Students' Persectives on Homework and Problem Sets in STEM Courses

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Introduction

Homework is an integral part of virtually every university-level course, and a critical component of the learning experience for students. It is the main platform from which students are expected to work on their own to navigate the material and internalize the concepts. Homework comes in a variety of forms and can be effective for students in a number of different ways. Successful homework can not only greatly improve a student's understanding, but can also encourage enthusiasm about and comfort with the material of the course. Unsuccessful homework, on the other hand, can quickly discourage students, hindering their ability, interest, and comfort with the material. How a homework assignment is designed, organized, and supported will determine how the student experiences and is influenced by it.

In this paper we explore what attributes form a successful homework experience. The measure of success will be determined by students and how they describe a homework experience that they were satisfied with. This definition is created not by studying how students explicitly define success in homework, but rather implicitly, by studying the attributes of homework that they view as positive and negative learning experiences. Using both quantitative and qualitative data from their answers, we explore how their experiences define what constitutes a successful versus an unsuccessful homework experience, then use these findings to generate suggestions for educators to make their assignments successful.

This study originated from the desire to improve the homework assignments in a sophomore-level Static Mechanics course at Stanford University. We decided that qualities that define successful and unsuccessful homework might be uniquely, understood by looking at students' experience with homework in general in the STEM (Science, Technology, Engineering, and Mathematics) fields, then taking that understanding and adapting it to a single course. We were also interested in obtaining a broader understanding of how students felt about their experience with STEM homework assignments at the university level. Getting a comprehensive understanding of students' perspectives about STEM homework could provide insight into how all members of the STEM community could work to make the experience better, which could lead to deeper learning, stronger connections, and increased excitement in students about their STEM experience.

Literature Review

Homework has been a controversial area of study in education, and for many decades researchers have been debating the most effective ways to implement it and to impact student learning. It is clear that the influence of homework on a student's academic performance is affected by many different variables, both within the student and from the teacher. One notable factor that many studies have shown has a huge influence on the role that homework plays is the student's age. As students get older, homework shows an increasing trend in how much it affects the student's learning. One important study revealed that "the average high school student in a class doing homework would outperform 75% of the students in a no-homework class. In junior high school, the average homework effect was half this magnitude. In elementary school, homework had very little effect on achievement gains," (Cooper, 1998). Although these numbers do not extend past

high school, the trend clearly shows that as we get older and into more advanced curriculum, homework has an increasing effect on our academic performance. A study of higher education engineering faculty claimed that "most educators at the university level agree that homework completion and extensive student effort outside the classroom/lecture hall is critical to successful undergraduate education," (Minami, 2009). We can see that homework has a strong influence on the learning experience, even at the high education level.

The effectiveness of homework is largely influenced by how it is created and what it is composed of; this is where the influence of the teacher comes in. Many studies focus on how to motivate students to engage with their homework assignments, or argue about if homework is effective in general. All homework, however, is not created equal. A large determining factor of the effectiveness of an assignment and the students' willingness to engage with it depend on the quality of the homework itself, which is determined by the teacher. The educator plays a greater role in the homework process than just administering in- they are responsible for crafting it to best meet their students' goals and needs for the course. This means that teachers are responsible for designing their homework, taking into account the many different aspects of homework that will determine how influential the assignments are in helping students succeed. (Epstein, 2001). In this paper we will show how our findings lead to concrete design principles, which are meant to assist educators as they generate homework assignments, in order to create more effective homework assignments.

One influential study that addresses this idea of designing effective homework assignments is *How Learning Works* (Ambrose, 2010). The book outlines 7 "principles of learning" that the authors use to summarize how students learn and what is affecting and directing their learning processes. These principles are accompanied by stories from a teacher's perspective that illustrate what they are describing, along with detailed descriptions as to how these principles manifest themselves, and a list of specific strategies to direct teacher behavior in order to help them maximize student learning.

Many of the data analyzed in this paper lead to a similar type of finding and form of analysis as is presented in *How Learning Works*. Through the analysis, we hope to provide educators with general design principles and suggestions that they can use when generating or revising the homework portion of their courses. This analysis, however, comes not from an educator's point of view, but rather from the students'. Whereas Ambrose used an educator's perspective and learning sciences research, all of the data and quotes in this study come from students directly, and the analysis is done primarily by a student-researcher, so the findings are from a student's perspective as well. Like Ambrose, our findings are summarized into general principles, and then later are expounded upon to give concrete suggestions on how educators can incorporate them. This paper, however, focuses on the homework experience specifically.

Methods

A survey was distributed to students at Stanford University, asking for responses from students who had recently took or were currently taking one or more STEM courses during the Spring of 2013. The survey was distributed via email to potentially applicable students and preformed online through Qualtrics™ , a surveying and data collection service. The survey contained 20

questions, some with multiple parts, and took between 10-15 minutes to complete. Seventy-nine full survey responses were received, and over 20 more mostly completed responses. All responses were taken into account during the analysis of the data. Interviews were also conducted with teaching staff (instructor and teaching assistants) of the statics course for which the homework redesign was specifically targeted. Their experience and advice helped direct some of the findings of this document.

The survey questions were written by the researchers and were generated based on experience with homework in STEM courses, both from a teaching and a student perspective. The survey was composed of five main sections:

1. **General questions** about the student's school, year of study, major, and average number of problem sets assigned per week.
2. **Positive Homework Course.** Questions relating to a homework experience in a STEM course that the student would describe as "positive."
    a. Initial questions asked for the name of the course, and the type(s) of homework utilized in the course. The name of the professor was asked, but was optional.
    b. Then students were asked to rate on a scale from Never, Rarely, Sometimes, Often, to All of the Time, the amount to which they felt the homework was: enjoyable, intellectually stimulating, relevant to the material of the course, relevant to the exam material, relevant to real life situations, relevant to your plans for the future, critical to your learning process of the material, fairly graded, graded and returned in a timely manner (see Figure 1 for layout).
    c. Finally, students were asked to type out what specific strategies the course used that made it a successful experience for the student.
3. **Negative Homework Course.** All of the same questions as above, but relating to a homework experience in a STEM course that the student would describe as "negative."
4. **Homework Grading.** Questions about grading in courses in the STEM fields. Students were asked to choose their ideal grading ratio for STEM courses by distributing the total percentage of their grade (100%) into the following categories as they choose: Homework, Midterm Exam(s), Final, Class Attendance/Participation, Projects/Lab, and Other. Students were allowed to leave categories as 0% if they did not feel that any of their grade should be determined by that category. After, there were two questions asking students if they felt that grades were a good motivation to learn and if receiving grades hurts their educational process more than it helps it.
5. **Homework Completion Strategy.** The final section of questions was related to each student's homework completion process. The questions listed different ways of working (with peers, attending office hours, seeking help on the internet, etc.) and asked students how often they did each of them, how often they felt each was necessary to complete the homework, and how effective the methods are for their learning process.

IMAGE CAPTURE OF SECTION 2. PART B OF SURVEY

Please select the amount to which you have felt the homework was:

	Never	Rarely	Sometimes	Often	All of the Time
Enjoyable	○	○	○	○	○
Intellectually Stimulating	○	○	○	○	○
Relevant to the material of the course	○	○	○	○	○
Relevant to the exam material	○	○	○	○	○
Relevant to real life situations	○	○	○	○	○
Relevant to your plans for the future	○	○	○	○	○
Critical to your learning process of the material	○	○	○	○	○
Fairly Graded	○	○	○	○	○
Graded and returned in a timely manner	○	○	○	○	○

Figure 1. Section 2 part b question visual, where students were asked to rate the nine categories.

This analysis will be taking a mixed methods approach where we will combine findings from both quantitative and qualitative data to draw our conclusions. For this paper we will focus on the results from the second and third survey sections described above, along with select data from the other sections to supplement the findings when needed. Quantitative data were analyzed in Excel and using Qualtrics™ .

Qualitative data were exported into Dedoose™ , a data coding software, and were coded there by one of the researchers. Coding was done to all of the responses to the last question from sections 2 and 3 above, where students explained specifically what homework strategies in the course had made it either a positive or a negative experience. Each answer was coded separately as either pertaining to a negative or a positive experience, and then coded further to express the topic or strategy the student was talking about. Each answer was coded with as many different codes as the researcher felt were present in the response. For example, one student said of a positive homework experience:

"[The homework] encouraged students to think creatively to solve problems and to branch out and explore real life situations."

This was then coded as "P INTELLECTUALLY STIM" and "P REAL LIFE," where the P at the front represents a positive experience. The other part of the codes came from the student saying that they were being intellectually stimulated in a positive way and also discussing the connection of the material with real life situations. Another example is from a student who discussed a negative homework experience:

"Not enough background in the lecture to solve the problem and long times between returned homework so see where past mistakes were made."

This was coded as "N GRADING," because the student had a bad experience with not getting assignments graded and returned on time, and "N ALIGNMENT WITH CLASS," because there was not enough overlap between class learning and the homework assignments for the student to feel capable of solving the homework.

One of the charting capabilities that Dedoose™ has is called a code co-occurrence chart. This chart allows the researcher to see how often two codes were marked on the same excerpt (see Figure 6 in the findings section for a visual capture of the chart). The numbers in the boxes represent how many excerpts there are that are coded with both the code along the x-axis and the code along the y-axis that line up with the column of the number. This allows the user to draw connections between how certain attributes might work together or influence each other based on how often they show up in the same scenario. Later in this paper we will refer to the code co-occurrence chart values to discuss relationships between different attributes of homework.

Why Problem Sets?

As mentioned at the beginning of this paper, homework has a huge influence on a course and how students learn the material. Although homework comes in many forms, the problem set is one that has become very common in STEM courses, and has become a typical format for many technical courses, often starting long before college. A problem set here is defined as a group of assigned problems, often requiring the use of mathematical equations and/or scientific concepts, that students are asked to complete, usually individually. Problem sets for a course are generally due in a consistent schedule, and often take multiple hours to complete. They are graded based on completion and correctness, and usually each problem has a specific "right" answer, demonstrating a students' ability to apply concepts learned in the course to solve a problem on their own.

Section 1 of the survey asked students for the number of problem sets that they had to complete on average per week in their most recent quarter taking STEM courses. Sixty-four percent of the students, a clear majority, had to complete two or more problems sets per week (see Figure 2). This means that STEM majors typically are required to allocate multiple chunks of their time each week to working on problem sets and learning the material required to solve them. When a problem set is due and when office hours (for additional help) are offered can strongly define the pattern of a student's week, and having to juggle multiple problem sets dominates this scheduling even further.

AVERAGE NUMBER OF PROBLEM SETS PER WEEK (n=104)

Answer		%
0		7%
1		29%
2		38%
3		18%
4		5%
5		3%
6+		0%
Total		100%

Figure 2. The numbers on the far left represent the number of problem sets that the student responded they had to do each week on average. The percentages on the right demonstrate the amount of students who had to complete that number of problem sets. The bars in the center are a visual representation of those percentages.

When students were asked to answer questions about a successful and an unsuccessful STEM homework experience that they had, they were asked the type(s) of homework primarily used in the course. Students were asked to check all formats that applied for the course, as some utilized multiple formats for homework assignments. Problem sets comprised a clear majority for both successful (Figure 3a) and unsuccessful (Figure 3b) experiences, which makes sense, they are the primary form of homework in many technical courses. This prevalence of the problem sets in both categories gives us a clear indication that there is a "right" way and a "wrong" way to do problem sets, because it shows that this format can lead to either a successful or an unsuccessful experience. This also demonstrates that problem sets present a significant opportunity for educators to affect improvement, because they are so widespread.

These data also demonstrate that although problem sets constitute the majority of homework for both experiences, there is still a greater percentage of other types of homework, especially group and individual projects, represented in the successful homework experience than in unsuccessful one. This demonstrates that in the right course or situation, other types of homework can have great potential to be effective. This does not mean that for all courses a system other than a problem set should necessarily always be considered, but it definitely demonstrates the potential for other formats to be integrated into the homework structure in addition to or in collaboration with problem sets.

TYPES OF HOMEWORK USED- POSITIVE EXPERIENCE (n=91)

Answer		%
Problem Sets		76%
Online Problems		8%
Individual Projects		21%
Group Projects		26%
Reading/Writing Assignments		11%
Other:		9%

TYPES OF HOMEWORK USED- NEGATIVE EXPERIENCE (n=66)

Answer		%
Problem Sets		95%
Online Problems		12%
Individual Projects		12%
Group Projects		15%
Reading/Writing Assignments		9%
Other:		2%

Fig. 3a and 3b. represent the percentage that students responded that the type of homework listed on the far left was utilized in the courses they responded with for both the successful and the unsuccessful homework experiences. The bars in the middle are a visual representation of the percentages listed on the right.

Findings

The analysis of the data led to the creation of six design principles for educators to use when generating homework, based on the quantitative results and the qualitative responses from students. The six principles are:

- *Establish a Rhythm*,
- *Find the Sweet Spot*,
- *Be Excessively Clear*,
- *Everything is Connected*,
- *Progress is Building*, and
- *Make it Accessible*.

These represent overarching principles of six themes that educators can use to direct the creation of their homework assignments. Although all principles represent important facets of the homework experience, this paper will focus on two most intensely: *Find the Sweet Spot* and *Everything is Connected*. We have chosen to focus on these two principles specifically because they best demonstrate how different components of the data can be applied to support one unified principle. It is important to note that many of these principles are interconnected and influence each other. Summaries of the other four categories are provided at the end of the "Suggestions for Educators" category. They are meant to be used to help guide educators, but should be adapted and transformed according to each educator's situation and needs.

Find the Sweet Spot

In the survey, students were asked to rate the homework of a particular course that they identified as being a "positive" and another course that they felt was a "negative" experience in the nine different categories shown in Figure 4.

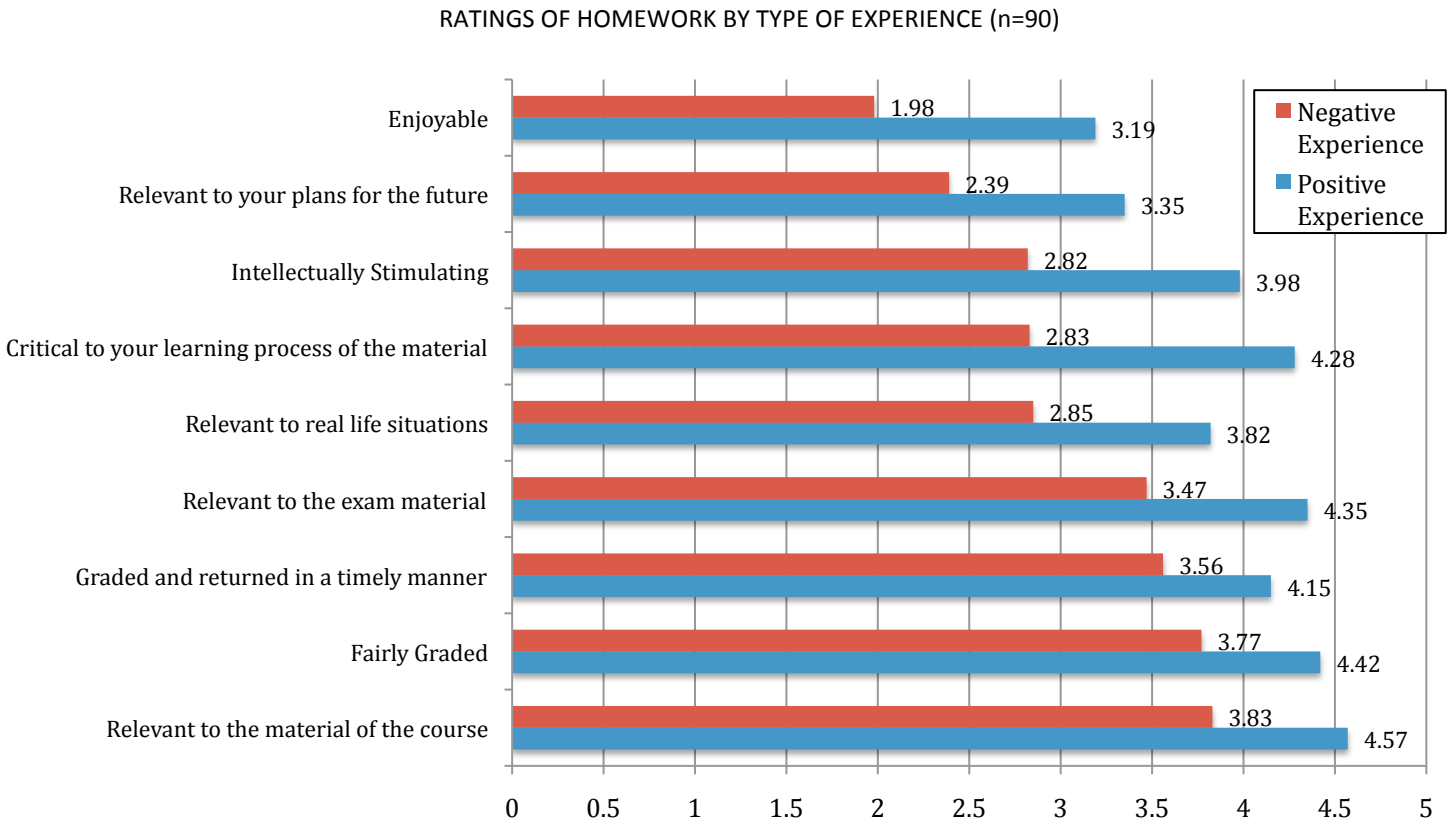

Figure 4. Chart that display the average values of all of the ratings of the nine categories for the successful and the unsuccessful experiences. Students were asked to rate the amount to which they felt the homework experience in that course was all of the nine categories, rating on a scale from Never (1) – Rarely (2) – Sometimes (3) – Often (4) – All of the Time (5).

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	P ENJOY - N ENJOY	1.424	1.053	.130	1.165	1.683	10.985	65	0.0000
Pair 2	P INT STIM - N INT STIM	1.292	.996	.123	1.046	1.539	10.464	64	0.0000
Pair 3	P RELV TO MAT - N RELV TO MAT	.773	.973	.120	.533	1.012	6.449	65	0.0000
Pair 4	P RELV TO EXAM - N RELV TO EXAM	.906	1.256	.157	.592	1.220	5.771	63	0.0000
Pair 5	P RELV TO LIFE - N RELV TO LIFE	1.121	1.342	.165	.791	1.451	6.788	65	0.0000
Pair 6	P RELV TO FUT - N RELV TO FUT	1.076	1.460	.180	.717	1.435	5.985	65	0.0000
Pair 7	P CRIT TO LEARNING - N CRIT TO LEARNING	1.530	1.255	.155	1.222	1.839	9.903	65	0.0000
Pair 8	P FAIR GRADE - N FAIR GRADE	.727	1.075	.132	.463	.991	5.497	65	0.0000
Pair 9	P TIMELY RETURN - N TIMELY RETURN	.636	1.260	.155	.326	.946	4.101	65	0.0001

Figure 5. Results of the paired-samples t-test conducted on all 9 of the categories.

The first thing to notice is that all nine of the categories are rated higher in the successful versus unsuccessful experience categories, in most cases by over one whole point out of five. This suggests that all of these categories do have an influence determining whether or not a student has a good homework experience. This also demonstrates, however, that there is not a clear single category that determines whether or not a student will have a positive experience; rather, they all contribute to it, and each has its own "story." For example, having a high rating in the "Intellectually Stimulating" category suggests that the homework was mentally engaging for the students, whereas a high rating in the "Critical to your learning process of the material" category implies that the homework was an essential part of the student's understanding and mastery of the curriculum.

Critical to the Learning Process

A paired-samples t-test was conducted to evaluate how much students felt the homework was critical to their learning process of the material (item 4 in Figure 4). The responses in the "critical

to your learning process of the material" category for the positive and negative experience were compared. The results indicate that the mean for a successful homework experience (M= 4.36, SD=.797) was significantly greater than the mean for a unsuccessful homework experience (M=2.83, SD=1.075) , $t(65) = 9.903$, $p<.001$. I found that how the homework contributed to the student's learning of the material to be one of the most frequently discussed topics in the fill-in the blank section, where a lot of students emphasized the use of their time being valuable only if they could see a clear connection between completing the homework and understanding the material they were expected to master. Expecting homework to correlate directly to learning the material of the course is a fairly basic assumption. The difference between the two experiences in this category, however, show that for some courses that connection needs to be made even stronger. One student said of an unsuccessful homework experience:

"The problem sets do not correlate with exam material. The problem sets tested how well you knew the material, but...did not comprehensively cover material covered in class, nor [teach] the problem-solving skills necessary to be successful on exams."

The student seems frustrated because although the homework seemed to test general knowledge of the material, it did not help the student prepare for the other aspects of the course. Because there is a gap between how the material is being represented in class and on exams versus on the homework, the student does not feel that the problem sets are successfully preparing them for the other facets of learning the material and navigating the course.

Another student discussed their negative experience, saying: *"I think the problems were designed to be too difficult, such that it didn't let me learn the new material, and was just a struggle overall."*

This student found the problems on the homework to be so challenging that they were not able to make any progress with the material. Although it might seem that difficult problems would encourage students to rise to the challenge and master the material more thoroughly, this level of difficulty just seems to have pushed this student away entirely.

A third student said of another unsuccessful experience: *"Lots of small assignments, not much depth; easy to forget things quickly"*

This student seems to be having the opposite issue of the student above, but with a similar result. These problems were not difficult enough and did not engage the student, resulting in a lack of depth and an inability to master the material.

These three examples show a sample of what many students wrote about learning the material of the course, and when examined more closely a strong trend that emerges. Many of the students who were having issues with their homework being critical to their learning process of the material were deterred because the level of difficulty of the assignments did not match what they needed to properly engage with the material. When the difficulty level of the homework is too high the students get discouraged, but when it is too low, they are not able to progress enough. Looking further this presence of difficulty related to learning the material of the course, we can examine the relationship between codes for a negative experience with learning the material of the

course, coded “N Course Learning,” and a negative experience with the difficulty level, coded “N Difficulty.”

By looking at the code co-occurrence chart (see Figure 6), which displays how frequently two different codes occur in the same excerpt, we can see that the highest number of overlap between two codes occurs between N Course Learning and N Difficulty. This suggests that a misaligned level of difficulty can negatively impact how students are learning and interacting with the material.

CODE CO-OCCURRENCE CHART- NEGATIVE EXPERIENCE CODES

Codes	N ALIGNMENT WITH COURSE	N GENERAL	N PROBLEM FORMAT	N COURSE LEARNING	N DIFFICULTY	N EXPECTATIONS	N INTELLECTUALLY STIM	N REAL LIFE
N ALIGNMENT WITH COURSE				2	3	1	1	
N GENERAL				1				
N PROBLEM FORMAT				3	4		2	
N COURSE LEARNING	2	1	3		20	3	9	
N DIFFICULTY	3		4	20		4	8	
N EXPECTATIONS	1			3	4			
N INTELLECTUALLY STIM	1		2	9	8			
N REAL LIFE								

Figure 6. Negative code co-occurrence chart generated in Dedoose™. The numbers in the boxes represent how many excerpts there are that are coded with both the code along the x-axis and the code along the y-axis that line up with the column of the number.

Intellectually Stimulating

Going back to Figure 4, which demonstrates average ratings in the nine categories for successful and unsuccessful homework, we also want to examine the “Intellectually Stimulating” category (item 3 in Figure 4). A paired-samples t-test was conducted comparing the positive and the negative ratings for the “Intellectually Stimulating” category, and results indicate that the mean for a successful homework experience (M= 4.11, SD=.831) was significantly greater than the mean for a unsuccessful homework experience (M=2.82, SD=.808) , $t(65) = 10.464$, $p<.001$. This topic was also frequently brought up in the qualitative responses, and often played a huge role in how students interacted with the material and how they determined if the homework assignments were a good use of their time. This shows that if an assignment is not very intellectually stimulating, the student might not feel very engaged with it, even if they find the subject of the

course as a whole to be interesting. One student commented on a course:

"PSET problems...generally do not require novel insights or leaps. Essentially busy work (generally find and insert answer rather than problem solving)"

In this quote, the student found that their homework experience was unsuccessful because the way the material was presented did not ask them to think critically or push themselves to draw connections between the information. The problems were not challenging enough to become intellectually stimulating, and therefore were seen as busy work and not engaging to the student. Another student wrote that:

"There was no focus on thought process or understanding. It seemed very much like a puzzle to figure out the combination of equations or numbers to successfully plug in."

This student is also frustrated by the lack of intellectual stimulation provided by the homework. In this situation, the difficulty level is too high, so the problems become obscure and instead of allowing the student to grow through understanding they are required to work their way through the mechanics of the problem.

Similar to its presence in relation to the "critical to your learning process of the material" category, the level of difficulty of a homework assignment also plays a huge role in if students become intellectually stimulated by the assignment. Looking at the code co-occurrence chart again (Figure 6), the second highest number of code overlaps with "N Intellectually Stimulating" is with "N Difficulty." The frequent co-occurence between the two suggests that it is important to make the problems the appropriate amount of difficulty to ensure that students are able to learn the material of the course without getting discouraged from the problems being too difficult or unengaged from the problems being too simple.

From these relations, the design principle emerges: "Find the Sweet Spot." For decisions related to difficulty, amount, or variety, there is always a point- the sweet spot- where students will have the fullest learning experience without being too overwhelmed such that they feel discouraged.

Everything is Connected

A course consists of many different parts- the lecture, homework assignments, peer interactions, textbook readings, and more- all of which work together to create a learning experience for the student. During the process of taking a course we will draw connections between the different parts, and use these connections to expand and solidify our learning. We also draw connections to things outside of the course, such as our prior knowledge, other courses, and real life situations. In *How Learning Works*, the first principle of learning is "students' prior knowledge can help or hinder learning." The book goes on to discuss how students inevitably draw connections to what they have previously learned and assumptions they have already formed. These connections can either be a solid foundation for students to build on, or can misdirect students if the connections are misaligned from what the curriculum expects them to be. Looking back again at Figure 4, there are a few categories that deal explicitly with this idea of connections, but we are going to focus on one in particular- "Relevant to real life situations."

Relevant to Real Life Situations

A paired-samples t-test was conducted comparing the positive and the negative ratings for the "Relevant to real life situations" category, and results indicate that the mean for a successful homework experience (M= 3.97, SD=..911) was significantly greater than the mean for a unsuccessful homework experience (M=2.85, SD=1.085) , $t(65) = 6.788$, $p<.001$. A successful homework experience is more likely to draw connections from what the students are learning to how it can be used and what it means in a situation outside that of the course. The concept of connecting homework to real world situations was also incorporated into the last question in section 5 of the survey. The question asked the students to rate how effective they felt a provided list of homework methods were in contributing to their learning process in STEM courses in general. As seen in Figure 7, the strategy of incorporating real life situations into homework is one that students find to be very effective in contributing to their learning experience.

EFFECTIVENESS OF HOMEWORK METHODS (n=64)

Question	Mean Value (highest possible value=5)
Incorporating real life applications of course material	4.29
Physical printed handouts of lecture notes/slide provided in class	3.94
Take-home exams	3.69
Homework problems directly from the class textbook	3.49
Online homework problems	3.00
Mandatory or graded class attendance	2.99
Online teaching modules	2.90

Figure 7. The mean values of student ratings of how effective the listed methods are in contributing to their learning experience in a STEM course. Students were given five options to rate each method (Very Ineffective, Ineffective, Neither Effective nor Ineffective, Effective, Very Effective). The highest rating of "Very Effective" is assigned a value of 5, the lowest rating of "Very Ineffective" is assigned a value of 1, and the other options successively increase by one point.

Relating the homework assignments to real life situations was also a prevalent theme found in the qualitative data. Examples of quotes from students about a positive homework experience include:

"The class emphasized learning from exposure to real world sites rather than monotonous course work."

"Challenges that had a clear, real-world objective."

"It felt like the knowledge gained in the class was more useful and applicable than in most typical STEM classes."

Connecting the homework to real life situations helped these students become more engaged with the material and made the assignments more compelling than typical coursework. It gives students a reason to learn the material beyond doing well in the course, because they can concretely see how what they are learning can help them do something else that they might be interested in. A student who had a negative homework experience said:

"I felt I had little context for how I might actually use the information later. I didn't know what was really important to learn and what wasn't. It was difficult to build intuition, and it was unclear what intuition I needed to acquire."

Because this student had no context for what they were learning, they were unable to organize the information and build the motivation to engage with the material. Allowing students to see the broader scope of what the curriculum applies to can help ground them and give them purpose.

Other Forms of Connection

In order for students to feel motivated to approach the homework, they have to feel like they have a solid foundation of learning related to what they will be asked to do. They can get this foundation from lecture, readings, projects, or previous assignments in the course that introduce them to the curriculum they will be asked to master on the homework. If they do not feel that this foundation is there, however, they can feel alienated or frustrated by the task of solving problems with knowledge they haven't been exposed to yet. One student said of a negative homework experience:

"Homework was a separate entity from lecture; it was as if I had to fill in material that lecture left out to do the homework."

The student had to learn the material on his own because the teacher did not draw a strong enough connection between what was taught in class and what the students were asked to do on the homework. If these connections are made stronger, however, students can have a very successful experience. A different student talked about a positive homework experience:

"The professor's enthusiasm and careful design of the course, most specifically very relevant and well-written readings, made the course enormously successful."

Here the student demonstrates how having each part of the course be a good experience, and being able to draw connections between them, can enhance the learning environment and make for a successful experience.

To emphasize the importance drawing connections between not only each part of the course but also their relationships to other knowledge and real life situations, we created the design principle "Everything is Connected." This is to remind educators to constantly think about how each part of their course interacts with each other, and also to draw relatable connections to real life situations to keep students engaged.

Suggestions for Educators

Find the Sweet Spot

There is a sweet spot for many different facets of the homework, such as its quantity, its difficulty, and its use of technology and other learning tools. Take the time to find what the ideal level of each of those qualities is for your course, and even for the specific group of students. Doing this is essential to ensuring that the students stay comfortable with the course while still being intellectually stimulated enough to be engaged and learning to their fullest potential. A few specific suggestions include:

- Be very aware of the difficulty and the amount of time each problem set takes! Although some teachers think of homework as a place to start to challenge students, if the difficulty level is too high it will greatly discourage them and could lead to them actually learning less. The same goes with the amount of problems- although teachers might want to fit every part of the curriculum into the homework, having too many problems will often push students to focus on just getting the answers to be able to get it done instead of actually thoroughly learning the material.
- Acknowledge that all students benefit from different types of learning and incorporate systems that are not just straight lecture or problem sets. Be careful not to overdo this, however- if a course loses at least a general level of consistency, students will not know what to expect and will be frustrated. Find the right number of different learning styles to keep students engaged without throwing them off too often.
- Although grading is usually a large incentive for students to get their homework completed, many students have found that having more flexible due dates and lenient grading systems helps them to learn because the focus shifts from getting it done in order to get a good grade to taking the time the student needs to understand the material while still being able to complete the assignment. Try and find a sweet spot with grading where students still have an incentive to keep up with their work but aren't so afraid of the consequences that they'll sacrifice learning to get it done.
- The use of technology is quickly having a stronger influence in the classroom, but this too has a sweet spot. It is a great tool to use the deepen understanding and ways of learning, but giving students a new system to learn or expecting them to do heavy amount of work over the internet can quickly push them away if they have to spend too much time learning the system or aren't able to go through the solving process in ways they are typically accustomed.

Everything is Connected

A course should continue to draw connections between each facet of the curriculum, as well as integrate as much as possible the homework, lectures, exams, and projects to each other. It is also critical to students' motivation to see a connection between what they are learning in the course and how they can apply that knowledge in other courses and in their lives outside of school.

- The lecture material and structure should connect to that of the homework. If they seem unrelated, it makes the homework much less approachable, and reduces students' motivation to

pay attention in class.
- Try and use similar modes of formatting, thinking, or processing between the homework and other aspects of the course. Similar to the reasoning for establishing a "rhythm," students appreciate having a cohesive system where all the parts relate to each other.
- Frame the problems in a way that relates them to the other course material and to real life. Students are much more willing to put in hard work to understand and remember the material if they think it will be useful to them later. One of the biggest causes of frustration for students is spending time learning material that they don't feel is going to be of any use to them, so give them a reason to want to learn!
- The success of certain parts of the course greatly influence students' feelings of other parts. For example, one of the most common associations mentioned in the data from students' comments on a positive homework experience related their ability to complete the homework to their in-class learning experience. If they did not feel like they were able to learn the material well in class, they understandably felt very frustrated when asked to apply the concepts to problem solving.

Summaries of the four other design principles, generated from the same study but not supported in this paper:

Establish a Rhythm

Students like to know what to expect from a course, and prefer if there is a pattern that they can fall into in terms of what is expected of them. This means having assignments spaced out evenly, consistency to the lecture structure, predictable levels of difficulty, and greater access to help and guidance closer to due dates.

Be Excessively Clear

It can be easy for teachers to assume that students understand what is expected of them, but it is often helpful to reiterate explicitly what you are expecting from students. This includes providing grading rubrics, informing them frequently how far they should be in the curriculum, and making distinctions between what is critical material and what is supplemental.

Progress is Building

Students want to feel themselves growing and progressing through a course, and the best way to do this can be to show them how what they are learning builds on a foundation of knowledge they have already established and allows for further progress with continuing studies. Teachers should constantly reconnect new portions of the curriculum with sections that were already taught, as well as ask students to draw connections themselves between knowledge they have acquired outside of the course and the curriculum within it.

Make it Accessible

Give students as many resources as possible to internalize and interact with the material, and make them all readily accessible, ideally online. Although some teachers believe that limiting the

handouts and lectures notes to in-class distribution will increase attendance, this also punishes those who simply need continued exposure outside of the classroom, and ultimately reduces learning for all parties. Teachers should also make themselves available and approachable as much as they can, and explicitly show their students that they are interested in helping and want them to learn the material in whatever way is best for them.

Conclusion

Homework is an influential part of a student's learning experience, and has a lot of potential to greatly increase their engagement with and knowledge about the material of a course. Teachers should design their homework assignments carefully to maximize their success for their specific course and group of students. Educators should "Find the Sweet Spot" for the various aspects of their assignments by carefully calibrating variables such as difficulty, amount of time, and methods used. They should also remember that "Everything is Connected," and work to constantly reinforce the connections between each part of their course to their homework assignments, as well as with real life situations.

Future work could explore going further in depth with the other design principles listed, and show how they all connect to and interact with each other. Another survey with questions directed towards those principles could help support them and expand them even further. Another future study could also explore the application of the design principles to homework methods outside of problem sets, and seek to understand which different systems of homework work well together, and how to know when each system is most appropriate to use.

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