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Evolution of Understanding and Attitudes in a Discrete Mathematics Course for Computer Science Students

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Abstract

This study examines students' understanding of and attitudes toward discrete mathematics within a computer science program. We investigate how their conceptual understanding evolves over the semester and how learning discrete math influences their broader attitudes toward mathematics. As a baseline, we also measure students' attitudes toward programming. In addition, we explore the skills students perceive as important to discrete math and how these perceptions change from the beginning to the end of the course. While students show significant learning gains across all topics, both self-assessments and technical assessments reveal particular challenges with induction and proofs. Despite these difficulties and a decline in students' perception of math's relevance to CS careers after the course, their confidence and enjoyment of mathematics increase, and their anxiety decreases. These findings offer valuable insights for educators aiming to align discrete math instruction with students' prior knowledge, refine topic emphasis, and foster positive shifts in mathematical attitudes.

Introduction and Motivation

Computer science (CS) is a rapidly evolving discipline, whereas discrete math remains relatively stable. Despite the extensive research on computer science education that explores students' perspectives on programming and other core topics, there is relatively little work examining computer science students' perceptions of discrete math. The only work we could find was Magda and Gardner-McCune [14] who looked at CS students' motivations to study discrete math and which topics they found most challenging. Magda and Gardner-McCune [14] also identified perceptions of discrete math as a gap in the literature.

The role and relevance of discrete math in the CS curriculum has been a topic of ongoing discussion within the CS education community since the 1970s [18], continuing through the 1980s [5, 16], the 1990s [21], and the 2000s [15]. The 2020s has also brought questions on the importance of math with work by [6] analyzing the math requirements of 199 computer science (CS) programs. They found substantial variability in the placement of discrete math in the curriculum, as well as what math, in general, is needed to be a successful computer scientist. In this paper, we set out to understand students' understanding, perspectives, and attitudes toward discrete math and how they change over the duration of the course.

This study takes place in a required 100- level CS class at a public R1 hispanic-serving university in the midwest. Specifically, our research addresses the following questions:

RQ1 - How does students' understanding of discrete math topics evolve from the beginning to the end of the course?

RQ2 - In what ways does learning discrete math influence students' attitudes toward mathematics more broadly? As a baseline, we compare their attitude towards mathematics to their attitude towards programming.

RQ3 - What skills do students perceive as important for success in discrete mathematics, and how do these perceptions change from the beginning to the end of the course?

We collect data through surveys and assessments to capture students' mindsets and technical understanding of discrete math. This study aims to provide educators with an authentic insight into students' perceptions and understanding of discrete math, helping them design more effective courses.

Background

Discrete mathematics is a foundational topic for computer science. ACM topic recommendations [13] include sets, relations, functions, cardinality, recursive mathematical definitions, proof techniques, permutations, combinations, counting, pigeonhole principle, modular arithmetic, logic, basics of graphs, and order notation. Our 100- level discrete math course has eight modules including logic, proofs, sets, relations, functions, induction, counting, and probability.

Because discrete mathematics is inherently abstract, there has been considerable work focused on developing pedagogical strategies and curricula that make the subject more tangible and engaging through hands-on, active, and collaborative approaches [4, 7, 10]. A 2011 review article highlights the wide range of methods explored for teaching discrete math effectively [17]. However, despite these efforts, there remains a gap in the literature regarding students' understanding of discrete mathematics.

Discrete mathematics is not well standardized within the U.S. K–12 Common Core mathematics curriculum [9, 20], resulting in inconsistent exposure for students prior to college. Despite its importance, many students struggle to grasp or appreciate the value of discrete math until much later in their academic or professional journeys, if at all [11]. This perceived lack of relevance often leads to low motivation among students [19]. Simply having a computer scientist, rather than a mathematician, teach the course does not necessarily help students see its practical significance [12].

This study sets out to fill a gap in CS education literature by investigating students' understanding, attitudes, and perceived skills of discrete math before and after taking a Discrete Math class. This process involved collecting data from surveys and assessments, and then quantitatively analyzing it to extract insights to answer our research questions.

Methods

This is an IRB-approved, quasi-experimental study. Students enrolled in a Discrete Math course were recruited to participate. It involved the use of pre- and post- surveys and assessments to evaluate changes in students' understanding, attitudes, and perceived related skills of discrete math. Responses were collected using a combination of online and paper formats. The data discussed in this paper was collected in the Fall 2024 semester. These findings only include students who consented, met the minimum age requirements, and had complete responses within a given category.

The pre- and post-surveys/assessments each included two components. First, an online survey, which students received via link and QR code during the first lab. Second, an assessment to evaluate technical understanding of discrete mathematics, delivered on paper during the first lab. Paper, as opposed to online, assessments were used to minimize the influence of external sources (internet, messaging apps, gen AI tools, etc.)

The study population comes from a public hispanic-serving university. Demographics collected were gender, racial/ethnic background, parental education level (PEL), and class standing, shown in Table 1. We had around 27% women, 28% Black and Hispanic, 43% first generation college students, and 63% first and second year students. The demographics of our consenting population is representative of our full population.

Category	Group	% (n)
Gender	Male	63.92% (62)
	Female	26.80% (26)
	Prefer not to respond	5.15% (5)
Race/Ethnicity	White (non-Hispanic)	10.31% (10)
	Asian/Asian American	49.48% (48)
	Black/African American	5.15% (5)
	Hispanic or Latino	23.71% (23)
PEL	Graduate Degree	25.77% (25)
	Bachelor's Degree	21.65% (21)
	Technical/Associate Degree	4.12% (4)
	Some College	16.49% (16)
	High School	16.49% (16)
	Grade School	6.19% (6)
Class Standing	Senior	14.43% (14)
	Junior	19.59% (19)
	Sophomore	37.11% (36)
	Freshman	26.80% (26)

Table 1: Demographics of study population. PEL - Parental Education Level.

Analysis

The surveys included a combination of Likert-scale items, multiple-select questions, and open-ended responses. We employed a mixed-methods approach in our analysis. The quantitative component involved descriptive and inferential statistics, with pre- and post-course comparisons assessed using two-tailed t-tests to determine statistical significance. For the qualitative component, we conducted a thematic analysis of three open-ended questions. This paper will focus only on the results from our quantitative analysis.

Results

RQ1: Understanding - Students' self-rated understanding of course topics provided valuable insights into their learning progress. In both the pre- and post-surveys, students were asked to rate their understanding of eight key topics covered in the course: logic, proofs, sets, relations, induction, functions, counting, and probability. Table 2 summarizes the mean responses, including the differences between pre- and post-survey scores. We assigned numerical values to responses as follows: Very confident understanding = 2, Fairly confident understanding = 1, Never heard of topic = 0, Fairly confident not understanding = -1, and Very confident not understanding = -2. Among the topics, relations and induction showed the largest gains in self-reported understanding. However, induction had the lowest post-course mean score (0.89), indicating that students were initially least familiar with induction and continued to feel less confident about it after completing the course. Conversely, topics such as functions, counting, and probability exhibited the smallest gains in understanding.

There is currently no validated concept inventory specifically for discrete math [1]. While a 2006 Working Group made initial efforts to develop one, no finalized inventory was ever published [3]. Developing such an instrument is beyond the scope of this study. However, we included technical questions covering our eight course topics in both the pre- and post-surveys to assess student learning, see Appendix I. Table 3 summarizes the results of this technical assessment. Improvements were observed across all topics to varying degrees. The normalized gain of the average scores, a measure of relative improvement calculated from the population's pre- and post-assessment means, was 0.495. The effect size, calculated as Cohen's d using the same population means and standard deviations, was 0.859, indicating a large educational impact according to conventional benchmarks [8].

Topic	Pre-	Post-	Difference
Logic	0.2178	1.4653***	1.2475
Proofs	-0.1811	1.2079***	1.3267
Sets	-0.4059	1.4158***	1.8218
Relations	-0.8020	1.4158***	2.2178
Induction	-1.1386	0.8911***	2.0297
Functions	0.8515	1.4653***	0.6139
Counting	0.4455	1.0495**	0.6040
Probability	0.6436	1.0396*	0.3960

Table 2: Student self-reported understanding of discrete math concepts. Significant results are marked ***($p < 0.001$), **($p < 0.01$), or *($p < 0.05$). ($n = 101$)

Question Topic	Pre-	Post-	Difference
Logic (Truth Table)	0.804	0.917	0.113
Logic (Negation)	0.443	0.619	0.175
Set (Building)	0.753	0.784	0.031
Set (Venn Diagram)	0.887	0.907	0.021
Relations	0.845	0.990	0.144
Induction (Recurrence)	0.629	0.701	0.072
Functions	0.948	0.979	0.031
Counting 1	0.515	0.845	0.330
Counting 2	0.474	0.773	0.300
Probability 1	0.505	0.845	0.340
Probability 2	0.825	0.938	0.113

Table 3: Percentage of students who correctly answered different question topics in the pre- and post-assessments and the overall average score for the pre- and post- assessment. ($n = 97$)

RQ2:Attitudinal Constructs - Both the pre- and post-online surveys included Likert-scale questions designed to assess students' sentiments toward Self-Efficacy, Enjoyment, Anxiety, and Relevance in relation to mathematics. These questions were drawn from a non-validated survey instrument previously used to explore computer science students' attitudes and beliefs about mathematics and its relevance [2].

Here are a few statements that students responded to:

- Confidence – "I have confidence in my mathematics ability."
- Learned – "I feel that I have learned good math concepts from the math courses that I have taken so far."
- Can Apply – "I can apply a wide variety of mathematical techniques to solve a particular problem."
- HW and Q – "I believe doing homework and asking questions in class can improve my math ability."
- Give up – "When math work is hard, I usually give up."
- Fascinate – "Math word problems fascinate me."
- Interesting – "Math is very interesting to me."
- Enjoy Board – "I enjoyed watching a teacher work on a math problem on the board."
- Distracted – "I think of other things when a math teacher is talking or working on a problem."
- Boring – "Math is boring."

- Nervous – "I feel nervous when a math teacher asks me questions in class."
- Bad Grade – "I worry a lot before a math test."
- Worry – "When I take a math test, I worry that I will get a bad grade."
- Not Relevant – "Improved math skills are not important in a computer science career."

In addition to assessing students' attitudes toward mathematics, we asked the same set of questions about programming to provide a basis for comparison. For example, to measure confidence, students responded to both: "I have confidence in my mathematics ability" and "I have confidence in my programming ability." Responses on the Likert scale, ranging from Strongly Disagree to Strongly Agree, were converted to numeric values from -2 to 2, respectively. We calculated the difference in mean scores between pre- and post-surveys to determine overall changes for each question. Paired t-tests were then used to evaluate the statistical significance of these differences, with results summarized in Table 4.

Construct	**Pre-Math**	**Post-Math**	**Pre-Prog**	**Post-Prog**
Confidence	1.14	1.34*	0.69	0.79
Learned	1.22	1.40*	0.98	0.98
Can Apply	0.90	1.17**	0.69	0.94**
HW and Q	1.54	1.51	1.49	1.33*
Give up	-0.89	-0.67	-0.83	-0.40**
Fascinate	0.25	0.50*	0.72	0.75
Interesting	0.88	1.09*	1.19	1.13
Enjoy Board	0.88	1.07*	0.89	0.82
Distracted	-0.27	0.14**	-0.26	0.25***
Boring	-0.77	-0.77	-1.10	0.73**
Nervous	0.24	-0.09*	0.08	-0.11
Bad Grade	0.60	0.10***	0.48	0.23
Worry	0.50	0.11**	0.49	0.19**
Not Relevant	-0.46	-0.04**	-0.15	-0.06

Table 4: Mean students' responses to Likert scale questions target students' sentiments toward Self-Efficacy, Enjoyment, Anxiety, and Relevance regarding general mathematics and programming. Significant results are marked ***($p < 0.001$), **($p < 0.01$), or *($p < 0.05$). ($n = 100$)

The findings in Table 4 reveal several notable trends. Students' confidence and enjoyment of mathematics increased after taking the discrete math course, while their math anxiety decreased. However, their perception of math's relevance to a career in computer science declined.

Specifically, students reported higher confidence in their mathematical ability and in how much they learned after the course, an increase not observed for the equivalent programming questions. Confidence in applying both math and programming skills improved from pre- to post-survey.

Students' enjoyment of math also generally increased following the course, and this increase was greater than the change in their enjoyment of programming. Interestingly, students reported both an increased enjoyment of watching instructors solve math problems on the board and, simultaneously, a greater tendency to feel distracted during these demonstrations. While students generally did not find math boring, their perception of programming as boring increased after the course.

Math-related anxiety showed improvement post-course, with students feeling less nervous when called on in class, worrying less before math tests, and being less concerned about receiving poor grades. These reductions in anxiety were somewhat greater for math than for programming.

Finally, despite gains in confidence and enjoyment, students reported a decrease in the perceived relevance of math to a computer science career after completing the discrete math course.

RQ3: Perceptions of Skills - Both the pre- and post-online surveys included Likert-scale questions designed to assess students' perceptions toward skills needed in discrete mathematics. These questions were designed by the authors. Table 5 summarizes the mean responses, including the differences between pre- and post-survey scores. We assigned numerical values to responses as follows: Skill is "needed a lot" = 5, "needed a little" = 4, "needed an average amount" = 3, "not needed very much" = 2, and "not needed at all" = 1.

Skill	Pre-	Post-	Difference
Memorization	3.6439	3.9346*	0.2906
Problem Solving	4.7820	4.6296*	-0.1523
Computational Thinking	4.7121	4.2315***	-0.4806
Verbal Communication	3.6842	3.2315***	-0.4527
Written Communication	3.7895	3.7037	-0.0858
Formal Writing	3.1439	3.5463*	0.4024
Creativity	3.7045	3.4907	-0.2138
Abstract Thinking	4.3561	4.1389*	-0.2172
Analytical Thinking	4.7218	4.3056***	-0.4162
Logical Thinking	4.7895	4.6759*	-0.1135

Table 5: Student perceptions of skills needed for discrete math. Significant results are marked ***($p < 0.001$), **($p < 0.01$), or *($p < 0.05$). ($n = 139$)

Perceptions of the need for skills such as memorization and formal writing increased from pre- to post-course. In contrast, perceptions of the importance of problem solving, computational thinking, verbal communication, abstract thinking, and logical thinking decreased over the same period. Perceptions of written communication and creativity remained relatively stable.

The increase in perceived reliance on memorization is concerning and may indicate that students adopted a more formulaic approach to navigating discrete mathematics. The increased emphasis formal writing is a positive outcome and aligns with key course goals. The decreases in perceived importance of computational thinking and verbal communication are understandable, as these skills were not explicitly emphasized or developed further during the semester.

More concerning, however, are the declines in problem solving, abstract, analytical, and logical thinking, as these are core competencies that discrete mathematics courses are intended to cultivate. Notably, this pattern is consistent with the observed increase in memorization, suggesting that students may have shifted toward surface-level strategies rather than deeper conceptual reasoning.

Coming into the course, students perceived the most important skills to be problem solving, computational thinking, analytical thinking, and logical thinking. By the end of the course, only problem solving and logical thinking remained among the top-ranked skills. The decline in perceived importance of computational thinking is understandable, as many students initially enter the discrete mathematics course with the misconception that it is a programming-focused class. The decrease in analytical thinking, however, is less straightforward and warrants further investigation.

Limitations and Threats to Validity

Only 33.8% of students from a single semester of our discrete math course consented to participate in this study. This relatively low response rate, compared to our prior research studies, is likely due to required changes in our IRB consent process. Additionally, since the study was conducted in a 100-level discrete math course, the results may not generalize to programs that teach discrete math later in the curriculum. Furthermore, our sample consists of students from a low- to mid-selectivity public university, which may limit the applicability of our findings to students at highly selective CS programs.

Conclusions

RQ1: Understanding - Students' self-assessed understanding showed significant gains across all eight topics, with smaller improvements in functions, counting, and probability. This is consistent with their greater prior exposure to these areas. These topics might be candidates for reduction or elimination to allow more focus on less familiar, more challenging topics like induction and proofs. Comparing self-assessments with a technical assessment revealed alignment in induction (the topic with the lowest gains and lowest post-test scores) but a disconnect in counting and probability, where students' confidence was high but performance was not. Observations from instructors also suggest that the topic of functions is often too straightforward and may add limited value to the course. Also, observations from instructors indicate proofs and induction to be the most challenging for students.

RQ2: Attitudinal Constructs - Despite students' limited prior understanding, the course had positive effects on their attitudes. Self-efficacy and enjoyment generally increased, while anxiety decreased after completing the course. Our beginner-friendly curriculum, which assumes minimal prior math or computing knowledge despite the prerequisites, appears effective at supporting students' attitudinal growth. At the same time, the results point to a misalignment between improved student experiences in mathematics and their understanding of its relevance to computer science careers. Despite gains in confidence and enjoyment, students increasingly view mathematics as less connected to their future work in CS.

Collectively, these findings underscore the importance of not only supporting students' confidence and reducing anxiety, but also making the purpose and applicability of discrete mathematics more explicit throughout the course. Emphasizing real-world applications, connections to downstream CS courses, and relevance to industry and research may help bridge this gap.

RQ3: Skills - Despite students' attitudinal growth in mathematics, there appears to be some incorrect perceptions of the skills needed to do discrete mathematics. This study highlights meaningful shifts in how students perceive the skills required for success in a discrete mathematics course. While increases in perceived importance of formal writing align with intended learning outcomes, the growing reliance on memorization raises concerns about students adopting more procedural or formulaic approaches to the material. Although the decreased emphasis on computational thinking can be attributed to a correction of initial misconceptions about the nature of the course, the declines in problem solving, abstract, analytical, and logical thinking are more troubling. These skills are central to discrete mathematics and are foundational for students' future coursework in computer science.

Taken together, these findings suggest a potential misalignment between course goals and students' perceived learning experiences. The shift toward memorization, coupled with decreased emphasis on higher-order reasoning skills, indicates that students may not be fully recognizing or developing the deeper conceptual thinking that discrete mathematics is designed to foster. Future work should examine how instructional strategies, assessments, and messaging about course objectives can more explicitly emphasize and reinforce abstract reasoning, analytical thinking, and logical problem solving. Addressing these perceptions may help encourage deeper engagement with the material and better support students' long-term development in computer science.

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Appendix I - Technical Questions

For questions 1 and 2, you will use the three symbols defined in Figures 1, 2, and 3:

p	q	$p \wedge q$
T	T	T
T	F	F
F	T	F
F	F	F

$p \wedge q$ is true only when ***both*** p and q are true

false for all other combinations

Figure 1

p	q	$p \vee q$
T	T	T
T	F	T
F	T	T
F	F	F

$p \vee q$ is true when *either* of p or q is true

$p \vee q$ is false only when p and q are both false

Figure 2

p	$\neg p$
T	F
F	T

$\neg p$ is simply the opposite of p.

Figure 3

1. p = True, q = False, r = True

Select the expression that evaluates to False.

a. $p \vee \neg q$

b. $p \vee q \vee r$

c. $\neg (p \wedge \neg q)$

d. $\neg (p \wedge q \wedge r)$

2. The variables f, h, and p each represent statements.

f: The student got an A on the final.

h: The student turned in all homework.

p: The student is on academic probation.

Select the expression that could represent the statement:

“The student is not on academic probation and the student got an A on the final or turned in all the homework.”

a. $\neg p \wedge (f \vee h)$

b. $(\neg p \wedge f) \vee h$

c. $\neg p \wedge f \wedge h$

d. $(p \wedge f) \vee h$

3. Which of the following statements must be proven to be True to guarantee that the following statement is False?

There are two consecutive integers that are both odd.

a. For every positive integer x, x is not odd or x + 1 is not odd.
b. For every positive integer x, x is not odd and x + 1 is not odd.
c. If x and y are positive integers, then x is not odd or y is not odd.
d. If x and y are positive integers, then x is not odd and y is not odd.

For question 4, you will use the two definitions below.

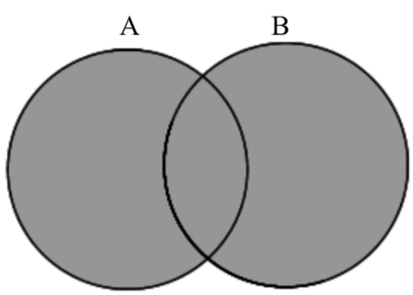
$\mathbb{R}$: The set of all real numbers.
$\mathbb{Z}$: The set of all integers.

4. Using the two above definitions, which of the below sets best represent the pattern or rule used to create the set:

$\{3, 5, 7, 8, 11, 13\}$

a. $\{x \in \mathbb{Z}: 3 < x < 14\}$
b. $\{x \in \mathbb{R}: 3 \leq x < 14\}$
c. $\{x \in \mathbb{Z}:$ x is odd and $3 \leq x \leq 14\}$
d. $\{x \in \mathbb{Z}: x$ is prime and $3 \leq x < 14\}$

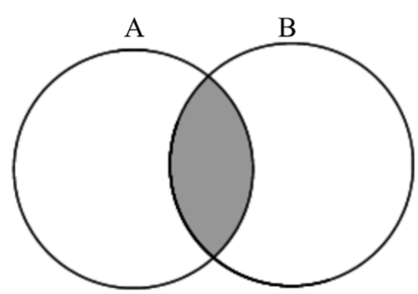
Union (∪)
The union of two sets contains every item in at least one of the two sets.



The shaded area is A∪B.

Figure 4

Intersection (∩)
The intersection of two sets contains every item in both of the sets.



The shaded area is A∩B.

Figure 5

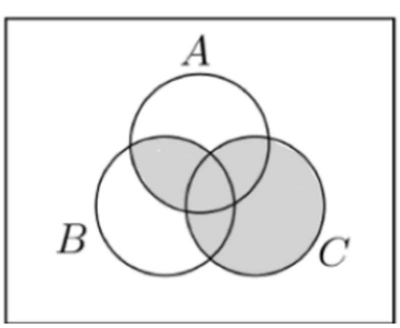


Figure 6

For question 5, you will use the concepts shown Figures 4 and 5.

5. Select the expression that best creates the set of items which is represented in the Venn diagram shown in Figure 6:

a. $(A \cup B) \cup C$
b. $(A \cap B) \cap C$
c. $(A \cup B) \cap C$
d. $(A \cap B) \cup C$

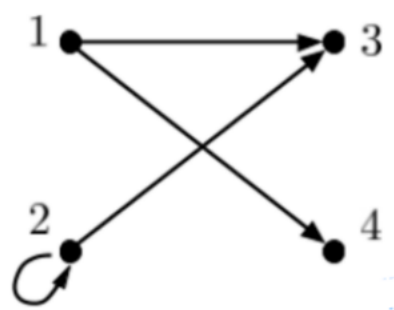


Figure 7

6. Select the set of number pairs that best represents the number pairs shown in the arrow diagram in Figure 7:

a. $\{(1,3), (1,4), (2,3)\}$
b. $\{(1,3), (1,4), (3,2)\}$
c. $\{(1,3), (1,4), (2,3), (2,2)\}$
d. $\{(1,3), (1,4), (3,2), (2,2)\}$

7. A population of mice increases by 10% every year. Define g_n to be the number of mice after n years. Select the equation that best describes the number of mice after n years (g_n).

a. $g_n = (1.01) \cdot g_{n-1}$
b. $g_n = (1.1) \cdot g_{n-1}$
c. $g_n = (0.01) \cdot g_{n-1} + g_{n-2}$
d. $g_n = (0.1) \cdot g_{n-1} + g_{n-2}$

8. The sets A and X and the collection of relations $f\colon A \rightarrow X$ is represented by the arrow diagram shown in Figure 8. Select the set of pairs that best represent the relationships shown in the arrow diagram (Figure 8).

$A = \{a, b, c, d\}$
$X = \{1, 2, 3, 4\}$

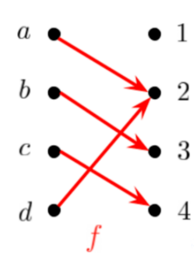


Figure 8

a. $f = \{(a,2), (b,3), (d,2)\}$
b. $f = \{(a,2), (b,3), (c,4), (d,2)\}$
c. $f = \{(a,2), (b,3), (c,4), (d,4)\}$
d. $f = \{(a,1), (b,3), (c,4), (d,2)\}$

9. A lunch special at the local diner comes with a choice of beverage, choice of sandwich, and choice of side. There are 4 different beverages, 7 different sandwiches, and 3 different sides. How many different choices are there for a lunch special?

a. $4 + 7 + 3$
b. $4 \cdot 7 \cdot 3$
c. $2^4 + 2^7 + 2^3$
d. $(4^7)^3$

10. A particular state's license plate has 7 characters. Each character can either be a capital letter or number between 1 and 10.

How many license plates are there in which every character is different from the one next to it?

a. $35 \cdot (34)^6$
b. $(34)^7$
c. $35 \cdot 43 \cdot 33 \cdot 32 \cdot 31 \cdot 30 \cdot 29$
d. $(35)^7$

11. A red and a blue die are thrown. What is the probability that the numbers on the two dice are the same?

a. $1/6$
b. $5/36$
c. $5/6$
d. $31/36$

12. A coin is flipped 5 times. Each outcome is written as a string of length 5, where each character in the string is either H for heads or T for tails, such as THHTH. Select the set of strings that holds each of the possible outcomes where, out of the five times the coin is flipped, exactly one of the coin flips comes up heads.

a. {HTTTT, THTTT, TTHTT, TTTHT}
b. {HTTTT, THTTT, TTTHT, TTTTH}
c. {HTTTT, THTTT, TTHTT, TTTHT, TTTTH}
d. {HTTTT, THTTT, TTHTT, TTTHT, TTTTH, TTTTT}