

# Expanding Inclusivity with Learner-Generated Study Aids in Three Different Science Courses

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**ABSTRACT:** Note taking is a seemingly simple study strategy, yet as a source of learner-generated content its perceived effectiveness varies across subjects and from student to student, as not all students are able to create high-quality notes without guidance. While often advocated by the instructors, the use of notes as exam aids (whether used in open-books exams or not) is a pedagogical practice that has invited some controversy, but there are studies that justify the use of student-created reminder sheets by acknowledging that students must review the material in order to organize and create their study aids. Preparing for exams by actively developing formula sheets or other study aids assists students in studying, even if they are not consciously aware they are studying. We would like to suggest that modeling the process of creating successful study aids from class notes is an inclusive practice that leads to improved outcomes in low-performing students and increases their agency. Creating scaffolds for note taking, whether through sharing examples or prompting synthesis of information, allows for higher-quality note taking across all learners. We provide examples from three separate courses in which the instructors took this approach in widely different ways, and we offer a set of best practices for other instructors interested in using these resources in their own courses.

**KEYWORDS:** *Second-Year Undergraduate, Organic Chemistry, Internet/Web-Based Learning, Multimedia-Based Learning, Computer-Based Learning*

## INTRODUCTION

One of the unique challenges of teaching in higher education is the fact that students come into it from a wide range of backgrounds and different levels of rigor from prior experiences, and more so with learning habits that might help or hinder them in mastering the content of their courses. Students from privileged backgrounds not only have tangible socioeconomic advantages, but also intangible ones, such as better study habits.<sup>1</sup> Even a simple class activity such as taking notes might become problematic, as in most cases it is the high-performing students who will seize the opportunity to turn their class notes into helpful study aids.<sup>2</sup> Duncan (2007) found that when students were able to use notes on their tests, there was a significant difference in the performance of students who chose to use notes as compared to those who did not. He suggests that one factor which may have influenced this outcome is the fact that students that are more successful were more likely to be familiar with good strategies used to prepare notes, which gave them a double advantage on the exam.<sup>3</sup>

There has been much debate over whether the use of student aids on examinations is a suitable pedagogical practice. Lippert (1974) made his point in this *Journal* early on, extolling the virtues of “cheat sheets” as learning aids.<sup>4</sup> Some may argue that the use of worksheets, formula sheets, or textbooks on exams encourages laziness among students. In some studies, the increase in student performance and understanding when students are allowed to use study aids is largely found to be statistically insignificant in comparison to the students that were not given the opportunity to use these tools.<sup>5</sup> In comparison,

Perrin (1997) justifies the use of student-created reminder sheets by acknowledging that students must review the material in order to organize and create their sheets.<sup>6</sup> Hamed (2008) found that students who used a self-prepared worksheet for an exam scored higher than students who were permitted to use their textbooks, supporting the idea that there must be a distinction between provided study aids and learner-generated content.<sup>7</sup> In other words, preparing for exams by actively developing formula sheets or worksheets assists students in studying, even if they are not consciously aware they are studying. Furthermore, the use of student-generated materials also reduces stress and test anxiety.<sup>8</sup>

There is evidence to suggest that teaching students about metacognition empowers them to manage their own learning processes.<sup>9</sup> When students are asked to think about their own study habits, and when they are given a chance to reflect on their attitudes and emotions related to learning, changes can be made that go beyond a particular class or instructor. A challenging class might be a good training ground for students, since most of the students enrolled will require help to master the material and might therefore have an open mind to interventions that modify their study habits. Specific activities designed to increase the

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students' metacognitive abilities in chemistry courses offer a path for students to be intentionally reflective, and to improve their performance in courses that could otherwise hinder their ability to complete their degree programs.<sup>10,11</sup>

This commentary came as a result of the three authors connecting via social media on a conversation about inclusive teaching practices, and realizing that our in-class experiences (both as students and instructors) offer a potentially inclusive, easy to implement, and easy to scale solution to the broad groups of students that struggle with generating study aids for our courses, regardless of their prior preparation or experiences: offering all the students in the class a scaffold to come up with their own study aid for a specific module/exam, as a way to summarize and aggregate what they are learning. While individual results may vary (because of many confounding factors), collectively our experiences in teaching chemistry and biology courses suggest that all students benefit from such an activity regardless of how pretty or even legible their notes are, by connecting the concepts to what they already know and/or integrating newly learned material. Below we will describe our diverse approaches and offer a set of best practices that may facilitate teaching in an inclusive classroom. Because the three of us have been teaching different courses across chemistry and biology, we believe our suggestions may be relevant to other STEM disciplines.

### ■ CASE 1: IN-PERSON INTRODUCTION TO ORGANIC CHEMISTRY COURSE

Course description: CH220 (Introduction to Organic Chemistry at North Carolina State University) is a semester long 3 credit course with two lecture meetings per week (delivered as 1 h 15 min long classes each, over 15 weeks). It is a standalone course that is offered for students in majors that do not require the traditional two-semester organic chemistry sequence. Typical enrollment is approximately 100–150 students per course per semester, all in one single section.

Two in-person sections (Fall 2010 and Spring 2011) of Introduction to Organic Chemistry (CH220) with the same instructor were compared for this case study. The students in both classes completed worksheets using a scaffold provided by the instructor (one worksheet per chapter, an example of which is shown in Figure 1), but only one class (Fall 2010) was permitted to use the worksheets when taking the final exam. The students were informed whether or not they would be allowed to use their worksheets during the final exam at the beginning of the semester. The worksheets were assigned a very small percentage of the overall grade for each semester (1% of final grade). All of the worksheets were scored to assess level of completion by one single grader to ensure consistency across sections. The grader was an undergraduate teaching assistant, trained by the faculty member in charge of the course and using rubrics specific for each worksheet.

Average final exam grades showed no significant difference between the students that were allowed to use the study aid when taking the final exam as compared to the students that did not use the study aid. However, the instructor noticed a small difference when the lower-grade quartile of students were isolated from the rest of the group, suggesting that low-performing students were more likely to complete their study aids when they knew that they could use them for their final exam and as a result saw some modest increases in their final exam grade.

#### Reactions of alkenes

Name: \_\_\_\_\_

Reaction	Mechanism	Example	Notes
Hydrohalogenation			
Hydration			
Halogenation			
Hydrogenation			
Oxidation (Hydroxylation)			
Oxidative cleavage			
Polymerization			

Figure 1. Example of a study aid provided by the instructor for students to complete.

The instructor noticed that even the high-performing students will not put forth their best effort when there is no incentive to do so, with many students choosing not to complete the assignments altogether. However, upon providing students with an incentive to complete the study aids, the effort invested on study aids increases. It is likely that the high-performing students have already developed systems to use for understanding material and preparing for tests, which could explain the lack of participation when they are not provided an incentive to complete the assigned study aid scaffolds. However, the low-performing students also chose not to complete the assigned scaffolds when there was no incentive provided. Thus, these students missed valuable structured review that may have aided understanding. Fortunately, upon providing appropriate incentives, class participation in study aids increases, which leads to a moderate improvement in test scores.

Although traditionally high-performing students may prefer to prepare study aids according to their own system, there may be an additional benefit when the whole class creates a study aid based on the same scaffold. Namely, students who have demonstrated mastery of course concepts may be able to help their peers assemble their own study aids. The template offers a set of key concepts, selected by the instructor, that they consider essential to understanding/mastering the material. While some students may be able to figure out what those are or stumble upon them themselves, by design or by accident, offering a prebuilt template provides a more equitable environment for all the students in the class.

### ■ CASE 2: IN-PERSON GENETICS COURSE

Course description: BSCI 30156 (Elements of Genetics at Kent State University) is a semester long 3 credit course with two

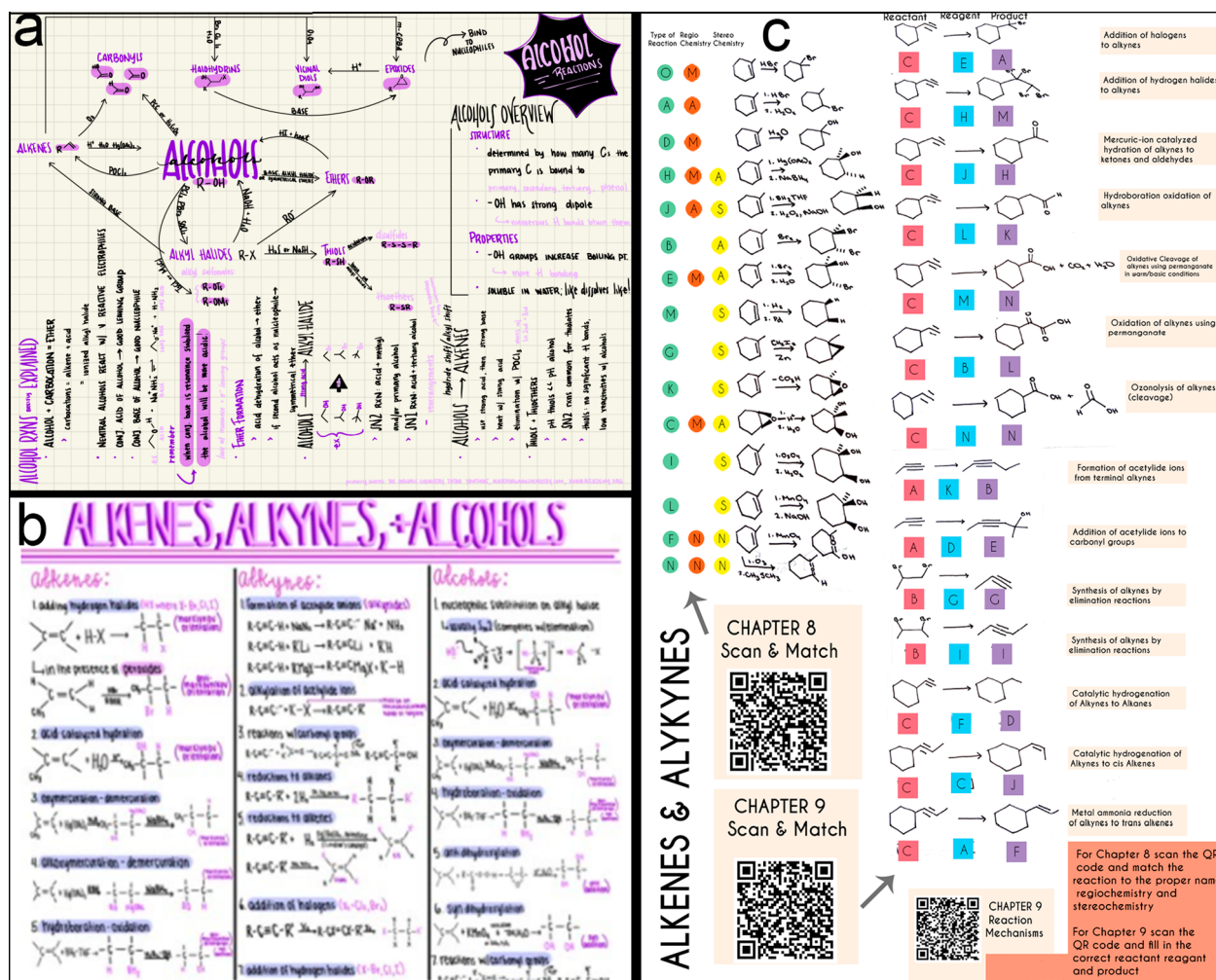


Figure 2. General themes observed in the learner-generated study aids: (a) reaction webs and (b, c) organized columns.

lecture meetings per week (1 h 15 min long, over 15 weeks). It is a required course that sophomores and juniors from various biology majors are required to take for their majors, although the roster often includes a sizable fraction of students who are freshmen and have completed AP credits, as well as seniors. Typical enrollment is approximately 150–200 students per course per semester that may be split between two sections taught by the same or different instructors.

The performance of students in one in-person section (Spring 2015) of Elements of Genetics (BSCI 30156) was examined across different exams, to see whether voluntary preparation of a study aid consisting of one page of (handwritten) notes helped students perform better on the subsequent exam compared to their prior performance in the class. The students were not allowed to use the study aid during the exam; however, those who chose to do the activity received a very small percentage added to their overall grade as a bonus (1% of final grade). The assignment focused on elements of bacterial gene regulation (specifically, lac operon) and required that notes included two sections: (1) to draw a schematic bacterial operon and briefly describe how it is regulated, and (2) to create their own exam question that concerns the regulation of bacterial operon (e.g., given a specific mutation, whether the operon will behave in an inducible or constitutive manner). The study aids were not graded but were evaluated on whether or not they included both required sections. The emphasis was on writing the assignment

in longhand following the study of Mueller and Oppenheimer (2014),<sup>12</sup> although a few students chose to type up their notes to be combined with hand drawings.

The exam performance was compared between those who completed the assignment and those who chose not to do so, while attempting to control for regular class participation. Specifically, ~85% of the class (58 out of 68 total students in the section) had regular lecture attendance (monitored using Turning Point “clickers”). Of these, about 25 students (~37%) opted to complete the assignment, while 43 did not complete it. Comparison of the exam grades showed that the group that completed the activity had significantly improved their exam performance (median 80% versus 72% in those who did not do the activity on that specific exam), although the same groups performed identically on three prior exams. The instructor was also able to compare the performance of two groups on the same topic as the activity, but prior to doing the activity, because the topic was already discussed during prior lectures, with in-class questions asked and answered using clickers. Both groups performed indistinguishably on clicker questions asked in prior classes, both on definitions questions and on problem-solving questions, indicating that the extra activity likely played some role in expanding students’ comprehension of the topic, including for those with the lower scores. In other words, while the benefits of longhand notes may be marginal for the top-performing students, other than for their

own satisfaction, the act of creating learner-generated materials is helpful to students with average or below-average performance. Indeed, it may be the latter group that would benefit from such activities the most, particularly if scaffolded examples are offered earlier in the course, to help students visualize how such notes can be created on a regular basis. Similarly, the act of thinking of exam-like questions based upon freshly learned material would likely further solidify their understanding, moving the needle from the remembering level of Bloom's taxonomy to the analysis and synthesis levels.<sup>13</sup>

### ■ CASE 3: ONLINE ORGANIC CHEMISTRY COURSE

Course description: CHEM 2323 (Introductory Organic Chemistry at the University of Texas at Dallas) is a typically an in-person semester long 3 credit hour course with two lecture meetings per week (1 h 15 min long each, over 15 weeks). Course content focuses on elementary physical organic chemistry and basic reaction methodology. Typical enrollment is approximately 150 students, and it is a required course for multiple majors at the university. The normal format is lecture-based with typically modest student participation. UT Dallas is among the top 10 most ethnically diverse college campuses in the United States.

During the 2020 Fall semester, all in-person activities were suspended, and we entered a fully online teaching modality, requiring online course development. Lectures were prerecorded, and biweekly online discussion sections allowed students to directly interact with the instructor. Given the uniqueness of this event, this case study focuses on this single semester; however, our results are similar to those presented in cases 1 and 2.

Introductory Organic Chemistry, as taught at many institutions, is typically a large, traditional lecture course with a considerable amount of memorizable content. Prior to the third and final exam, students were asked to voluntarily create visual study mnemonics that summarized the reactions learned in the course to be used as study aids. These study aids were not going to be allowed to be used during the exam; the point was to have students actively practice writing the reactions to help organize their thoughts. To get students to think more broadly about how to organize a study aid, the emphasis on the study aid was to create a "work of art". Students that volunteered and submitted a study aid could skip one online quiz (worth ~1% of their grade). These "works of art" were collated into an online art gallery for the entire class to review. If students found the works of art helpful, they could "like" the image. There was no reward for receiving the most "likes"; however, those students were publicly congratulated in the discussion section, and their efforts were distributed to the rest of the class.

The pedagogical aspect of the project remained consistently high; students correctly illustrated reaction conditions for the several substrates taught during the semester. Interestingly, however, their output varied remarkably. Because students had to organize these reactions in ways that made sense *to them*, the diversity in how the study aids were prepared was consistently high among entries. Thematically, many students created "webs" of reactions, or neat and organized columns. Representative examples are presented in Figure 2.

Summarily, the assignment allowed students to create study aids that would help cover all of the reactions taught in the course of the semester. Students were told to bring an artistic element to the assignment, which resulted in a wide diversity of study aid formats that visualized the content in a wide range of

styles. Ultimately, 33 stylistically different study aids were created and made available to all students in the class.

### ■ BEST PRACTICES FOR MODELING AND SCAFFOLDING STUDY AIDS

While studies on effective note taking strategies span at least several decades, ongoing changes to classrooms, from small face-to-face classes to large or online classes, coupled with rapid technological changes, make it challenging to generalize across a broad range of subjects or different educational stages. Here we attempt to offer a few relatively simple strategies that can be easily implemented in STEM college classrooms to allow all learners to master some basic high-quality note taking regardless of their prior preparation, to facilitate more inclusive, and more engaged, classrooms. Some of this advice is aimed at students, and some at instructors.

Advice for students follows:

- Good notes are hard to write, so do not be discouraged when your first attempts are not as detailed or comprehensive as you would like. You will get better with practice.
- Apply the Goldilocks principle of note taking; in other words, your notes should be short, but not too short or too long, to enable inclusion of relevant details, but without spelling all of them out on paper. In the context of many science textbooks, each chapter can be summarized in a page or less of notes. The purpose of this rule is to allow learners to aggregate and synthesize the material, so that it can be internalized.
- If your notes are too long, do not be afraid to revise them, taking out some of the concepts that are already familiar or can be easily deduced from other written concepts.
- Class notes, like toothbrushes, are personal in nature. What may be apparent to some learners may not be apparent to others, and so when borrowing notes from classmates, be prepared to augment them with your own details.

Advice for instructors follows:

- Consider providing students with an easily understood and accessible rationale for why preparing these student-generated study aids may contribute to the better understanding of the material and, hence, better grades. Some of those reasons include using study time more efficiently, taking control of their own learning process, and being able to self-assess their understanding of the class material.
- Consider offering low-stake incentives, such as a small percentage of the total grade, for note taking, whether graded or not, to both nudge the broad participation, and to acknowledge that note taking takes persistent effort.
- If the assessment format of your class allows (such as open-book or take-home exams), encourage use of student-generated notes as exam aids.
- Consider offering guided/scaffolded note templates for information-dense material, to ensure that students do not overlook important concepts (see Figure 1 for example).
- To help with the overall engagement, consider sharing all or best examples as an in-class or online gallery. This could both offer examples to students who are unsure where to start and promote camaraderie in the class, whether face-to-face or virtual.

## ■ IMPLICATIONS

This study has shown, in three different courses, that nondisposable, student-created assignments such as completing study aids provided by the instructor, making summaries, or creating study aids with the purpose of sharing them with the rest of the class may provide a beneficial structure to help traditionally low-performing students better understand course material and achieve higher test scores. Moreover, it was established that providing students with the incentive of using their study aids on tests increases participation. From these results, the use of study aids on tests improved student outcomes, with the effect being most prominent in the lowest-performing subset of students in the class. The use of learner-generated study aids is now an integral part of these three courses, and a detailed study of the ways in which students complete and use their study aids in each case is in progress. For instructors who would like to implement and test these strategies in their own classrooms, one way to ascertain the effect of the study aids for their student population would be to test students' understanding of a few core concepts before and after the intervention, ideally using the answers from the same students. This approach may also offer opportunities to study development of deeper study skills,<sup>14</sup> such as whether the students are able to make connections between prior concepts and current material, inclusion of "big idea" terminology, etc. While the individual outcomes from the note taking may vary between learners or semesters, the overall impact of teaching students how to generate their own synthesis of material across broad subjects is likely to have a ripple effect on their subsequent performance in other classes and will build classrooms that are more inclusive.

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### Notes

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