview		Survey	
Time	N=16	%	N=123	%
1-2 days per week	11	64.7	70	55.6
3-5 days per week	2	11.8	27	21.4
6-7 days per week	-	-	5	4.0
A few times per semester	3	17.6	19	15.1
Before Exams	2	11.8	-	-
Never	1	5.9	4	3.2

Note. Percentages add to over 100% because participants could select more than one method.

Table 6
How Often Students use Professor's Notes

	Interview		Survey	
Time	N=16	%	N=123	%
1-2 days per week	6	37.5	62	50.4
3-5 days per week	3	18.8	15	12.2
6-7 days per week	-	-	2	1.6
A few times per semester	2	12.5	22	17.9
Before Exams	5	31.3	-	-
Never	2	12.5	22	17.9

Note. Percentages add to over 100% because participants could select more than one method.

Purposes Students Use Notes For. Knowing when students take and use notes resulted in a desire to understand for what purpose(s) students use their personal notes and the professor's notes. Additionally, through use of the survey, clarity was desired regarding how different types of notes are used when studying for exams. Overall, no definitive conclusions can be drawn about the most common purpose(s) students use their notes for. One common way students use their notes is to study for exams, but no claim can be made regarding which type of notes students use more frequently when studying. All results regarding the purposes students use their notes for can be found in Tables 7 and 8.

Table 7
Purpose(s) Students Use Personal Notes For

	Interview		Survey	
Purpose	N=14	%	N=113	%
Completing homework	9	52.9	107	84.9
Completing quizzes	4	23.5	75	59.5
Studying for exams	8	47.1	117	92.9
Recitation	1[a]	6.3	88	69.8
During outside help	3[b]	18.8	16	12.7
Other	5	29.4	5	4.0

Note. Percentages add to over 100% because participants could select more than one method.
[a] N=16 for this interview question
[b] N=8 for this interview question

Table 8
Purpose(s) Students Use Professor's Notes For

	Interview		Survey	
Purpose	N=14	%	N=113	%
Completing homework	1	7.1	74	65.5
Completing quizzes	-	-	43	38.1
Studying for exams	7	50.0	92	81.4
Recitation	-	-	42	37.1
During outside help	-	-	7	6.2
Other	10	71.4	13	11.5

Note. Percentages add to over 100% because participants could select more than one method.

To expand on the 'other' category from Table 7, interview participants said they occasionally skim their personal notes (n=2), skim their personal notes every day after class (n=1), and only skim their personal notes when stuck (n=1). In the survey, 4 of the 5 participants who selected 'other' said they never use their personal notes. As for the 'other' use of the professor's notes (Table 8), interview participants use the professor's notes to fill in missing information in personal notes (n=6) and to clarify confusing information (n=2), while survey participants use the professor's notes to look up missing information (n=3) and to take notes from the professor's slides (n=2). These responses support that there are inconsistencies in how students use their notes.

Summary & Disconfirming Evidence.

When Students Take Notes. One inconsistency regarding when students take notes was that 16 interview participants do not take notes in recitation, but 39 (31.0%) survey participants selected recitation as a time when they take notes. There is a clear gap between interview and survey participants in this regard. The interviews participants' thoughts included 11 participants who generally do not take notes in recitation because they complete problem sets during that time, but will sporadically take notes if the teaching assistant (TA) goes over new or confusing

information. The other 5 interview participants said they never take notes in recitation (n=2), they do not take notes but will note problems they should study for the exams (n=2); or they do not take notes in recitation, but use class notes to help solve recitation problems (n=1).

These interview responses indicate that participants do not actively take notes during most recitations. However, many of the interview responses indicate that there are occasions when note-taking is warranted in recitation. This may explain why almost a third of survey participants indicated they take notes in recitation, but no interview respondents stated this. That is, if these interview participants were completing the survey, they may have selected 'During recitation' as a time that they take notes had they not been given the opportunity to elaborate their answers as they did in the interviews.

Despite the inherent inconsistency in recitation note-taking preferences between participants in the survey and interviews, it still stands that both survey and interview participants prefer to take the majority of their notes during lecture, but also take notes at other times.

When Students Use Notes. As Tables 5 and 6 displayed, there were some inconsistencies between the interview and survey response options. Although specific survey questions and response options were based on interview responses, the survey did offer some response options that were not mentioned by interview participants. These changes were made because some answers may not have arisen during the interviews simply because of the small sample size. For example, no interview participant reported using their notes more than five days a week, but the option of '6 – 7 days' was added to the survey in case this frequency did occur in the larger sample.

In addition to the inconsistencies in response options, there were also inconsistencies between the interview and survey participants who selected ‘a few times per semester’ and/or ‘before exams.’ Many interview participants indicated they use notes only before exams, but since this was not an option in the survey, some participants instead selected ‘a few times per semester’ and wrote that it was just before exams. Therefore, in future use of this survey, ‘before exams’ should be added as an option. Despite these inconsistencies, the claim still stands that students tend to use their personal notes more frequently than the professor’s.

Purposes Students Use Notes For. Similar to the inconsistencies described in the section above, there were differences in how/if recitation was discussed regarding the purposes students use their notes for. The interview participants were directly asked about their use of personal notes in recitation, but never about the professor’s notes. This option was still added because it is conceivable that students may use the professor’s notes in recitation. These inconsistencies do not change the claim that students greatly vary in how they use notes in chemistry.

Another option developed for the survey (displayed in Tables 7 and 8), ‘during outside help’, came from 8 interview participants who were asked if they take or use notes in office hours and/or help sessions. Three of these participants never seek help outside of class. Another three take notes while receiving help outside of class, but only on information they have been struggling with. The final two participants go to office hours, but do not add information to their notes because (1) they understand the concepts once they hear an explanation and do not need to write it and (2) they only seek help on problems they are stuck on, which they believe does not require taking additional notes. Overall, three of these participants take notes in office hours, but no participant mentioned the use of notes they already had during office hours. In addition, like the question about recitation, interview participants were not asked about their use of the

professor's notes in office hours. It was added to the survey for the sake of consistency and to see if it allowed for a claim to be made about the purposes for which students use their notes.

As shown in Tables 7 and 8, there were inconsistencies in responses between the interviews and survey, which lead to no definite claim being made about this data. These inconsistences cannot be fully accounted for, but the largest difference between the interviews and survey was that the question about purpose(s) for which notes are used was not always directly asked by the interviewer. The semi-structured nature of the interviews led to having this topic come up naturally, and conversations ensued about how notes are used in Chem 110 without the question being directly asked. However, this may have led to a misrepresentation of the purpose(s) for which interview participants use notes because they were not asked specifically about homework, quizzes, exams, etc.

If these participants were given the survey and asked to 'check off' each way they use their notes, it is possible that they would have selected more options than were discussed in the interviews. However, the conversations in the interviews were valuable because participants' natural explanation of how they use notes was useful when developing the options for the survey. Overall, despite any inconsistencies presented here, it can still be concluded that participants take notes at times other than just in class and that they use their personal notes more frequently than the professor's. Future work on this topic may allow for more definite conclusions regarding what purpose(s) students use their notes for.

Theme 3: How Students Determine What is Important to Record

Purpose & Claim. With an understanding that students go through a decision-making process regarding how they take notes, there was a desire to understand how students decide what to record in their chemistry notes. The focus group participants indicated that it is often

difficult to write everything down during chemistry lectures, which implies that students must make decisions about what they should or should not worry about including in their notes. Therefore, interview and survey were asked how they decide what to record in their chemistry notes. To follow-up on these ideas, survey participants were asked if they believe taking notes during chemistry lecture is the best use of their time. This question was developed after the interviews because the interviews consistently indicated that students are making purposeful decisions. This decision-making was discussed in Theme 1 and will continue to be discussed throughout the presentation of data. Therefore, more information regarding how students perceive note-taking was desired.

Overall, when asked about how they decide what is important to record, participants continued to indicate purposeful decision-making processes. This claim is justified through the data that shows that students base their decisions on the content being taught, written surface cues, verbal cues from the instructor, and when they believe they will need the information later. In addition, the average participant indicated that taking notes in lecture is 'probably' the best use of lecture time.

Evidence. To support the claim that participants are making purposeful decisions about note-taking, data regarding how students decide what is important to record is displayed in Table 9. Most responses displayed in Table 9 indicate decision-making on the part of the learner. However, not all decisions made by the learners are ones that are likely to lead to successful learning. For example, those who focus on writing only main concepts, what they do not already know, what they might forget, or information that may continue to be relevant are making decisions based on what information is important to their learning in chemistry. These learners

are not using surface cues to make decisions, but instead are reflecting on main points and if they already know information or not. These decisions, therefore, may lead to higher learning gains.

Table 9
How Do You Decide What is Important to Record?

	Interview		Survey	
Decision	N=16	%	N=126	%
Main Concepts/Important Info	6	37.5	38	30.2
Examples/Calculations	5	31.3	30	23.8
Definitions/Equations	4	25.0	26	20.6
Bolded/Underlined/Bulleted Info	5	31.3	4	3.2
Professor says but does not write	4	25.0	23	18.3
Everything on PowerPoint	3	18.8	16	12.7
Everything on Chalkboard	2	12.5	24	19.0
What they do not know/will forget	4	25.0	17	13.5
What will be on Exams	1	6.3	5	4.0
Tips/Tricks	-	-	5	4.0
Info to be Memorized	-	-	3	2.4
Info that will continue to be relevant	-	-	2	1.6

Note. Percentages add to over 100% because participants could select more than one method.

Those participants (See Table 9) who write example problems, calculations, definitions, equations, bolded/underlined/bulleted information, information to be memorized, or tips/tricks may not be taking as effective notes, but that does not mean that they are not making purposeful decisions about their notes. These decisions may not lead to as effective of learning because these decisions are based on more surface-level cues, but there is no definite way to know from the data available in the current if these participants are learning less than the other participants. Those participants who only record what will be on exams may be missing important concepts during class, but they are making decisions that align with their goal of performing well on

exams. Again, there is no way to gauge how much these participants are learning, but they are making purposeful decisions. Examples of decision-making include:

> I record what the professor writes on the slides and board along with important definitions and equations on the slide (survey, participant #146)
>
> I usually record definitions of chem terms, steps to completing a problem, and anything that the professor seems to put emphasis on. (survey, participant #153)
>
> Important concepts, things the professor repeats, and things that the professor doesn't write down (won't be released on the [PowerPoint] slides) (survey, participant #109)

Another decision made by learners was to focus only on what the professor says, but does not write. They are doing so because the professor posts notes after class and they can access those notes at that time. Therefore, this could be an effective way to take notes because the learner can focus more on what the professor is saying rather than on note-taking (e.g. participant #109 above). However, this could also be done blindly, so it is difficult to know whether or not this decision would lead to better learning outcomes.

Perceptions of taking notes in lecture. The survey also asked participants if note-taking is the best way to spend lecture time. This question was not asked in the interviews, but the interviews consistently indicated that students are making purposeful decisions regarding note-taking, so more information regarding how students perceive note-taking was desired. Therefore, survey question 4

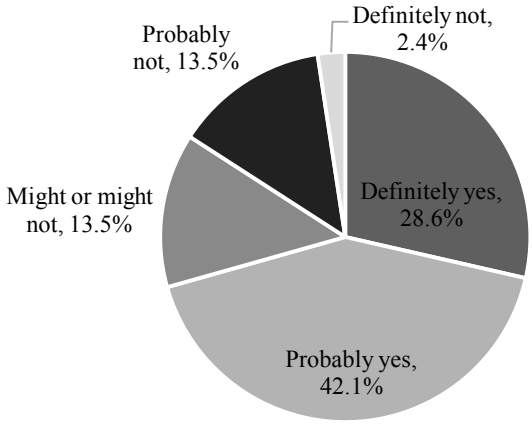

Figure 1. Participants' perceptions of whether taking notes is the best use of lecture time

(Appendix D) was designed to identify if students believe note- taking in class is important, or if they just take notes because they feel as though they are 'supposed' to. There were 89 participants (70.6%) that indicated that note-taking 'definitely' or 'probably' was the best way to use lecture time (See Figure 1). When the answer choices were converted to a 1 to 5 scale, where 'Definitely not' was 1 and 'Definitely yes' was 5, the average was 3.8. Therefore, the average survey participant indicated that taking notes during lecture is 'probably' the best use of lecture time.

Summary & Disconfirming Evidence. The participants listed in Table 9 who write everything on the PowerPoints or who write everything that is on the chalkboard but not on the PowerPoint are indicating very little decision making. It could be argued that these are purposeful decisions on the part of the learners, but because of the wide range of information that could be written down, this type of decision shows little awareness on the part of the learner of what information they are writing. Therefore, this indicates that these learners are not sure how to make decisions about what to write. While there were a fair number of participants who mentioned these ideas, some of them mentioned these ideas in conjunction with other ideas. Also, the majority of all participants did indicate some form of decision-making while deciding what to record, which supports the claim.

During the interview process, participants were asked additional questions about how they decide what to record in their notes (e.g. if they include real-world examples or demos in their notes and if anyone ever taught them how to take notes). The question about real-world examples was too specific to include in the survey, while asking interview participants if anyone taught them to take notes was too broad. The responses elicited from both questions did not sufficiently address the research questions and were not included in the survey.

Theme 4: Why Students take Notes

Purpose & Claim. Due to the variation in interview responses for the purpose(s) for which students use notes and the large number of ways in which they decide what to record, it seemed important to understand why students even take notes. For example, there were many interview participants who use notes only when studying for exams. Note-taking is a lot of work to do during lecture, so to only use them occasionally seems counterintuitive. Therefore, survey participants were asked in an open-ended manner to explain their main reason for taking notes in chemistry.

The major claim from this survey question is that students use notes as a tool through which they can achieve their academic goals. This claim is supported by students stating that take notes because note-taking helps them learn or remember the course material, and therefore helps with performance in the course. Not every student mentioned learning, as many of them mentioned their performance in the course, but nonetheless those comments also support the claim. As a sub-claim to this, it can be argued that this is a purposeful decision students are making. There are other avenues through which academic goals could potentially be met, but students are choosing note-taking as one way in which to meet their goals.

Evidence. All results regarding why students take notes are summarized in Table 10. The comments display in Table 10 show that students are using note-taking as a means through which they can achieve both performance and learning goals. Many participants wrote about the desire to complete assignments or get good grades, which are performance goals, while others wrote about learning or remembering information, which are learning goals. These ideas support the claim that students use note-taking as a tool through which they are able to achieve their goals.

Table 10
Why Student Take Notes in CHEM 110

Reason	N=122	%
Helps with studying and class assignments	55	45.1
Helps with learning material	26	21.3
Helps with remembering information	26	21.3
To get good grades/be successful in Chem 110	17	13.9
To remember what was covered in class	10	8.2
Notes are easier to use than other resources	3	2.5
Helps with paying attention in class	7	5.7
To have something to look back at	6	4.9
I do not take notes	5	4.1

Note. Percentages add to over 100% because participants could select more than one method.

To begin to expand on Table 10, and to support the claim that students use notes as a tool through which they can achieve their academic goals, some of those who mentioned using notes for studying or class assignments (e.g. homework, recitation worksheets, or quizzes) use their notes as a resource to complete their studying or class assignments. They had the following to say:

> My main reason is so I can review them outside of class to help me with other portions of the class. For instance, recitation, homework, and quizzes. (survey, participant #79)
>
> I take notes in chem 110 so I have a resource of information for when I do homework and quizzes. It helps me to understand how to use these concepts in various question applications. The notes also are great for studying for the exam (survey, participant #165)

This evidence shows that participants are using note-taking as a resource to complete assignments, and is also something that the participants who use their notes to learn or

understand material do. These participants did not explicitly explain why this is important to them, but a logical assumption is that these students know that studying and completing their assigned work will make it more likely that they (1) have a better understanding of the material and (2) get better grade in the course. The participants in Table 10 who said they take notes to help them retain or remember information were categorized separately than these participants because they may not be trying to attain as deep of an understanding as the participants who used words like "learning."

The participants who take notes to help them get good grades and/or be successful in the course (Table 10) are indicating that their reason for taking notes is performance driven. These participants may not be as focused on what they are learning, as they only mentioned their performance. However, their responses still support that claim that students are trying to use note-taking as a way to meet their academic goals. For example, participants said:

> To pass the class. (survey, participant #107)
>
> I want to receive a good grade and this is very important to achieve that goal. (survey, participant #166)
>
> Main reason for taking notes is to learn the material to do well on exams. (survey, participant #182)

There were a few participants who mentioned their performance in the course in conjunction with wanting to learn or understand material, which is yet another example of purposeful decision making. For example:

> So I can learn and get a better grade (survey, participant #137)
>
> To do well in the course and get a solid grasp of the information. (survey, participant #159)

These participants seem to believe that note-taking is tool that can help with their learning process and ability to do well academically, which directly supports the claim. Overall, even though not every participant was focused on learning, they were still making purposeful decisions to lead them to their academic goals.

Summary & Disconfirming Evidence. There was little disconfirming evidence with this claim, but those who use notes to help pay attention in class are not thinking of notes as a tool through which they achieve their goals. In addition, those who just want something to look back at or think notes are easier to use than other resources are not indicating that they use their notes to help them reach their goals. While these comments do not directly support the claim, there were few participants who made these comments. Overall, participants seemed focused on making purposeful decisions about note-taking in order to be able to use notes to help them reach both performance and mastery-based academic goals.

Theme 5: Changes in Note-Taking Habits

Purpose & Claim. Given that a main goal of this study was to understand if course content or instructional supports alter students' note-taking preferences, understanding how participants' note-taking habits change is important. That is, students may begin a course with an idea of how they should be taking notes, but after experiencing the course content and the available materials, they may change their method. For this reason, both interview and survey participants were asked if their note-taking methods have changed since the beginning of the semester.

The results lead to the claim that that the most common changes in note-taking habits were based in purposeful decision-making, as most participants who changed their habits either took more notes or fewer notes throughout the semester. While this may seem inconsistent,

participants' elaborations of these responses indicate consistency in the underlying reason for making a change (regardless of whether the change was to increase or decrease the amount of information contained in notes). Many participants, for example, made changes that they felt would lead higher learning gains or better performance in the course, which supports that they were going through a decision-making process.

Evidence. Results from those participants who responded 'yes', their habits have changed, can be found in Table 11. Those who responded 'no' were not asked to explain why, though that information may be useful to obtain in future studies. It should be noted that the most common change provided in the interviews was that students stopped taking notes before class. However, in conjunction with the survey results, it more clearly looks as though the most common reasons for changes in note-taking preferences were taking more notes or taking fewer notes.

Table 11
How Note-Taking Habits Changed

	Interview		Survey	
Change	N=10	%	N=66	%
Takes fewer notes	2	20.0	37	56.1
Takes more notes	3	30.0	8	12.1
Stopped taking notes before class	4	40.0	3	4.5
Stopped using a computer	1	10.0	2	3.0
Started taking notes before class	-	-	2	3.0
Notes are sloppier	-	-	4	6.1
Notes are more organized	-	-	6	9.1
Use the professor's notes more	-	-	6	9.1

Note. Percentages add to over 100% because participants could select more than one method.

Some of the participants who take fewer notes compared to the beginning of the semester said they do so because it is too difficult to pay attention in class while taking notes, and that it is easier to write the main topics and/or the 'big picture' instead. For example, participants said:

> Now I write down the most important things to simplify my notes and so I don't spend most of lectures writing stuff down and not paying attention. (survey, participant #105)
>
> I started focusing on what's important to write down so I could focus on what my professor was saying. (survey, participant #89)

This attentional issue indicates that students are aware of their ability to learn in class and are willing to adjust accordingly, which is a decision-making process. The other participants who take fewer notes said they do so because they know the professor will post notes online after class, so they focus only on writing what will be on exams during lecture. These participants believe they take more effective notes even though they write less.[2] Overall, participants are adjusting the way they take notes to help them reach their goals.

Opposite from those who take fewer notes were those who took more notes as the semester went on. Reasons for taking more notes included: they needed to take more extensive notes in chemistry as compared to their other courses, taking more notes helped them focus in class, they performed poorly on the first exam and thought taking more notes would improve their performance, and they began writing more practice problems down because they are helpful on homework and online quizzes. While these reasons are seemingly inconsistent, all reasons provided by participants either displayed an awareness of their learning in chemistry or were performance-driven. Therefore, these participants are all making purposeful decisions to change their note-taking habits in a way that will help them reach their goals.

---

[2] Participants did not expand on what they meant by 'effective,' but it is conceivable that they believe effective notes are notes that help them do well on exams.

The claim is further supported by the data in Table 11 because other participants said they stopped using a computer because it was too hard to keep track of the notes, stopped taking notes before class because it was not helpful in learning the material, or started taking notes before class because it helped with learning the material in lecture. Again, there seems to be inconsistencies within this data, but overall these participants are also supporting the claim that students make purposeful decisions about the way in which they take notes.

Summary & Disconfirming Evidence. The responses from Table 11 from the participants who said their notes are sloppier or more organized as the semester proceeds are not in direct support of the claim. These types of statements are surface-level and are not indicative of a decision-making process. Typically, it would reasonable to assume students do not decide to purposefully make their notes sloppy. It is possible that these participants said this because it is something that may naturally occur as you take notes over the course of a semester. However, these statements were not common and do not take away from the claim that students make decisions about how to take notes, even after the semester has begun.

Theme 6: Comparing Notes with Friends

Purpose & Claim. With an understanding of how, when, and why students take notes in chemistry, more information was desired about how students use their notes. One way in which students may use their notes is to compare them with friends' or classmates' notes during class, study groups, or recitation. This idea was generated by the researcher before the start of the study, based on experiences of students comparing notes during class, and was therefore discussed with participants in the focus groups. The focus group participants provided a wide variety responses, including that they will compare while doing homework or studying, when they are confused, or if their friend has a different professor who teachers differently. However,

there were also focus group participants who said they would never compare notes because they are afraid it would confuse them. To understand more about why students may or may not want to compare notes, both interview and survey participants were asked if they compare their chemistry notes with classmates or friends.

Overall, the major claim is that participants who compare notes indicated information seeking behavior and/or that they are seeking affirmation that their notes are complete or accurate. On the other side, interview participants who do not compare notes either do not think it would be useful or they never thought to compare notes. These two claims will be presented separately below.

Evidence.

Those who do compare notes. There were seven interview (41.2%) and 40 survey (31.8%) participants who do compare their chemistry notes. The reasons for comparing notes can be found in Table 12.

Table 12
Comparing Notes with Classmates or Friends

	Interview		Survey	
Reason	N=7	%	N=39	%
Study/HW group OR before exams/recitation	5	71.4	7	17.9
Missed info, discrepancies, mistakes OR confirm info is correct	-	-	30	76.9
Clarify confusing info	-	-	9	23.1
Compare with different professor	1	14.3	2	5.1

Note. Percentages add to over 100% because participants could select more than one method.

As stated in the claim, most of the participants are seeking affirmation that their notes are complete and/or accurate, or they are seeking information to add to their notes. Illustrations of this information seeking behavior that support the data in Table 12 include:

> I compare my notes to make sure I am getting the information right. In addition, if I missed something important during lecture (survey, participant #79)
>
> To check if I haven't made a mistake while taking notes in class. To maybe find something in my friend's notes that I missed (survey, participants #116)
>
> To make sure that I did not leave out any other important information for an upcoming test (survey, participant #201)

These participants are making comments about how they seek approval or affirmation from their friends that their notes are complete and accurate. Beyond those who compare to find discrepancies in their notes, the participants who compare notes with students who have a different professor said they do so because sometimes it is helpful to see a different professor's explanation of confusing information. Also, in addition to the reasons listed in Table 12, there were 2 survey participants who compare notes with fiends if they miss class and 1 interview participant who will ask their classmates what they are writing when they are unsure of what to write. All of these comments indicate information seeking behavior and therefore support the claim.

Those who do not compare notes. There were 10 interview (58.8%) and 86 survey (68.3%) participants who do not compare notes. Only interview participants who do not compare notes were asked to elaborate, and those participants either do not think it would be useful or they never thought to compare notes. Since these responses did not inform the research questions in a meaningful way, the survey only asked those who do compare notes to provide an explanation.

Summary & Disconfirming Evidence. Although there are differences between the interviews and survey responses for this question (See Table 12), the differences are not as

extreme as it may appear. Most interview participants who compare notes said they either do so before exams (to confirm that they did not miss any important information that may appear on the exam), or while doing homework or recitation problems with their classmates (to confirm that they have all information needed to complete the problems). These behaviors support the idea that students are seeking information from their classmates, while also seeking affirmation that the information they have in their notes is accurate. However, most of the survey responses did not clearly mention exams, homework, or recitation as a time when students compare notes. Instead, the responses focused more on how students compare notes to confirm the information they have is correct or to find any missed information, discrepancies, or mistakes in their notes. This idea aligns nicely with the interview participants' responses (even though exams, homework, and recitation were not always mentioned) and supports the overall claim.

Theme 7: Note-Taking Habits in other Courses

Purpose & Claim. One goal of this study was to understand how the nature of course content affects how students take notes. Students may change their note-taking preferences depending on the course they are in and/or the course materials. In addition, focus group participants made many comments comparing different courses they are in and how their note-taking habits vary between these courses. Therefore, participants in this study were asked to explain if they take notes the same way in every course, and there was a focus on understanding the decision-making process participants go through when deciding how they will take notes for certain courses.

One claim is that those who take notes the same way in every course do so because of the consistency. Some of the main reasons mentioned were that taking notes the same way in every course helps with remembering information better, staying organized, and focusing on main

points. These participants also mentioned that their method 'works best for them,' which may also indicate that consistency is important. In addition, another claim is that the participants who have different note-taking preferences for different courses said that they change their note-taking habits based on the nature of the material in the course and the course materials provided. Therefore, an overall claim supports the idea that students are making purposeful decisions about how to take notes in each of their courses based on consistency, course material, and the course content.

Evidence.

Those who take notes the same way in every course. There were 10 interview (58.8%) and 63 survey (50.0%) participants who take notes the same way in every course. Only five of the interview participants who take notes the same way in every course offered an explanation. Those explanations, in conjunction with the survey responses, can be found in Table 13.

Table 13
Use of Same Note-Taking Method Across Courses

	Interview		Survey	
Reason	N=5	%	N=63	%
Always focus on main points	2	40.0	-	-
Always takes notes by hand	1	20.0	13	20.6
Consistent Organization	2	40.0	10	15.9
Helps with Learning	-	-	9	14.3
Do not know another way	-	-	3	4.8
'I like it'/ 'It works for me'	-	-	29	46.0

Note. Percentages add to over 100% because participants could select more than one method.

To expand on the results from Table 13, one of the interview participants who always focuses on the main points of a lecture, regardless of the subject, said that in math and chemistry, the main points are formulas and definitions, whereas in other courses there are no concepts to build on so the main points are 'just facts.' This indicates some awareness on the part of the student about how the nature of the course content is fundamentally different from course to

course. In addition to this, many of the survey participants who said they always hand write their notes said they do so because the act of writing helps them remember the information. For example, two of the participants said:

> Because for the most part I usually like to write notes down in my own handwriting because I feel if I am typing it on the computer [that] it is not going to help me remember it, but when I am writing I am reading along with it (survey, participant #111)
>
> Handwritten notes help me to memorize information and allow me more freedom in how I want to structure my note sheets. It's also convenient when I want to doodle. (survey, participant #135)

These participants are describing an encoding function of note-taking, which came up during Theme 1, and it leads students to use a consistent method across all courses. To expand on the comment made by survey participant #135 (above), this participant mentioned how hand-writing helps them remember, but also indicated that organization is important to him. The other participants who mentioned that taking notes the same way in every course helps with organization included one interviewee who keeps all notes for all courses in one large notebook to ensure no information is lost (including printing information and adding it into the notebook). Another interviewee organizes all notes by underlining the title, writing information under the title, and underlining/highlighting important information in all courses. Overall, survey participants' responses indicated that organization and consistency across all course notes is helpful for studying. More examples supporting this claim are:

> It makes it easier for me to follow across the board. I do not want to confuse myself with different techniques because the way I do it works and I do not want to change it. (survey, participant #165)

> I like to keep all of my notes in the same format because it helps me to stay organized and maintain a proper way to study them. (survey, participant #168)

Again, these comments support the claim regarding consistency. Consistency prevents these participants from getting confused while studying and makes it easier to locate information, which could indicate there may be a cognitive load issue when they try to use different methods. Beyond this, the remaining reasons in Table 13 were from only the survey participants because of the small number of interview participant responses. One of the survey participants who mentioned learning had the following to say:

> I learn best through hand writing my notes. I take notes like this in all my classes to help myself learn the information. (survey, participant #107)

This awareness of how note-taking may impact their ability to learn information is a strong skill that shows purposeful decision-making on the part of the learner, and also supports the claim regarding consistency.

Those who do not take notes the same way in every course. There were 7 interview (41.2%) and 63 survey (50.0%) participants who do not take notes the same way in every course. All results from these participants are displayed in Table 14.

Table 14
Use of Different Note-Taking Methods Across Courses

	Interview		Survey	
Reason	N=6	%	N=63	%
Depends on nature of content	5	83.3	18	28.6
Depends if notes are provided	1	16.7	20	31.7
Writes more in chemistry	-	-	10	15.9
Writes less in chemistry	-	-	9	14.3
Does not take notes in some courses	-	-	3	4.8

Note. Percentages add to over 100% because participants could select more than one method.

All seven interviewees who use different methods across courses gave an explanation, but one of the participant's difference was that colored pens cannot be used in chemistry because the classroom and desks are too small to have that many pens out. While this is worthwhile to consider for other reasons, it is not relevant to the research questions and therefore was not included in Table 14.

The two most common reasons displayed in Table 14 for changing note-taking methods from course to course are based on the course content and the nature of the materials provided in the course. One example of how the nature of the course content impacts students' note-taking choices is:

> For biology or psychology, it's mostly just concepts and ideas to remember and I just write those down. With chemistry, it's a little different with the figures and calculations. (interview, participant #76)

These types of comments indicated that participants write different types of information or different amounts of information, depending on the nature of the course content. There were also comments about how the course content determines if participants are able to type their notes or not. For example, participants said:

> I type my notes for my psychology and criminology classes (classes that don't involve a lot of math, equations, charts, pictures, etc.) on my computer. I take notes in my math class the same way I do in chemistry, in my notebook. (survey, participant #151).
>
> Chem 110 has a lot of diagrams and things that can't be typed so I must hand write Chem 110 notes. I usually type notes for my other classes because they don't have as many diagrams. (survey, participant #105)

These comments refer to how the nature of chemistry leads them to choose a different way to take notes. Some other survey participants also said they hand write in courses like math or physics, in addition to chemistry, because of the abundance of equations and diagrams.

Another common reason (See Table 14) for taking notes differently across courses was that different professors provide different note-taking supports. In this chemistry course, the professor posts annotated PowerPoint slides after class each day. However, some participants mentioned other professors who post notes before class or provided note packets. The participants described changes they make according to what materials are provided in their different courses, which sometimes includes writing more or less in chemistry than in other courses. One participant who described this in detail said:

> In Chem 110, I try to focus on how he problem solves and learning the method more than just note taking. In my other classes, I try to get down as much info as possible because the slides either are not posted after class or do not have the annotations when they are for my other classes. (survey, participant #90)

This participant is an example of someone who takes fewer notes in chemistry based on the nature of the course materials. However, the 10 participants who take more notes in chemistry (Table 14) said they do so because chemistry is harder, more material is covered, and/or they need more examples/notes in chemistry. All of these responses, regardless of how much they write in their notes, indicate that students are making decisions about their note-taking based on the way courses are designed, the content being covered, and materials provided.

Summary & Disconfirming Evidence.

Those who take notes the same way in every course. Opposite to the evidence supporting the claim about consistency were the participants who said they do not know any

other method through which to take notes. It is possible that those who do not know another method may have less of an awareness of how and if note-taking is linked to effective learning. Therefore, the consistency is not necessarily linked to learning or decision-making, and is instead the students only option through which to manage their notes.

In addition, the most common reason provided by a large majority of survey participants who take notes the same way in every course was that they like their method and/or they think their method works best for them (See Table 13). This was not commonly addressed in the interviews and there is no evidence as to why. Survey participants who mentioned this said their method is a habit or they have always done it that way, and made comments such as:

> [That's] the way that works best for me so I stick with it (survey, participant #150)
>
> Why change something that works for me (survey, participant #101)
>
> I take notes the same way in all of my classes because it is how I best learn. It is habitual. (survey, participant #157)

While it is possible that these participants indeed have an effective note-taking method, it is also possible that they are like those who do not know any other method. This could be impacting their learning in a negative way, but there is no definitive way to draw a conclusion on this and therefore this information does not support the claim regarding consistency.

Those who do not take notes the same way in every course. Those who change their note-taking methods for different courses did not provide much disconfirming evidence, other than those participants who simply do not take notes in some of their courses. However, the claim is that students choose their note-taking methods based on course content or materials provided, so it is possible that these participants are actively not taking notes because the course materials are sufficient or they understand the course material. No definitive conclusion can be

drawn, but the majority of the data supports the claim that students who change their note-taking methods for different courses do so because of the content or the materials provided.

Theme 8: Use of Representations in Note-Taking

Purpose & Claim. As discussed earlier, it is possible that students take notes differently in their courses depending on the nature of the course content. Chemistry is almost like learning a new language for many students because of the immense number of new symbols, equations, and chemical representations students are exposed to. Therefore, a better understanding of how these multiple representations are used in students' notes is needed.

Overall, the claim here is that participants recognize the importance of non-verbal representations, but only use them in their notes when time permits or when the representations are not too complex. Both the survey and interview participants indicated that they attempt to draw representations, but they often feel rushed or think their drawings will not be accurate enough. Those who choose not to draw non-verbal representations made comments about how they will make a note to look back at the professor's notes, look in the eBook, or take pictures of the representations. These students are not ignoring the importance of the representations, but often feel too rushed to write and interpret representations in class. Overall, this claim supports the idea that students make purposeful decisions while note-taking.

Evidence. During the interviews, all 17 participants were asked about how they incorporate representations into their notes in chemistry and if they pay attention to representations while studying. This question was not asked in an explicit yes/no format, but the results can be found in Table 15. To follow-up on the interviews, the survey also asked if participants include diagrams or graphs in their notes. 'Yes' was selected by 56.5% of survey participants (n=70) and 43.5% selected 'No' (n=54). These results can also be found in Table 15.

Table 15
Use of Representations in Notes

	Interview		Survey	
Use	N=17	%	N=124	%
When quick/easy to draw	8	47.1	55	44.4
Revisits in eBook or PowerPoints	10	58.8	11	8.9
Saves on computer or uses tablet	1	5.9	2	1.6
Recreates them after class	1	5.9	5	4.0
Takes photo with cellphone	-	-	24	19.4
eBook or PowerPoint are more accurate	3	17.6	3	2.4
Organization of info	5	29.4	-	-
Does not include- Uses eBook or PowerPoint	-	-	27	21.8
Does not include- Not all the same	-	-	4	3.2
Summarizes them in words	-	-	5	4.0
Prints them	-	-	3	2.4
Not important- will not be on exam	-	-	3	2.4

Note. Percentages add to over 100% because participants could select more than one method.

Yes, includes non-verbal representations. Participants who record non-verbal representations only when they are quick/easy to draw mentioned the complexity of the representations as a reason why it can be difficult to accurately record representations during the restricted time given in class. These participants attempt to hand draw at least some of the figures and diagrams, and they shared these comments:

> The easy [diagrams] I draw myself and label. The harder ones I go back and look at them. If the graph represents a concept I write the concept down and don't draw the graph (survey, participant #200)

> If [it's] complicated I'll mark it to come back and draw or paste it in later. I prefer to draw if possible though because I feel it increases my understanding (survey, participant #80)

> I usually draw the diagrams if they are quick and easy ones to draw. If not I will check the lecture slides when they are posted and reference them from there (survey, participant #105)
>
> If it's an image, I know probably I won't have time to draw it or something like that, so I'll probably just write down the main points (interview, participant #68)
>
> Whenever I can (e.g. whenever there is enough time to copy down a graph/diagram in my notes) I try to draw the graphs/diagrams presented in the lecture slides. If I realize that there is not enough time to draw the graph/diagram, I make a note of what slide it is on for reference later (survey, participant # 118)

These participants recognize the importance of representations in chemistry, and strive to include them in their notes, but are not always able to include them. This is a purposeful decision on the part of the learner.

To follow-up on this idea, those who go back to representations in the eBook or in the professor's PowerPoint slides after class said they do so when time is tight (e.g. see survey participant #200 above). Many of them make a note of where to reference the representation later instead of drawing it while note-taking in class. Again, this supports the idea that students recognize the importance of representations, but struggle to incorporate them into their notes in class. Therefore, these participants make a purposeful decision about how to overcome this obstacle.

As Table 15 displays, a few participants either recreate images after class or save the representations onto their computer or tablet after class. One interview participant (participant #72) saves the images from the eBook onto their personal computer after class, while participant #74 tries to get the representations down in class, but recreates representations on their computer

after class because the representations look nicer. Another way in which technology is used by participants to keep track of representations are the participants who take photos with their cellphones. Many of participants who mentioned technology, though, said they prefer to hand draw the representations. They use technology (especially photos) when diagrams are too complex or they do not have time to draw. Participants who use their phone to take pictures of representations made comments such as:

> I draw it by hand if the graph is not challenging to draw. I take a picture of it if the graph is detailed (survey, participant #157)
>
> Hand draw [and/or] take a picture if I [cannot] draw it in time or if it is too complex to draw in my notes (survey, participant #137)

These participants are consistent with those who make a note to revisit representations in their notes. That is, they seem to understand the importance of non-verbal representations, but they struggle to incorporate them into their notes during the time-constraints of class. However, they are actively making a decision to revisit the representations at a later time.

No, does not include non-verbal representations. Those who do not include non-verbal representations in their notes are not all unaware of the importance of these representations. For example, those who choose to just look in the instructor's notes or the eBook for representations do so because those representations are more accurate than their personal drawings, or generally believe their personal drawings are inaccurate. For example:

> I knew I wouldn't be able to draw them as well as it was on the computer, so [I] just went back to the eBook (interview, participant #64)
>
> They are not easy to draw free hand and if wrongly interpreted can lead to confusion while learning concepts (survey, participant #119)

These participants recognize the importance of representations, but struggle to include representations in their notes because of complexity. This directly supports the claim that representations are difficult for students to include in their notes because of time and/or complexity.

Another common reason among those who never draw non-verbal representations in their notes was because representations are available in the instructor's notes or in the eBook. Participants can look up the representations anytime, so there is no need to write them in class. Some of these participants also mentioned time and/or complexity as a reason for not recording representations in class. For example, one of these participants wrote:

> It is hard to draw and take a lot of time and I don't want to miss my professor explaining it or working through the problem. I usually look at it later online (survey, participant #89)

These participants are similar to those who mentioned that their drawings are inaccurate because they realize they can look at the representations any time. However, the difference is that these participants never consider drawing because they feel as though it would be a waste of time since the representations are available in other course materials. This is a purposeful decision on the part of these learners. One example of this is:

> Drawing the diagrams is simply too time consuming. If I copied down every diagram, I would fall behind (survey, participant #130)

It is hard to tell if these participants recognize the importance of representations, even though they know they can go back to references the representations later. However, some participants who exclude representations are not doing so because they do not see the importance. Instead, there were some participants (see Table 15) who said they do not include

them because they are too specific and that students need to be able to see the representations in a more general way. For example:

> They usually are specific to a certain situation so I [don't] feel the need to copy that exact information, but if they apply to a more general concept such as a general phase change diagram/graph then I might copy it (survey, participant #167)
>
> They are a waste of time and space. Graphs are not all going to be the same. There will be deviations. You need to understand the important characteristics and features for the graphs/diagrams and data (survey, participant #82)

These participants do recognize the importance of being able to interpret the representations, and it is possible that they have more representational competence than their classmates because they see the 'bigger picture.' They are making a purposeful decision not to include the representations, but this does not mean they do not think they are important.

Summary & Disconfirming Evidence. Organization was mentioned by a few of the interview participants who do not draw representations. These participants discussed how charts and tables can often help organize information while studying. For example, participant #62 learned the geometries of molecules from a chart that organized the angles and shapes and participant #74 recreated images on the computer because the information is overwhelming if it is not organized into a table. This idea was not found in survey responses, and does not directly support the claim that participants struggle to include representations due to time or complexity. However, it does indicate that the participants appreciate how non-verbal representations can help them learn.

In addition to this, and beyond the data in Table 15, not all participants seem to be comfortable with representations. There were 2 interview participants only draw representations

when the professor draws or adds to one. Also, 2 interview participants think representations are confusing. Both of these ideas indicate that there are students who have trouble deciding on their own what information is important and may not have strong representational competence. For example, those who find representations confusing said:

> There are some diagrams where there are abbreviations for everything, and I'm not sure what the abbreviations mean, so I have to go online and look them up (interview, participant #73)
>
> I don't always understand the language used in the diagrams (interview, participant #71)

Participant #71 went on to say that the material is new, and the diagrams are using the new material, and therefore it is difficult to piece it all together without help. Therefore, there may be students who struggle with representations in general and it may be unfair to categorize them in regards to how they use representations in their notes. Finally, there was one survey participant who made a forward statement regarding representations when he described that he does not believe representations are important. He said:

> A lot of the times (in my opinion) graphs and diagrams are just fluff, and the most important material to take notes on is elsewhere on the slide (survey, participant #198)

This participant may not see how representations align with course assignments, or perhaps he struggles with representational competence in general. No definite conclusions can be drawn about why he thinks the other information in the course is more important, though. However, the majority of the data presented here does support the claim that students struggle to incorporate non-verbal representations into their notes, and that they often must go through a decision-making process when faced with these representations.

Use of Representations Follow-Up Questions. The final data presented here does not follow with the thematic portion of the data presented about representations, but does inform the research questions. There was a desire after the interview process to continue to understand the use of representations in note-taking, so three additional survey questions were implemented. First, a better understanding of how important representations are to students was desired because it was unclear by their fears of time and complexity when taking notes. Therefore, survey participants were asked about this on a Likert scale. The second question was used to gain a better understanding of which representations students tend to focus on when studying for exams, since the interview responses were not clear. Finally, the last question asked students about how confident they would be in interpreting a graph they had never seen before. This question was designed to get at the idea of representational competence.

When asked how important students feel it is to study graphs and diagrams in their chemistry class, and 125 survey participants responded. Almost 75% of participants indicated that it is very or moderately important (n=93). The breakdown of participant responses can be found in Figure 2. When participants' responses were converted to a 1 to 5 scale, where 'Not important at all' is 1 and 'Extremely important' is 5, the average was a 3.6, which is between very and moderately important.

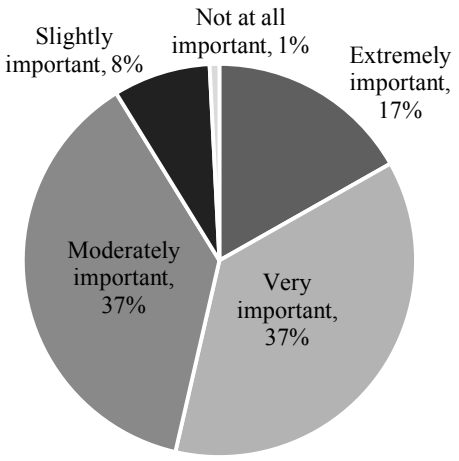

Figure 2. How important participants believe it is to study graphs and diagrams in chemistry

The results for the second question, regarding the representations students study for exams, can be found in Table 16. Of the participants who only chose one option (n=9), 6 selected

'Those on the instructor's slides.' Similarly, 'Those on the instructor's slides' was chosen by 20 of the 27 who selected 2 options, 36 of the 41 who selected 3 options, and 21 of the 24 who selected 4 options. 'Those used in practice exam questions' was a common choice for those who selected 3 or 4 options (37 and 22 participants, respectively).

Table 16
Graphs and Diagrams Studied for Exams

Representation	N=125	%
Those on the instructor's slides	105	84.0
Those that are in your notes	68	54.4
Those presented in the eBook	57	45.6
Those used in practice exams	93	74.4
Those used in the homework	69	55.2
None	2	1.6

Note. Percentages add to over 100% because participants could select more than one method.

The final question regarding representations was asked in both the interviews and the survey. This question asked participants how confident they would be in interpreting a graph on an exam that they had never seen before. This was inspired by focus group comments indicating that some students seem to struggle more with graph interpretation than others, and was not added until after the first interview. There were 11 of 16 interview participants who are confident (68.8%), 3 who could 'probably' do it (18.8%), and 2 who are not confident (12.5%). Of the 11 confident participants, 5 did not expand on their thoughts, but the other 6 said graphs represent relationships, and if you know the relationship, it is not hard to interpret graphs. For example:

> It's not too hard to interpret a graph. I think that just depends if you're good at seeing patterns or trends (interview, participant #68)

This indicates that these students understand what graphs represent. Of the 3 participants who said they 'probably' could interpret a graph, 2 of them said the 'basic roots' or 'important characteristics' could potentially help them determine what the graph means. These participants, therefore, also indicated some understanding of what a graph represents. On the other hand, 1 of the 2 participants who said they are not confident said this issue came up before and the only way to figure it out was to ask a friend. The second participant usually draw out graphs and memorizes how to interpret them, so a new graph would be intimidating.

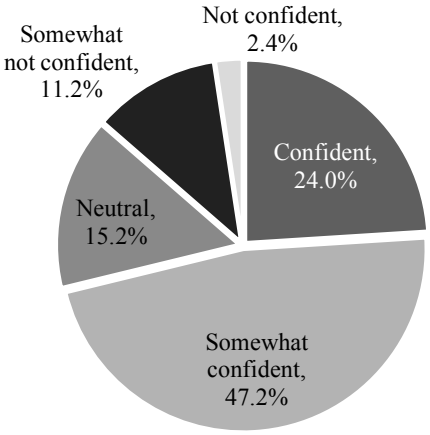

Figure 3. Participants' confidence in interpreting a graph they had never seen before

Survey responses to this question included 1 participant who did not respond, and over 70% of participants (n=89) who are confident or somewhat confident they could interpret a graph they had never seen before. Converting responses to a 1 to 5 scale, where 'Not confident' is a 1 and 'Confident' is 5, yielded an average of 3.8, which indicates the average participant is somewhat confident. All results can be found in Figure 3.

Chapter 4

Discussion

Summary of Findings

The goal of this study was to gain a better understanding of the way in which students take notes in their chemistry course. The questions asked throughout all phases of the study were designed to target how students take notes and decide what to record, if/how they change their note-taking based on the course material, and how they utilize notes. In addition, there was an interest in understanding how non-verbal representations are incorporated into students' notes and if the nature of course material impacts the use of non-verbal representations. A series of claims, grounded in the data, were presented and the key finding linking most claims is that students make purposeful decisions concerning their note-taking.

Self-Regulation Framework

The decision-making that is evident on the part of the learners throughout this study indicate self-regulatory processes. There are several well-developed models of self-regulation, each using varying theoretical backgrounds, but the model used to frame the data from this study is Zimmerman's social cognitive model of self-regulation (Zimmerman, 1989; Puustinen & Pulkkinen, 2001). Zimmerman states that to be self-regulated, 'students' learning must involve the use of specified strategies to achieve academic goals on the basis of self-efficacy perception' (Zimmerman, 1989). To this end, the students in this study are doing this when they are making purposeful decisions about note-taking strategies to both learn the material and perform well in the course.

Zimmerman's model provides a framework throughout which we can better understand the decision-making processes undergraduate chemistry students go through. Zimmerman's

framework is based in Bandura's triadic reciprocity and therefore assumes that self-regulatory processes are based on the learner themselves, the environment, and behavior (Zimmerman, 1989; Bandura, 1986). This triangulation applied to self-regulation means that students choices are not only personal, but are also influenced by their environment and behaviors. In the chemistry course of interest in this study, the environment could include the course materials, the professor, or classmates, just to name a few. The behaviors in this study could refer to choices like students not including non-verbal representations or using different note-taking methods in different courses.

Zimmerman points out that self-regulation is not a fixed characteristic of a student. Instead, students' self-regulatory processes depend on context and can vary greatly (Zimmerman 1989, 1995). This is an important point when considering the students in this study because, while they are making purposeful decisions, these decisions may not be consistent across all of their courses and the decisions may not be accurate or lead to high learning outcomes. One example from the data presented of student's self-regulation varying in different contexts is the students who use different note-taking methods across courses (particularly the students who change their note-taking habits based on the nature of the course material). The different uses of verbal versus non-verbal representations students their notes are another great example of how self-regulatory processes can vary.

The social cognitive model of self-regulation is a 3-stage cyclical model that includes a forethought, performance, and self-reflection phase (Zimmerman, 1989; Puustinen & Pulkkinen, 2001). When the participants in this study were making choices based on their goals or were making strategic plans about how to take or use their notes, they were in the forethought phase. Examples of this include the participants who purposefully choose not to use their computers to

take notes because they cannot type fast enough, those who use choose not to take notes in recitation, or those who choose to take notes because it helps them later with class assignments. Next, the performance phase, is evident in the data when students were using attention and task strategies. Examples of this include the participants who do not use their computers because they are too distracting, those who use the act of note-taking to help them remember information (e.g. encoding), or those who take fewer notes so they can listen more closely to the professor. Finally, the self-reflection phase focuses on performance and reflection on the causal attributions of the performance. Examples of this reflection phase in the data presented include the participants who adapted the use of non-verbal representations after they realized they could not write them all, or the participants who compare notes with friends to try to reflect on what they wrote and if there are any mistakes.

It should be noted that these three phases do not have distinct lines and some of the examples of student decision-making could be argued to fit into more than one of the stages of Zimmerman's self-regulation model. Regardless, self-regulation is a reasonable model to use in the future when looking at these note-taking choices because self-regulation is based on students' decisions and the context in which they make those decisions.

Future Work

This study suggests that student make purposeful decisions while taking notes in their chemistry courses. One major way to expand on this would be to directly investigate how the model of self-regulation presented could explain the findings from this study. Other ways to extend the findings in this study would be to fill some of the holes in the data. The disconfirming evidence presented throughout all thematic sections of the results indicated some inconsistencies in the findings. While these inconsistencies did not take away from the claims being presented in

this study, a better understanding of how these pieces fit into students' self-regulatory processes and/or decision-making skills would be useful. Also, many of the data tables presented differences in answers between the individual interviews and the survey responses. Most of these differences could not be explained, and therefore should be clarified in future studies. One way in which this could be accomplished would be through a refinement and redistribution of the survey.

In addition, the students recruited in this study were all part of the same section of general chemistry. While this sample was useful for the exploratory nature of this study because it provided some consistencies between participants, it is not generalizable to the large population of college students who struggle every year in introductory general chemistry. A future study exploring a more representative sample of college chemistry students would be useful. Other factors, such as final course grades, motivation, or chemistry background knowledge, could also be considered when studying students' note-taking preferences.

Conclusion

As this study demonstrates, the students in this chemistry course are not inherently lazy or haphazardly studying. The students are attempting to make good choices that they believe will lead them to better learning and higher performance in the course. However, despite their efforts, many of these students fall short of their goals. One noteworthy comment, made by interview participant #67, perfectly illustrates some of the frustrations these students feel:

> I feel like you are always trying to get the grade. Like you are trying to learn, but you are trying to get the grade you need. I am learning what I need to get the grade on the test. I know that will transfer to something, but I don't know what that is now, but I think I will know eventually (interview, participant #67)

As this participant is eluding to, the students are often overwhelmed in courses like this. Chemistry is a difficult course for many students, so understanding more about how self-regulation and decision-making influence student performance in all general chemistry students may be prudent for improving performance in these courses.

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Appendix A: Demographic Questions

The following demographic information was collected on paper during all focus groups and individual interviews:

1) Current semester standing:
    - 1st – 2nd semester
    - 3rd – 4th semester
    - 5th – 6th semester
    - 7th – 8th semester
    - 9th – higher semester
2) Major
3) Ethnicity:
    - Caucasian
    - African-American
    - Asian
    - Hispanic
    - Other
4) Gender:
    - Male
    - Female
    - Other
5) Current GPA (if applicable)
6) Verbal SAT score
7) Mathematics SAT score

8) Currently enrolled in CHEM 108? (Yes/No)
9) Participants were asked to initial to give permission for the research team to obtain their final grade in their chemistry class.

The following modifications were made to the demographic questions listed above before the survey was distributed on Qualtrics:

1) Ethnicity was set to be "multiple select" for the online survey. It was unclear during the focus groups and individual interviews that participants could select more than one ethnicity.
2) Participants were not asked about their verbal or mathematics SAT score because there was a low response rate for those questions during focus groups and individual interviews. This indicated that participants may not remember their SAT scores and a self-report of SATs score may not be reliable.

Appendix B: Focus Group Questions

The following questions were asked during focus group #1. Some questions came up naturally throughout the course of the focus group and therefore were not directly asked by the interviewer.

1) How do you take notes in CHEM 110? Why do you choose to take notes that way?
2) When do you take notes for CHEM 110? [lecture, at home, with the book, etc.]
    a. Do you take notes before class with the eBook?
    b. Do you add to your notes while doing homework? If so, do you add problems or concepts to your notes?
3) Do you use your CHEM 110 notes outside of lecture? If so, how?
    a. Do you look at your notes after class?
    b. How often do you look back at your notes?
    c. Do you use your personal notes when studying for exams?
4) What type of content do you include in your chemistry notes? How do you decide what to include?
5) Do you include examples in your chemistry notes?
    a. Do you use the example problems in your eBook? Do you add them to your notes?
6) Do you include information about real-world examples or chemistry demos in your notes?
7) Do you ever use your phone or computer when you take notes in CHEM 110?
8) What do you think the difference is between good notes and bad notes?
9) Has anyone ever taught you how to take notes?

   a. If not, do you wish you had been taught?

10) Have your note-taking habits changed since the beginning of CHEM 110?

11) Do you use the same note-taking methods in all of your courses? Why or why not?

12) Do you ever use your professor's CHEM 110 notes that are posted online? How do you use them?

13) Do you ever compare notes with classmates or friends?

   a. If not, do you think it would be helpful?

14) Do you go to office hours for help with your notes?

15) Do you pay attention to all of the graphs, tables, diagrams, etc. that your instructor presents in CHEM 110? Do you write any of this information in your notes?

   a. What about those presented in the eBook?

   b. How do you decide which graphs, diagrams, etc. to pay attention to? Do you only look at those presented by the instructor, or do you look in the eBook or at other resources?

   c. How do you decide which representations are important?

16) There are researchers who study how students use different representations (such as graphs, equations, diagrams, etc.) in their learning, and many of them believe that knowing how to use these representations is useful when it comes to learning. Do you think this is true for CHEM 110? Why or why not?

   a. Would it be helpful if the instructor explicitly explained the connections between different representations during class?

   b. Has anyone ever pointed out to you how important this skill is?

17) Does technology help your use of different representations?

18) If there was a graph on an exam you had never seen before, but it was related to the content being covered on the exam, how confident would you be that you could interpret it?
19) What learning goals do you have for your chemistry class? What do your study and note-taking habits have to be like in order to achieve your goals?

The following adjustments were made throughout the focus groups and before the start of the individual interviews:

1) Expanded on the difference between conceptual and procedural knowledge before asking students about which they include in their notes.
2) The following questions were added:
    a. Sometimes your instructor uses "real-world" examples in class. Do you write that information down? Why or why not?
    b. What do you do when you do not know how to do a problem?
    c. What kind of information do you need to know for the exams? Where do you get this information? If not from the notes, why do you take notes?
    d. Do you draw graphs in your notes?
    e. If you draw at all, why do you draw? Do you ever look back at it, or do you write it because you think it's important?
    f. When asking about how researchers think using representations is important: Do you think you need this skill on the exams? Why or why not?

Appendix C: Interview Questions

The following questions were asked during the interviews. Some questions came up naturally throughout the course of the interview and therefore were not directly asked by the interviewer.

1) How do you take notes in CHEM 110? Why?
    a. Follow-up: what helps you take good notes in CHEM 110?
2) When do you take notes for CHEM 110? [lecture, at home, with the book, etc.]
    a. Follow-up: do you use your CHEM 110 notes outside of lecture? If so, how?
3) What type of content do you include in your notes? How do you decide what to include?
    a. Follow-up: do you take notes on more concepts (the underlying principles) or procedures (recopies for solving problems)?
    b. Follow-up: Do you include examples in your notes?
    c. Follow-up: What about information from the chemistry demos?
4) Sometimes your instructor uses "real-world" examples in class. Do you write that information down? Why or why not?
5) What do you do when you do not know how to do a problem?
6) What kind of information do you need to know for the exams? Where do you get this information? If not from the notes, why do you take notes?
7) What do you think the difference is between good notes and bad notes?
8) You have told me _____ about the way you learn in CHEM 110. What are the learning goals you have for this class? How do you think your choices in studying and note-taking help you achieve your goals?
9) Has anyone ever taught you how to take notes? Did you learn how to take notes in high school?

10) Have your note-taking habits changed since high school? Have your note-taking habits changed at all since you have started CHEM 110 this semester?
11) Do you use the same note-taking methods in all of your courses? Why or why not?
12) Do you ever use your phone or computer when you take notes in CHEM 110?
13) Do you ever use your professor's CHEM 110 notes? How do you use them?
14) Do you ever compare notes with classmates or friends?

MER Specific Questions:

15) Do you pay attention to all of the graphs, tables, diagrams, etc. that your instructor presents in CHEM 110? What about those presented in the eBook? Do you write any of this information in your notes?
    a. Follow-up: How do you decide which ones to pay attention to? Are there certain ones you always write or always ignore?
    b. Have you ever considered this to be important before?
16) Do you draw graphs in your notes?
17) If you draw at all, why do you draw? Do you ever look back at it, or do you write it because you think it's important?
18) There are researchers who study how students use different representations (such as graphs, equations, diagrams, etc.) in their learning, and many of them believe that knowing how to use these representations is useful when it comes to learning. Do you think this is true? Why or why not?
    a. Follow-up: Do you think it is a useful skill to have in CHEM 110? Why or why not?
    b. Do you think you need this skill on the exams? Why or why not?

19) You mentioned you [did/did not] use your [phone/computer] when taking notes. Does technology [help/hinder] your use of different representations? [Does technology make it easier/harder to keep track of representations?]
20) You mentioned you [did/did not] use the instructor's PowerPoint slides. Do the PowerPoint slides [help/hinder] your ability to keep track of the different representations?
21) During CHEM 110 exams, you are often asked to interpret graphs. If there was a graph on one of your CHEM 110 exams that you had never seen before, how confident would you feel about interpreting the graph? (Note: you can assume the graph is related to the content on the exam)

Appendix D: Survey Questions

The following questions were distributed as a survey on Qualtrics:

1) How do you take notes in CHEM 110? Check all that apply:
    - o By hand on blank paper
    - o By hand on printed PowerPoint slides
    - o Typed on my computer
    - o Typed on provided PowerPoint slide
    - o On my tablet
    - o On my phone
    - o I do not take notes
    - o Other _____
2) Based on your response above, please briefly explain why you choose to use that method(s) of note-taking in CHEM 110.

    [OPEN ENDED]
3) When do you take notes for CHEM 110? Check all that apply:
    - o During lecture
    - o Before lecture (e.g. using the eBook)
    - o After lecture (e.g. using the eBook and/or the PowerPoint slides)
    - o During recitation
    - o Other _____
4) Do you think taking notes in CHEM 110 lecture is the best way to spend lecture time?
    - o Definitely yes
    - o Probably yes

- Might or might not
- Probably not
- Definitely not

5) How do you decide what to record in your CHEM 110 notes?

   [OPEN ENDED]

6) How often do you use/study your CHEM 110 notes outside of class?

   - 1-2 days per week
   - 3-5 days per week
   - 6-7 days per week
   - Never
   - A few times per semester (if possible, please indicate when) _____

7) For what purpose(s) do you use your CHEM 110 notes? Check all that apply:

   - Completing homework
   - Completing quizzes
   - Studying for exams
   - Completing recitation worksheets
   - During outside help (tutoring/office hours/CHEM 108)
   - Other _____

8) Does your CHEM 110 professor post PowerPoint slides and/or notes?

   - Yes (if so, when do they post them?) _____
   - No

   IF "YES" was selected for question 8, the following questions were displayed:

   8a) How often do you use/study your professor's CHEM 110 notes outside of class?

(e.g. PowerPoint slides)

- 1-2 days per week
- 3-5 days per week
- 6-7 days per week
- Never
- A few times per semester (if possible, please indicate when) _____

8b) For what purpose(s) do you use your professor's CHEM 110 notes? (e.g. PowerPoint slides). Check all that apply:

- Completing homework
- Completing quizzes
- Studying for exams
- Completing recitation worksheets
- During outside help (tutoring/office hours/CHEM 108)
- Other _____

9) Have your note-taking habits in CHEM 110 changed since the beginning of the semester?

- Yes
- No

IF "YES" was selected for question 9, the following question was displayed:

9a) How have your note-taking habits in CHEM 110 changed since the beginning of the semester?

[OPEN ENDED]

10) Do you compare your CHEM 110 notes with classmates and/or friends?

- Yes

- No

IF "YES" was selected for question 10, the following question was displayed:

10a) What are your reasons for comparing your CHEM 110 notes with classmates and/or friends?

[OPEN ENDED]

11) Do you take notes the same way in all of your courses?

- Yes
- No

IF "YES" was selected for question 11, the following question was displayed:

11a) What are your reasons for taking notes the same way in all of your courses?

[OPEN ENDED]

IF "NO" was selected for question 11, the following question was displayed:

11b) What is different about the way you take notes in CHEM 110 compared to your other courses?

[OPEN ENDED]

12) What do you think the difference is between good notes and bad notes?

[OPEN ENDED]

13) Based on your response to the question above, please describe your own notes. Do you think you take "good notes" or "bad notes", and why do you feel that way?

[OPEN ENDED]

14) When a graph or diagram is presented during CHEM 110 lecture, do you put it in your notes?

- Yes

- No

IF "YES" was selected for question 14, the following question was displayed:

14a) In a class like CHEM 110, it can be hard to include graphs and diagrams in your notes. How do you go about including graphs and diagrams in your notes? (e.g. hand draw, take a picture of it, print it out, copy and paste, etc.)

[OPEN ENDED]

IF "NO" was selected for question 14, the following question was displayed:

14b) What are your reasons for choosing to exclude graphs and diagrams from your notes?

[OPEN ENDED]

15) How important do you feel it is to study graphs and diagrams in CHEM 110?

- Extremely important
- Very important
- Moderately important
- Slightly important
- Not at all important

16) What graphs and diagrams, if any, do you study for CHEM 110 exams? Check all that apply:

- Those on the instructor's slides
- Those that are in your notes
- Those presented in the eBook
- Those used in the practice exam questions
- Those used in the homework questions

- None

17) During CHEM 110 exams, you are often asked to interpret graphs. If there was a graph on one of your CHEM 110 exams that you had never seen before, how confident would you feel about interpreting the graph? (Note: you can assume the graph is related to the content on the exam)
    - Confident
    - Somewhat Confident
    - Neutral
    - Somewhat not confident
    - Not Confident
18) What is your main reason for taking notes in CHEM 110?

    [OPEN ENDED]
19) Choose the response that best describes your experiences thus far in CHEM 110:[3]

	Always	Most of the time	Sometimes	Once in a while	Never
How often are you able to analyze the results of the problems you solve in CHEM 110? (e.g. can you tell if your answer makes sense)	❍	❍	❍	❍	❍
When solving problems on your own in CHEM 110, how often do you feel you are able to connect the nanoscopic properties of atoms/molecules to their macroscopic function(s)?	❍	❍	❍	❍	❍
How often do you feel the problems you solve in CHEM 110 relate to technical problems facing society?	❍	❍	❍	❍	❍

[3] Question 19 was not used in the evaluation of the survey responses.