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ORIGINAL ARTICLE

Problem Solving in High School Biology: Students' Agentic Response to Differentiation

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ABSTRACT

Every student comes to science class with unique skills and problem-solving abilities; unfortunately, there is limited research on how to differentiate instruction so that equitable progress can be made for every learner. We used a novel pedagogical approach to differentiate for a wide range of problem-solving abilities when students were learning to solve high school biology problems. Eighty-seven students were given tiered problem sets and asked to choose and solve one of the three differentiated problems; each problem was presented with an explicitly different level of difficulty. Using a sequential explanatory mixed-methods approach, we examined which problem students chose to solve, why and how they chose their problem, and how well the student's choices aligned with their perceived abilities. A majority of students (88%) chose the problem that aligned with their perceived abilities, and the most effective alignment was the problem a little more difficult than they were used to solving. This differentiated approach helped ensure that a wide range of student abilities received equitable problem-solving experiences regardless of ability. Choice and alignment were important to students learning to solve problems.

KEY WORDS: Differentiation, individualized support, problem-solving, scaffolding

INTRODUCTION

Problem solving is a required skill for success in the 21st century (Csapó and Funke, 2017; Pelligrino, 2012); unfortunately, there is "little firm evidence" about how to teach students to solve problems (Csapó and Funke, 2017, p. 20) and how to support their engagement. This gap in research is particularly significant in the context of science education, where students are expected to not only acquire content knowledge but also to apply it in dynamic, often unfamiliar situations. The traditional one-size-fits-all approach to teaching and learning science is not effective because students do not all come to class with the same skills and therefore, what they need to learn is not all the same (Tomlinson et al., 2003; Valiandes, 2015). Differentiation is a promising approach that addresses this challenge because it aligns the teaching methods, learning tasks, and assessment strategies to meet varying levels of student's readiness (Gregory and Chapman, 2012); teachers consider this to be a worthy goal but it is difficult to accomplish (Kahmann et al., 2022). To address this need, this novel study applies differentiation to address the needs of individual students enrolled in larger heterogeneous high school general biology classes (average class size is 34). The aim is for students to engage in moderate problem-solving challenges that either align with or slightly exceed their present abilities, to lead them on paths of solving incrementally more complex problems, and to guide and support them with what they need to improve their problem-solving skills (Danili and Reid, 2004; Gulacar et al., 2014; Tsaparlis and Angelopoulos, 2000; Wood et al., 1976).

LITERATURE REVIEW

Differentiation to Address Student's Needs

Differentiation is a theoretical construct that refers to the alignment of teaching with the unique needs of students (Gregory and Chapman, 2012). Heterogeneous classrooms contain a wide range of learners that include social, cultural, economic, and motivational differences (Tomlinson et al., 2003), students who learn effectively with the style and pace of the teacher, those who do not, and students who are learning a second language. Every student is unique in what they know, what they have experienced, and in their capacity to learn (Valiandes, 2015). Differentiation addresses those differences so that the unique ability of each student is considered, every student is supported, and every learner has the potential to learn (Kahmann et al., 2022; Tomlinson, 2014).

There are two primary "givens" for differentiation to succeed – every student needs to learn the required content, and the unique needs of every student need to be met (Tomlinson, 2014, pg. 3) Students must be challenged "at the proper level of difficulty" to remain motivated and not be overwhelmed (Tomlinson, 2014, p.4). For intellectual growth to occur, tasks should be just beyond what a student can currently accomplish, supported by a mentor or peer that provides guidance to the student when struggling to learn something new (Vygotsky, 1978).

The two actionable components of differentiation are (a) the instructional adaptations made by the teacher (macro instructional adaptations), and (b) the monitoring of every

student's progress (micro instructional adaptations) (Roy et al., 2013). Macro instructional adaptations may include assignment adaptations made by the teacher (Tomlinson, 2014) or flexible or fixed homogeneous ability groups determined by the student's abilities or interest (Corno, 2008). Micro adaptations occur during "the ongoing course of instruction," with the teacher monitoring student progress, providing positive feedback, answering student questions, and asking guiding questions (Corno, 2008, p. 163; Vygotsky, 1978).

Differentiation provides possibilities for student engagement during the learning process. It is generally known that student engagement, involvement, and behavioral and emotional intensity vary in response to instruction that is too challenging or too easy. Instructional supports play a critical role in students' subsequent behavioral, emotional, and cognitive engagement during the learning process; when engagement increases, student goal orientation on the task, focus, intensity, interest (Reeve et al., 2004), and self-regulation (Zimmerman, 2002) are positively effected.

To date, there is limited empirical evidence about ability groups and their use for differentiation within regular and special education classes (Lindner et al., 2021). In an older meta-analysis of within-class grouping by Lou et al. (1996), differentiation increased achievement for students when teachers assigned them into smaller ability groups and those ability groupings were determined by what the teacher perceived of each student's abilities – not by what the students of themselves.

At the primary level, no significant effect has been found for using only differentiated homogeneous ability groupings (Deunk et al., 2018); it was found that successful differentiation requires more than a teacher simply placing students in groups based upon the teacher's assessment of a student's abilities and needs (Deunk et al., 2018). Ability groupings need to be embedded within a "broader educational context" (p. 1) so that equitable instruction can be provided and the needs of diverse students can be met (Wilkinson and Penney, 2014). Most importantly, it has been found that ability groupings that limit a student's educational opportunities are not beneficial because they constrain a student's potential to achieve (OECD, 2012; Wilkinson and Penney, 2014).

While teachers generally agree that differentiation is an important aim, a meta-analysis by Kahmann et al. (2022) found that teachers had "doubts and difficulties" (p. 2) implementing differentiation. Differentiation requires complex pedagogical skills (van Geel et al., 2018, p. 51), and teachers do not necessarily have the resources or time to develop or find the materials they need to align with student's needs (Kahmann et al., 2022). For differentiation to be successful, teachers must monitor the progress of every student, provide individualized support (Bransford et al., 2000; Prast et al., 2015), and achieve standards-driven accountability (McTighe and Brown, 2005). Unfortunately, when differentiation is not achieved, teachers may end up teaching toward "the middle of the distribution" and not addressing the needs of the more and/or less capable students (Varsavsky and Rayner, 2013, p. 789).

However, learning can be supported when teachers interact with students, and students are provided with opportunities to engage and express their own needs. When students play a role in their own development, they have agency (Bandura, 2001), and agency can increase engagement (Reeve and Tseng, 2011) through the expression of student choices, interests, difficulties, and motivations. "Agentic engagement" provides information to the teacher on what is needed for individualized support, and it supports students so that they can communicate with the teacher what is effective for their learning and how to keep their motivation high. When teacher-student interactions are enhanced, it increases the opportunity for better learning outcomes.

Tiered Approaches for Individualized Support

Students need a firm understanding of the underlying subject matter to solve novel problems (Chu and Reid, 2012). Learners need to understand the concepts in genetics, for example, to solve relevant problems in genetics. If a student is asked to solve a problem that demands skills at or below their present abilities, there will be no growth (Tsaparlis and Angelopoulos, 2000), and if a student is asked to solve a problem that is too difficult, the student will become confused and frustrated (Pea, 2004; Tsaparlis and Angelopoulos, 2000). When a student is presented with moderate challenges, they are more apt to persevere, even when the task is difficult (Bransford et al., 2000).

The purpose of well-structured, scaffolded problem sets is to support every student's problem-solving skill development by presenting tasks slightly more difficult than they are used to solving (Gulacar et al., 2014). Problems that present logical steps and lack of "noise" can positively influence growth because students can work on problems within their present range of abilities (Gulacar et al., 2014; Tsaparlis and Angelopoulos, 2000). According to Gulacar et al. (2014), less complicated, less complex tasks should be provided to students with lower cognitive abilities, while more abstract, more complex tasks should be provided to students with higher cognitive abilities. Tiers, or problem scaffolds (as described by Wood et al., 1976), can be created as functional supports so that students can progress from their present mental capacity to that of their next level of development. Tsaparlis and Angelopoulos (2000) recommend having students work on problems that either align with or slightly exceed their present abilities and helping students to solve sequentially more complex problems (p. 144) as they gain experience and confidence. Scaffolded (or tiered) problems can control the elements of complexity that are initially beyond the learner's capacity, thereby focusing students on the elements within their range of expertise and not overwhelming their cognitive abilities (Danili and Reid, 2004; Wood et al., 1976).

To provide additional support, teachers (or more experienced peers) can ask guiding questions, provide positive feedback, and answer student's questions (Vygotsky, 1978). This personalized

support is required so that students do not become overloaded, especially when solving novel problems (Kirschner et al., 2006). Once a student learns to solve a problem type and the algorithm is learned, the answer to that question is no longer considered unknown (Krulick and Rudnick, 1989); this process of learning through scaffolded problem sets and the support of an experienced other allows students to build confidence by working on solving more complex problems in a progressive manner (Wood et al., 1976).

Two studies provide insight into the use of tiered instruction. In the first study by Richards and Omdal (2007), tiered instruction was used to align secondary science content with the needs of low, middle, and high ability students. This tiered approach mostly benefited the students with lower-level abilities. In addition, Richards and Omdal (2007, p. 426) stated that "two or three (tiers) should be sufficient" to address the majority of learners for each instructional concept (in a mixed ability classroom).

In a second study, teachers evaluated students' abilities beforehand and provided tiered problem-solving lessons in analytical geometry for each ability group. The student group that used the tiered approach (with support and scaffolds) achieved better success than the control group that did not use scaffolds. The average and lower-than-average ability learners achieved better results (Bikić et al., 2016).

Purpose of Study and Research Questions

This study focuses on teaching students to solve problems by addressing individual needs through differentiation with a unique twist: Empowering each student to choose his or her desired tier of problem difficulty.

Students are presented with a series of problem sets in which only one of three problems is to be chosen, explicitly presented as having different levels of difficulty.

The following research questions guided this study:

RQ1. Why did students choose their specific problem, and did their reasons for choosing their problem change over time?

RQ2. How did the students' choice of problem complexity align with their perceived abilities to solve it?

RQ3. When learning to solve problems, how did students perceive the value of choice and alignment?

METHODOLOGY

The purpose of this study is to evaluate how students respond to differentiated, three-tiered problem sets, and to determine if students can choose the problem complexity that aligns with their perceived needs. The importance of this approach is twofold – to ensure that students' ongoing needs are met, and to validate the learning and research design through ongoing student feedback.

Research Design

The study used a quantitative-dominant approach (QUAN + qual) (Johnson et al., 2007) with an explanatory sequential mixed methods design (American Psychological Association, 2024; Teddlie and Tashakkori, 2009). The iterative QUAN + qual process (Onwuegbuzie and Combs, 2010; Teddlie and Tashakkori, 2009) was used to encourage a deeper understanding of the student experience and minimize research reflexivity.

Participants

This study was conducted in a U.S. high school with an enrollment of approximately 2,500 students. Eighty-seven students in four high school general biology classes participated in this study; the average class enrollment was 34 students. All students were taught by the same teacher, and the teacher was the first author of this paper. The teacher held an undergraduate degree in biology, a master's degree in education, and had more than fifteen years of science teaching experience. Students were 15–16-years-old (grade 10) except for two students aged 17–18-years-old (grade 12). Student abilities ranged widely, from those learning English as a second language and those who struggle to learn at the pace of teaching in a general education classroom, to the intellectually gifted. All students needed to pass this class to graduate from high school. All students experienced the same learning environment and educational expectations regardless of their participation in the study. Only those students who self-selected themselves into the study and provided a signed consent form with their parent/guardian had their data saved, analyzed, and included in this report. Not all participants provided data for every research question, and the n-value changed (and is noted and addressed) depending on the time within the study. This research is exempt under the pre-2018 Common Rule of the Department of Health and Human Services Protection of Human Subjects, Subpart A, 46.104 Exempt Research (d)(1). The definition for this exemption is as follows:

> "Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods (U.S. Department of Health and Human Services, 2021)."

Materials

Curricular design

There are two phases to this curricular design – the science learning phase and the assessment/problem-solving challenge. The science content was aligned with the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013a). The assessments/problem-solving challenges were aligned with both the NGSS and the Programme for International Student Assessment (PISA) science proficiency levels (OECD, 2017). Data were collected after each assessment/problem-solving

challenge and at the end of the year. Detailed descriptions of both the science content and the assessments/problem-solving challenges are detailed below.

Science content as the basis of the study

The NGSS sets goals for what students should know and be able to do, but the teacher, school, district, and state have autonomy for determining the curriculum and the pedagogical methods (NGSS Lead States, 2013a). In this study, students learned biology by participating in small and large group activities, having discussions, conducting experiments, evaluating demonstrations, experiencing short periods of direct instruction, watching videos, and reading. A culture of problem solving was encouraged. The science learning phase was followed by an assessment where students demonstrated their science content knowledge by solving a novel problem.

Assessment/problem-solving challenges

These problem-solving challenges were designed with three levels of problem complexity (tiers 1, 2, and 3); the easiest problem was offered in tier 1, and the most complex problem in tier 3. All problem-solving tiers assessed student proficiency in the NGSS content standard. The goal was to challenge each student to solve one standards-based problem in high school biology that either aligned with or slightly exceeded their present abilities.

The problem-solving challenges were designed and validated using three parameters: (1) The science knowledge guidelines defined by the (NGSS Lead States, 2013a), (2) The problem-solving guidelines defined by the PISA science proficiency levels (OECD, 2017), and (3) The teacher's pedagogical knowledge of the steps needed for students to build problem-solving skills in that content area.

The three parameters for validating the problem-solving challenges are described below.

Science proficiency guidelines: The NGSS

All assessments/problem-solving challenges were aligned with the NGSS and clarification statements (NGSS Lead States, 2013a), and with what every student should know and be able to do in science (National Academies Press, 2013).

Problem-solving guidelines: PISA science proficiency levels

All tiered problems were aligned with the PISA science initial draft of the science proficiency levels (OECD, 2017). The PISA is an international assessment used to determine student preparation for entering the workforce at the end of compulsory schooling. To understand the range of what students can typically do at the age of 15 in science, the OECD created the initial draft of proficiency scale descriptions for science (OECD, 2017). These PISA proficiency descriptions helped guide and validate the design of the tiers and problem complexity for tiers 1, 2, and 3.

Teacher pedagogical knowledge and problem design

All assessments/problem-solving challenges were aligned with how the teacher understood students to learn the biology content, the steps needed to solve more difficult problems in a progressive manner, and how students have struggled previously when solving problems. According to McDonald and Naso (1986) (as cited in Bransford et al., 2000, p. 156), this approach refers to teachers knowing both their science discipline and the "conceptual barriers" for learning the content. The experience and insight of the teacher were used to create the "roadmap" for the curriculum, and the steps and methods that should be taught. To address the needs of diverse students, the teacher created structural levels of differentiation for the problem-solving challenges at both the macro and micro levels (Corno, 2008). At the macro level, students selected themselves into tiers/ability groupings when they chose problems that aligned with their perceived abilities, and the teacher provided "on the spot" assistance at the micro level when students struggled to solve their problems and needed support.

Every assessment/problem-solving challenge was calibrated for students to show proficiency in the Next Generation Science Standards when solving any of the tiered problems; this ensured equivalency in NGSS learning outcomes while providing different problem-solving choices. This approach is possible because the NGSS do not specify how difficult the problems have to be for students to show proficiency.

To design the problem complexities for each of the tiers, the PISA science proficiency levels (OECD, 2017) were used as guidelines. Figure 1 and Table 1 show how NGSS and the PISA levels were used in combination to ensure equivalency in the content standard while individualizing the problem-solving experience. Figure 1 provides a simple overview of the process, and Table 1 provides a more detailed description.

Figure 1 shows how the NGSS led the teaching of the science content, with the teacher considering how students tend to learn the content and where they typically struggle. The PISA science proficiency levels (OECD, 2017) were used to design assessment problems at three levels of problem complexity. Tier 1 was the least complex problem and tier 3 was the most complex; solving any of the tiers showed proficiency in the science standard. Students participated in six problem-solving challenges/assessments during the academic year.

Table 1 provides a more detailed view of the development of one of the three-tiered problem-solving challenges. Column A describes the Next Generation Science Standards and the clarification statement, describing what each student should be able to do to show proficiency. (Standard HS LS2-2 requires that students be able to analyze trends and "graphical comparisons of multiple sets of data [NGSS Lead States, 2013b].") The NGSS standards do not specify the difficulty of the problems required to show proficiency, so the PISA science proficiency levels (column B) were used to create the tiers of complexity. Column C describes the tiered problems designed in response to the NGSS and PISA science proficiency levels; these problems stipulated what students were asked to do to show proficiency in the NGSS biology content standard.

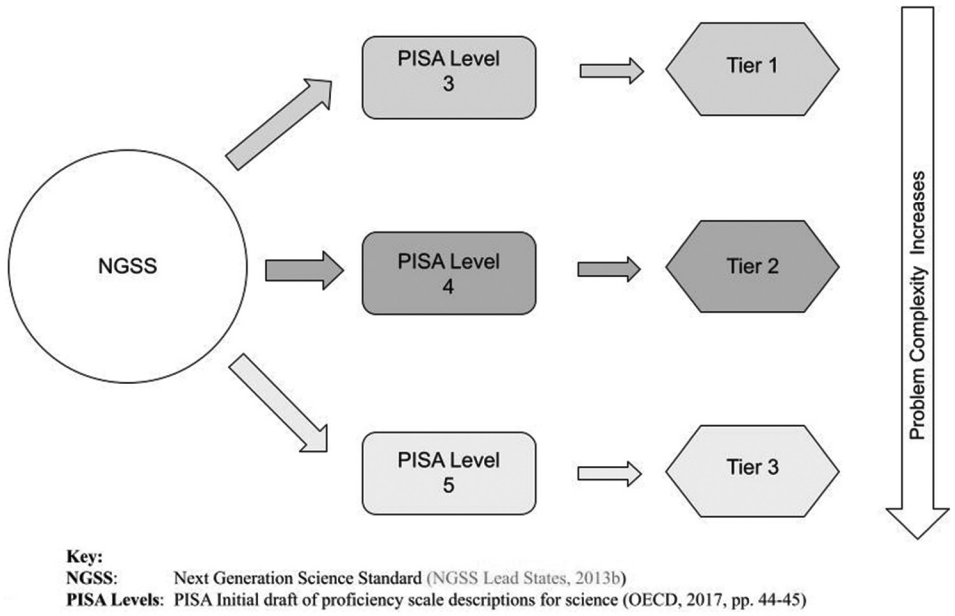

Figure 1: How the Next Generation Science Standards (NGSS) and the Programme for International Student Assessment (PISA) initial draft of proficiency scale descriptions for science informed the design of the three-tiered problem-solving challenge

Table 1: Detailed view of how the NGSS and the PISA science proficiency levels informed the design of the three-tiered problem-solving challenge HS-LS2-2

Column A: The NGSS (HS-LS2-2) and clarification statement (NGSS Lead States, 2013b)	Column B: Selections taken from the PISA Initial draft of proficiency scale descriptions for science (OECD, 2017, pp. 44-45)		Column C: Tiers and descriptions of the three-tiered problem-solving challenge in biodiversity What students are asked to do	
"Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. (Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.)"	PISA level 3	"Students are able to.interpret data in some given life situations that require at most a medium level of cognitive demand. They are able to make a few inferences from different data sources, in a few contexts, and can partially explain simple causal relationships."	Tier 1	1. Interpret trends 2. Suggest factors that negatively affect species' diversity over time.
	PISA level 4	"Students .can interpret data in a variety of given life situations that require mostly a medium level of cognitive demand. They can draw inferences from different data sources . can transform and interpret data and have some understanding who evidence of linked scientific thinking and reasoning and can apply this to unfamiliar situations. Students can develop simple arguments to question and critically analyze ...models, interpretations of data ...in some personal, local, and global contexts."	Tier 2	1. Interpret trends 2. Suggest factors that negatively affect species' diversity over time 3. Explain how one's own actions could negatively affect species diversity.
	PISA level 5	"Students. can interpret data in a variety of life situations in some but not all cases of high cognitive demand. They can... explain some multi-step causal relationships. They can.develop arguments to critique and evaluate explanations, models, interpretations of data.in some but not all personal, local, and global contexts."	Tier 3	1. Interpret trends 2. Suggest factors that negatively affect species' diversity over time 3. Explain how one's own actions could negatively affect species diversity 4. Design a program to help mitigate biodiversity loss in the ocean (from NGSS HS-LS 4-6*).

*NGSS HS-LS 4-6 was added to tier 3 to increase problem complexity (NGSS Lead States, 2013b). Note: OECD (2017), PISA assessment and analytical framework: Science, reading, mathematics, financial literacy and collaborative problem solving, revised edition, PISA, OECD Publishing, Paris. 44-45 https://doi.org/10.1787/9789264281820-en). NGSS: Next Generation Science Standards, PISA: Programme for International Student Assessment

To use the biodiversity problem-solving challenge as an example of the instructional process (Table 1), the teacher provided a graph that showed the mathematical representation between two trends in the Pacific Ocean –

one trend showing species biodiversity in general and how biodiversity changed between 1960 and 1980, and one trend showing the total amount of tuna and bluefish caught between 1960 and1980 (TERC, 2008). The three-tiered challenges were designed in agreement with Krulick and Rudnick (1989) who stated that the problem should either match or slightly exceed a student's abilities because this allows students to use "previously acquired knowledge, skills, and understanding" to solve problems (p. 5). For tier 1, students interpreted the two trends and suggested factors that may have affected the species diversity over time. In tier 2, students identified factors that affected species diversity over time and then explained how the student's actions may negatively impact species diversity. Tier 3, the most challenging problem, required students to complete tier 2 and design a program to help mitigate ocean biodiversity loss. (Note: NGSS HS-LS 4-6 was added to tier 3 to increase problem complexity [NGSS Lead States, 2013b]).

Implementation of three-tiered problem-solving challenges

The three-tiered assessments/problem-solving challenges were assigned to students at the end of each biology unit. Each student was asked to choose the problem complexity that either aligned with or slightly exceeded their abilities to solve it, and students were encouraged but not required to choose the problem a little more difficult than they were used to solving. Each correct solution earned a letter grade: A tier 3 solution earned an A grade, a tier 2 solution earned a B grade, and a tier 1 solution earned a C grade. All tiers were novel problems designed to assess student's understanding of biology while simultaneously challenging them to improve their problem-solving skills. The first measure of validation was for the teacher to observe and ensure that all students had problems aligned with their needs. The process of student choice created ability groupings, and the decision to differentiate for those groups was made by the teacher beforehand (macro differentiation). Engaging with tiered challenges was a new experience for students.

The instructional sequence and the approximate time for each step are shown in Table 2.

Measurement

A timeline of the quantitative and qualitative data collected during this study is shown in Figure 2. Preliminary analyses occurred after each data collection with a final, integrated analysis at the end of the study. The inclusion of more than one data type aided in revealing deeper relationships between the component parts, and the sequential approach encouraged reflection during the study. Qualitative data helped minimize researcher reflexivity by providing student feedback to the researchers during the study (Nemoto and Beglar, 2013; Maxwell et al., 2016, Chapter 13).

In RQ1, the focus was to determine why students chose their problem and if their reasons for choosing their problems changed over time. Students were asked which problem they chose to solve and why. Answers to the open-ended questions about why they made their choices were collected after Challenges 2 and 3; these informed researchers whether students were choosing the problem because it aligned with their problem-solving abilities, for example, if they wanted to earn a specific grade, or if they wanted to solve the easiest problem. If students provided more than one reason, only their first answer was included in the analysis.

Table 2: Instructional sequence for the three-tiered problem-solving challenges

Instructional sequence	Student steps (Paraphrased)	Time (Approximate)
1	"The three-tiered problem-solving challenge helps you build problem-solving skills."	5 min
2	"Solving any of the problems earns you a passing grade. Solving a level 1 problem can earn you a C grade, a level 2 problem a B grade, and a level 3 problem an A grade."	
3	"You can choose any problem you want but you should choose the problem that aligns with or slightly exceeds your ability to solve it. This process is like exercising your muscles – the more you solve problems, the more you improve. I can help you choose your problem if you need help."	
4	"You are encouraged to challenge yourself a little bit *but not too much*."	
5	"I can help but I cannot give you the answers."	
6	"You can use your notes and the Internet to help you, but the answers cannot be found directly in your notes or on the Internet." (This study was conducted before artificial intelligence services were available.)	
7	The teacher showed the tiered problems on the overhead screen, read each problem aloud, and explained the specifics for each problem. Students had the chance to ask questions. Students were invited to walk up to the table and choose the problem they wanted to solve, and they were invited to change their problem at any time if the problem turned out to be too easy or too difficult.	5–10 min
8	Students walked to the table and chose tier 1, tier 2, or tier 3.	3–5 min
9	Students worked until they finished. A few students changed their problem choice. All students finished their work by the end of the second 50-min class.	Two 50-min classes
10	Quantitative and qualitative data were collected.	10–15 min
Total time		Approximately 135 min

In RQ2, the focus was to determine if there was a relationship between how students choose their problems and how well their choices aligned with their perceived abilities to solve them. Quantitative data were collected to document which problem students chose to solve, how students chose their problem (question 1 in Table 3), and how well those problems aligned with their perceived abilities to solve them (question 2 in Table 3).

In RQ3, the focus was on determining how students value choice and alignment when learning to solve problems. Semantic scales were used to measure student feedback (questions 3 and 4 in Table 3)

Table 4 shows the three research questions and how they align with the quantitative and qualitative questions.

Both quantitative and qualitative data were collected in this study (Table 4). Students were asked why they initially chose their problem (RQ1) and to learn if their reasons changed over time. Students were also asked which level they chose, how they chose that problem complexity, and how well it aligned with their perceived abilities to solve it (Table 4, RQ2). Students' answers clarified the range of perceived abilities within the class, how well the sub-groups thought they aligned their perceived abilities with the problem complexities, and if the most appropriate alignment was at or slightly beyond their present abilities. At year-end, students were asked to determine the importance of both choice and alignment for the differentiated problem-solving challenges (Table 4, RQ3).

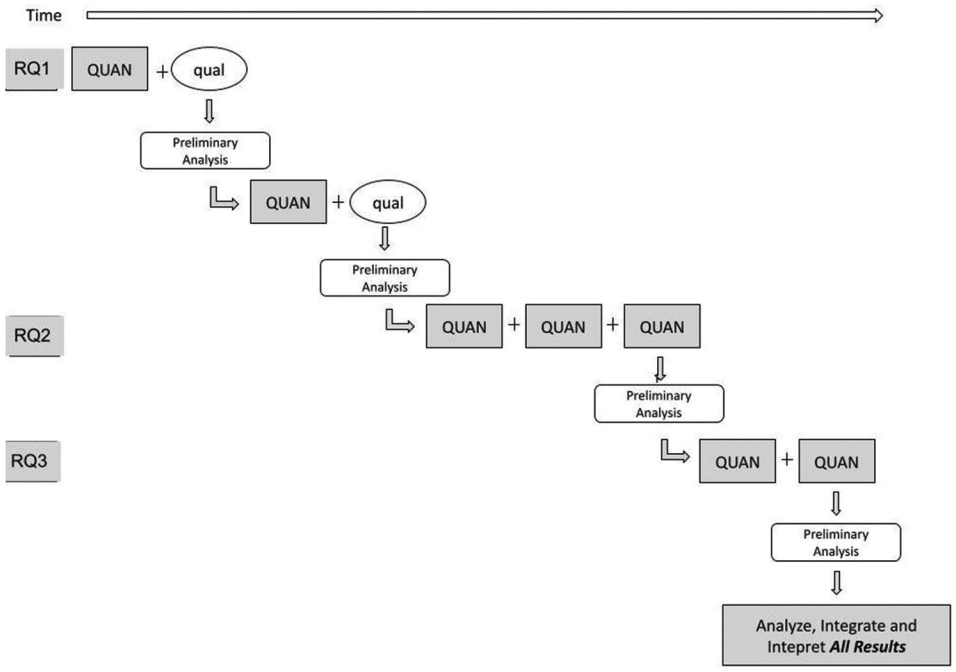

Figure 2: The sequential, explanatory quantitative dominant mixed-methods research implementation matrix

Table 3: Semantic differential scales used in this study

Question	Student answer choices				
1. "Did you choose a problem that was..."	"At your level of understanding, where you wouldn't have to struggle to solve it?"		"A little beyond what you knew how to solve, knowing that you would experience a moderate amount of struggle?"	"A lot harder than you would normally attempt, knowing it would be very difficult to solve and that you would experience a significant amount of struggle?"	
2. "How well did your choice align with your (perceived) abilities to solve it?"	"This problem was too easy for what I am able to accomplish."		"This problem was the right difficulty level."	"This problem was way too difficult."	
3. "What is the value of choice when working on three-tiered problem-solving challenges?" (Data collected at year end.)	Not important	Less important	Average	Important	Very important
4. "What is the value of alignment when working on three-tiered problem-solving challenges?" (Data collected at year end.)	Not important	Less important	Average	Important	Very important

Table 4: The research questions, what students were asked, and the aim of each question

Research question	What students were asked	Aim of the student question
RQ1. Why did students choose their specific problem, and did their reasons for choosing their problem change over time?	"Why did you choose this level?" (Students were asked this question two times during the study to evaluate a potential change over time.) (qual)	To determine why students chose their problem complexity. Was it to align with their abilities or for some other reason?
RQ2. How did the students' choice of problem complexity align with their perceived abilities to solve it?	"Which problem did you choose?" (QUAN)	To determine the problem that students perceived as aligned with their abilities.
	"How did you choose this level?" (QUAN)	To determine if students were choosing at their level of understanding, a little beyond what they knew how to solve, or a lot harder than they would normally attempt.
	"How well did your choice align with your perceived abilities to solve it?" (QUAN)	To determine if their problem choice was too easy, just right, or too difficult for them to solve.
RQ3. When learning to solve problems, how did students perceive the value of choice and alignment?	"What is the value of choice when working on three-tiered problem-solving challenges?" (QUAN)	To determine how students value choice when engaged in differentiated problem-solving challenges.
	"What is the value of alignment when working on three-tiered problem-solving challenges? (QUAN)	To determine how students value alignment when engaged in differentiated problem-solving challenges.

Data collection

The empirical data collected in this study were chosen due to its potential to bridge an existing gap in research and for its transferability and adaptation to future educational studies. Quantitative data were collected at four collection points during the academic year, and qualitative data were collected during the first two points. Students submitted quantitative data using Google Forms on personal computers. Students submitted qualitative data using pencil/pen and paper. Only those students who provided written permission (with their parent's or guardian's permission) had their results evaluated. The approved data were anonymized and securely stored.

Eighty-seven students were enrolled in the study. Not all students responded to all research questions. These differences in n-values have been evaluated and considered within the context of this study. N-numbers are listed alongside each result. The difference in n-numbers was not considered to be a detriment to the results or the analysis of this study.

Procedure

A sequential explanatory mixed-methods design (Buck et al., 2009) was employed during this one academic year. The resulting quantitative-dominant mixed-methods study includes quantitative and qualitative data (Nemoto and Beglar, 2013; Maxwell et al., 2016, Chapter 13).

The mixed-methods implementation matrix shown in Figure 3 is a detailed version of the timing, problem-solving challenges, and research questions asked of students during the study. Figure 3 also includes the number and types of quantitative data collected, and the text of the two open-ended questions. Quantitative data were collected to determine the problems chosen, but open-ended questions were used to deepen our understanding of why students made their choices.

This explanatory sequential design (American Psychological Association, 2024) (Figure 3) starts with a quantitative question, is supplemented with open-ended questions, and is followed by a series of quantitative questions. The combination of quantitative and open-ended questions plus teacher observations provides a more complete foundation for understanding how students respond to problem choice when confronted with differentiated problem sets (American Psychological Association, 2024; Nemoto and Beglar, 2013).

Data analysis

Quantitative data

There were two processes used to analyze quantitative data. When considering students' ability to align personal abilities with problem choices, frequency and Chi-squared tests were analyzed using the IBM Statistical Package for the Social Sciences Statistics 27.0.1.0. These results were organized into a contingency table so that the number of observations for each combination of groups could be analyzed. The frequencies within the contingency table provide insight into the problem complexity that students determined most aligned with their perceived abilities to solve – whether it be at their level of ability, a little beyond their present abilities to solve, or a lot more difficult than they would normally attempt to solve. To determine if there is a relationship between how students chose their problem complexity and how well those choices aligned with their perceived abilities to solve it, a Chi-squared test of independence was conducted to determine if the two variables were statistically related or independent. In other words, the Chi-squared test helped clarify if students were able to analyze the problem complexity and to choose the problem that aligned with their abilities.

During and at the end of the year, questions using semantic differential scales were asked using three- and five-point scales. During analysis, the categories of "not important" and "less important" were combined into one category, and "important" and "very important" were combined into another.

Qualitative data

The answers to open-ended questions were considered unique, coded using qualitative content analysis (Schreier, 2017), and

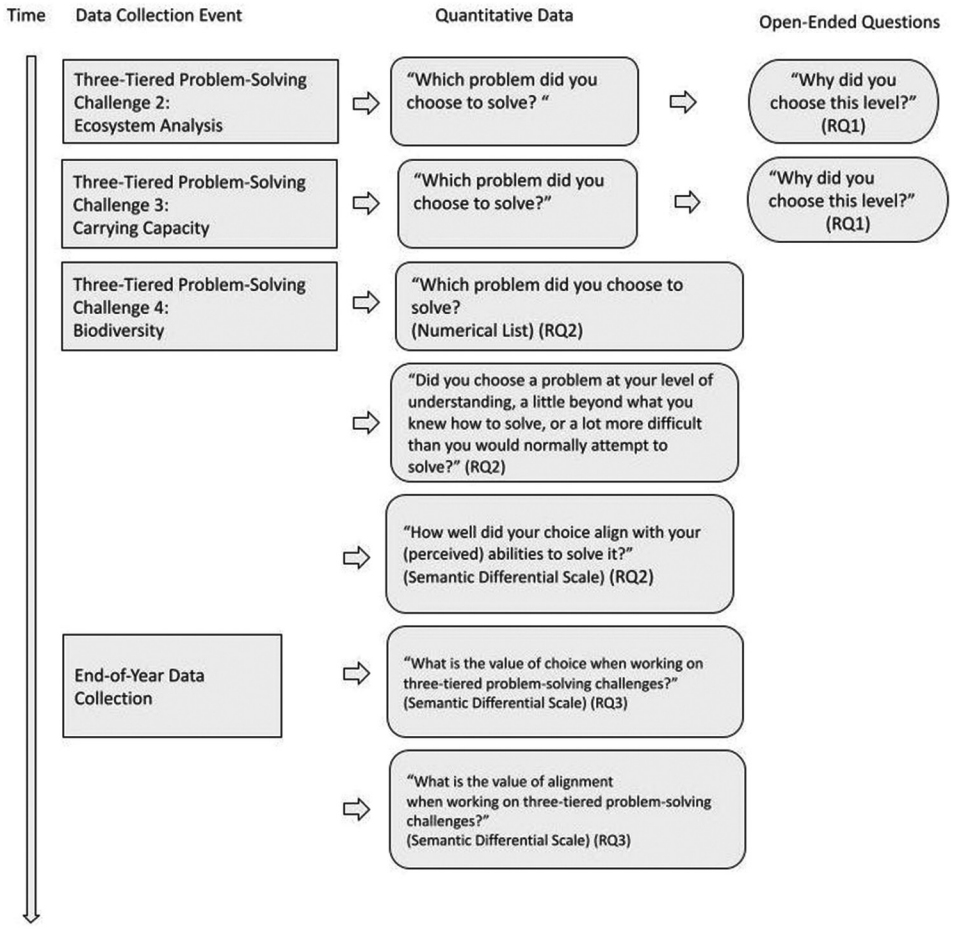

Figure 3: Mixed-methods implementation matrix with questions asked of students

analyzed using Atlas.ti version 9.1.3. The analysis began with familiarization with the data, coding patterns, identifying themes, reviewing those themes, and preparing the analysis (Braun and Clark, 2012). There was an iterative process of pattern seeking across student responses, which meant that each answer was considered three or more times. Inductive reasoning was used to prepare a focused view of the students' answers and their patterns (Kyngäs, 2020). The grouping codes were developed from those patterns and chosen due to their ability to be considered and applied for use within new educational settings. The results were summarized.

Mixed-methods

This study was analyzed using predominantly quantitative data, with qualitative data used to enhance understanding of student responses to the quantitative questions (QUAL + qual) (Onwuegbuzie and Combs, 2010; Teddlie and Tashakkori, 2009). The quantitative and qualitative data were analyzed as the study proceeded with a more thorough and integrated analysis conducted when the research was completed.

FINDINGS

RQ1. Why did students choose their specific problem, and did their reasons for choosing their problem change over time?

Students shared how/why they chose tier 1, 2, or 3 by answering open-ended questions after completing Challenge 2 and Challenge 3. The number of students who participated in Challenges 2 and 3 differed (n = 78 and n = 83, respectively). Three main categories were used in the analysis of student answers: "Wanting Alignment," "Wanting an Intellectual Challenge," or "Wanting a Specific Grade." The wording and intent of each student's response were considered multiple times before being placed into a category. Table 5 shows how student answers were categorized due to wording and subsequent analysis.

Sometimes student answers were straightforward and other times they were more complex. For example, when a student responded, "I wanted an A," this was straightforward for them, pursuing a specific grade. When a student wrote, "I knew I could do it," this was interpreted as the student having confidence in their ability to solve the problem and having perceived alignment. When a student wrote, "I wanted to try that level," this was interpreted as the student wanting an intellectual challenge.

When a student's answer included more than one reason for their choice, a rule was imposed to provide consistency; only the reason that was mentioned first was used for analysis. For

Table 5: How student answers to why they chose their problem were categorized

Category defined by the researchers	Overall message of the student's answer	Examples of student answers
Wanting alignment	Student conveyed confidence, competency, and/or perceived alignment for choosing their problem.	• "I knew I could do it." • "By reading all the levels first and knowing if I'm able to answer it or not." • "It seems like the right difficulty." • "I took the hardest one because I knew how to do it."
Wanting an intellectual challenge	Student conveyed an attempt to solve a problem more difficult than they had previously solved.	• "I decided to challenge myself." • "By challenging myself to a higher level than I was supposed to do." • "I wanted to try that level."
Wanting a specific grade	Student conveyed a specific grade as the most important consideration for choosing their problem.	• "Just by asking myself what grade did I really want." • "I chose whatever gave me the highest grade." • "I just wanted a really good grade that is why pick the level 3."

example, the answer of, "I like to shoot for the highest grade possible," and, "I felt like I understood what the material was telling me" were only coded for the first reason – wanting a specific grade.

Any answer that could not be interpreted within the parameters of this study was relegated to the category of, "Other." For example, the answer of, "I just wanted to do level 3" does not provide enough information, so it was placed into the "Other" category. Student answers were sometimes nuanced, and therefore, errors of interpretation were possible; the intent to convey student answers with integrity was made through the use of multiple, systemic analyses.

The relative percentages were calculated for each answer with the categories of "alignment," "grade," "intellectual challenge," and "other" as the dominant descriptors (Figure 4).

When analyzing the answers of all participating students, the reasons for students choosing their problem were not always the same for both challenges – there was a shift away from choosing a potential grade – and toward seeking alignment and an intellectual challenge (Table 4). The choice of alignment increased from 44% to 60%, the desire for an intellectual challenge increased from 12% to 17%, wanting a specific grade decreased from 36% to 20%, and for the category of, "Other," decreased from 8% to 4%.

When considering the smaller subset of 70 students who participated in both challenges and answered all research questions (Figure 5), the shift continued as it did with the larger group shown in Figure 4, but the percentages differed. Alignment increased from 46% to 60%, choosing for an intellectual challenge increased from 10% to 13%, potential grade decreased from 37% to 23%, and "Other" decreased from 7% to 4% (Figure 5).

To illustrate how students' reasons for choosing their problem complexity changed over time, three qualitative examples are shown in Table 6. The students labeled one and two changed their strategy for choosing their problem from wanting a specific grade to wanting alignment. The third student changed from wanting alignment to wanting an intellectual challenge.

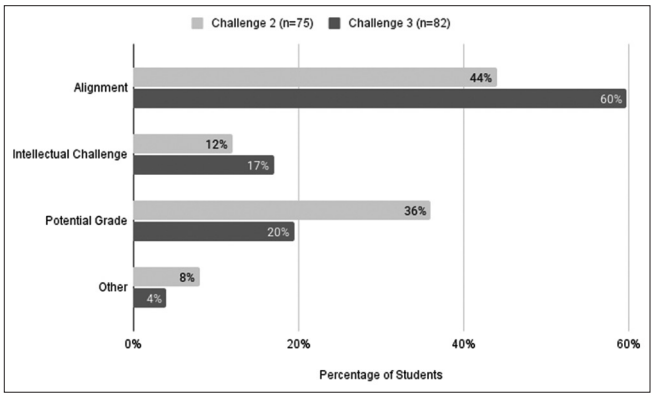

Figure 4: Total students and how they chose their problem: alignment, intellectual challenge, potential grade, or other

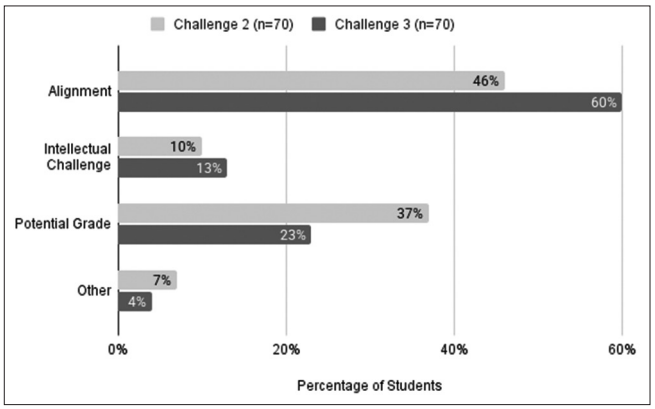

Figure 5: How seventy students chose their problem and how their reasons changed over time (n = 70)

RQ2. How did the students' choice of problem complexity align with their perceived abilities to solve it?

Challenge 4 (n = 75), which followed Challenges 2 and 3, evaluated how well students chose the problem that aligned with their perceived abilities. Students were asked to choose the problem complexity by solving either tier 1, 2, or 3 (tier 1 was the least complex problem and tier 3 was the most complex). Not all students chose the same problem; nearly half of the students chose the most difficult problem, one of

five students chose the easiest problem, and approximately one in three students chose the medium difficulty problem to solve (Table 7).

When asked how well their choice had aligned with their perceived abilities, a majority of students (66 out of 75) perceived their choice to be the "right difficulty," and nine students (7 + 2) perceived their problem to be too easy or too difficult (Table 8).

Table 6: How three students chose their problem in challenges two and three, and how their strategies changed

Student number	Reason for choosing the problem in challenge 2 and how it was coded	Reason for choosing the problem in challenge 3 and how it was coded
Student 1	"I wanted to try my hardest to get the best grade possible so I tried that hardest one." (Grade)	"It was challenging for me but not to the point where I couldn't figure it out." (Alignment)
Student 2	"I wanted a good grade." (Grade)	"Because I thought I could do it." (Alignment)
Student 3	"Wanted to solve level I because it is easy." (Alignment)	"cause i wanted to try it." (Intellectual Challenge)

Table 7: The problem students chose to solve in the three-tiered problem-solving challenge 4 (n=75)

Which level did you choose to solve?	Frequency	Percent
1 (Easy)	16	21.3
2 (Medium)	24	32
3 (Difficult)	35	46.7
Total	75	100

A cross-tab analysis compared students choice of problem with how well that choice aligned with what students thought they could solve (Table 8); a majority of students (41 out of 75) reported that choosing a problem "a little beyond what they knew how to solve, knowing they would experience a moderate amount of struggle" was the choice most frequently aligned with the "right difficulty level." Less than one third of the students (23 out of 75) reported that the "right level" was the problem "at their level of understanding, where they wouldn't have to struggle to solve it." Only 2 out of 75 students reported that when choosing a level "a lot harder than they would normally attempt," was the right difficulty level, and 2 students stated that their choice of problem was too easy. A Chi-squared test of independence compared the observed results with what was statistically expected, and there was a significant difference between "how students chose the level" and "how they perceived the difficulties." This result shows that students deliberately chose the problem that aligned with their abilities, rejecting the null hypothesis that the variables were independent ($\chi^2 = 38.82$, df = 4, $p < 0.001$).

Table 9 provides further details for students choosing Levels 1, 2, and 3. Students who selected Levels 2 and 3 were more inclined to choose problems slightly beyond their abilities (18 out of 24 students, and 19 out of 31 students, respectively), whereas students who opted for Level 1 tended to choose their problem because it aligned with their abilities (7 out of 10 students). In addition, two students found the complexity of Level 3 too easy. Overall, a majority of students (66 out of 75) perceived their chosen problem as the right difficulty level, which suggests that the three-level differentiation process worked to align problems with the needs of most students.

RQ3. When learning to solve problems, how did students perceive the value of choice and alignment?

Table 8: How students chose their problem complexity versus how well that problem complexity aligned with their perceived abilities to solve it (n=75)

How students chose their problem complexity	This problem was...			
	too easy for what I am able to accomplish	the right difficulty level	way too difficult	Total
How did you choose your level to solve?				
At your level of understanding, where you wouldn't have to struggle to solve it?				
Count	5	23	0	28
Expected	2.6	24.6	0.7	28
A little beyond what you knew how to solve, knowing that you would experience a moderate amount of struggle?				
Count	1	41	0	42
Expected	3.9	37	1.1	42
A lot harder than you would normally attempt, knowing it would be very difficult to solve and that you would experience a significant amount of struggle?				
Count	1	2	2	5
Expected	0.5	4.4	0.1	5
Total				
Count	7	66	2	75
Expected	7	66	2	75

Table 9: Problem choice versus the number of students who chose each level and how that choice aligned with their perceived abilities (n=75)

Level chosen	This problem was...			
	way too easy for what I am able to accomplish	the right difficulty level	way too difficult	Total
Level 1 was chosen				
At their level	3	7	0	10
A little beyond	1	4	0	5
A lot harder than normal	1	0	0	1
Total	5	11	0	16
Level 2 was chosen				
At their level	0	5	0	5
A little beyond	0	18	0	18
A lot harder than normal	0	1	0	1
Total	0	24	0	24
Level 3 was chosen				
At their level	2	11	0	13
A little beyond	0	19	0	19
A lot harder than normal	0	1	2	3
Total	2	31	2	35
Total	7	66	2	75

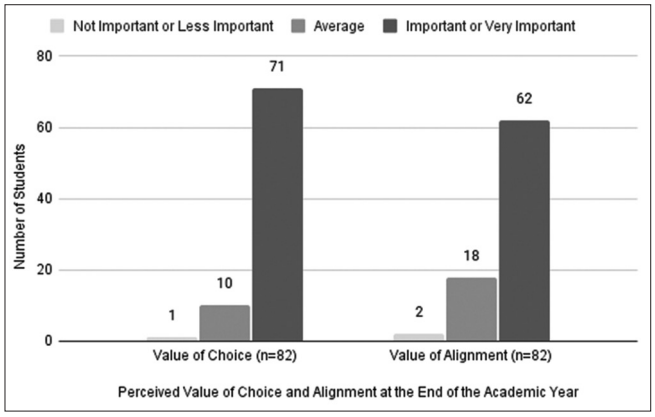

Figure 6: Student's perceived value of choice and alignment (end-of-year likert scale survey, n = 82)

At the end of the academic year, the value students placed on choice and alignment were measured using semantic differential scales (Figure 6). When considering choice, 71 out of 82 students reported that choice is important or very important when participating in three-level problem-solving challenges, 10 were neutral, and 1 student considered choice to be not important or less important (Figure 6). When students considered alignment, 62 out of 82 students considered alignment to be important or very important, 18 students were neutral, and 2 students considered alignment to be not important or less important (Figure 6).

DISCUSSION AND CONCLUSION

This study aims to clarify how students respond to differentiated pedagogy when learning to solve high school biology problems. When students were presented with three-tiered, differentiated problem sets designed with increasing levels of problem complexity (Corno, 2008; Danili and Reid, 2004; Roy et al., 2003; Tomlinson, 2014; Wood et al., 1976), most students (44%) chose the problem that aligned with their perceived abilities, 36% chose the potential grade their could earn, and 12% chose the intellectual challenge (Figure 4).

For the second data collection, students who chose their problem for alignment increased by 16%, students who chose for potential grade decreased by 16%, and students who chose for the intellectual challenge increased by 5%. Students were changing and/or refining their strategies for problem choice over time. If one were to argue that choosing an intellectual challenge is also a form of alignment, the total percentage of students seeking alignment would increase to 77%. When the sub-group of 70 students who had participated in both challenges and answered all research questions was evaluated on their second challenge, 51 out of 71 students (72%) made their problem choice based upon alignment or intellectual challenge (Table 5), a similar result. These results show that students were actively seeking alignment for what they were currently able to solve, or alignment with problems that would give them an intellectual challenge.

A strong statistical result revealed the relationship between how students chose their problem and how well their choice aligned with their perceived abilities to solve it ($p < 0.001$) (Table 7). The crosstab analysis revealed that the most aligned problem choice was the problem "a little beyond what they knew how to solve, knowing they would experience a moderate amount of struggle." It's important to note that students made their choices knowing that the teacher would support them if needed.

A majority of students (66 out of 75) perceived the problems to be the right difficulty level, which suggests that the three-level differentiation process effectively aligned problem complexity with the needs of most students. Further analysis showed distinct patterns for how students chose their problems based upon their perceived abilities (Table 8). A majority of students who selected Levels 2 and 3 chose the problem a little beyond what they currently knew how to solve, whereas a majority of students who selected the least complex problem, Level 1, chose that problem because it aligned with their perceived abilities. Some students found that even the most complex problem was too easy, indicating that more than three tiers may be necessary to challenge students with higher abilities.

These findings confirm previous theoretical and empirical studies on problem solving by Gulacar et al. (2014) and Tsaparlis and Angelopoulos (2000) who found that students should work on solving problems that either align with or slightly exceed their present abilities, and then progress to problems of higher complexity (Tsaparlis and Angelopoulos,

2000, p. 144) (also Danili and Reid, 2004; Krulick and Rudnick, 1989; Wood et al., 1976). These findings agree with the work of Bransford et al. 2000 (p. 61), who stated that students must be challenged "at the proper level of difficulty" to remain motivated.

These findings are also aligned with the principles of self-regulated learning (Zimmerman, 2002), in which students engaged in the forethought phase (planning and goal setting), the performance phase (monitoring and strategy use), and the self-reflection phase (evaluating learning outcomes). Our differentiated problem design enabled students to make choices based upon their perceived readiness and to evaluate their performance in real time to determine whether to progress to more challenging problems. This process supported their agency, which in turn may have enhanced their sense of ownership and motivation (e.g., Bandura, 2001). In particular, students' recognition of the importance of 'choice and alignment' (Figure 5) reflects the value they placed on their own agency in learning. These findings are critical for understanding that students find value in their personal agency when using the scaffolds and differentiated process, and that they recognize the value of the teacher support for their unique needs (Kahmann et al., 2022; Tomlinson, 2014).

Empowering students with the agency of choice gave us the opportunity to record students' self-regulation as it potentially evolved – 16% of the students shifted from choosing for a potential grade in Challenge 2 to choosing alignment or intellectual challenge in Challenge 3. It is possible that this movement represented a concurrent shift in student's self-regulatory strategies due to the evaluation of their learning goals, reflection, revision of their strategies, the planning of their approach, and/or setting new goals (Zimmerman, 2002). Even in isolation, a potential change in self-regulation for 16% of the students is worth contemplating. When these students chose alignment and intellectual challenge over a potential grade, learning became potentially more internalized, an improvement over the external reward of a grade and further potential evidence of an improved learning outcome.

In a time where there is limited research about how to differentiate for students learning to solve problems, this scaffolded, pedagogical approach provided two layers of differentiation – one at the instructional level and another with on-the-spot support (Corno, 2008; Richards and Omdal, 2007, p. 426). Students were supported to learn and be challenged to solve problems in high school biology at their level of competency. This pedagogical structure provided students with an environment where they could be "challenged without being overwhelmed (Pea, 2004; Valiandes, 2015)" and that the unique needs of every student had the potential to be addressed (Bransford et al., 2000, p. 61; Gulacar et al., 2014; Tsaparlis and Angelopoulos, 2000; Tomlinson et al., 2003; Tomlinson 2014, p. 4).

The problem-solving challenges reflect both the rigor of the NGSS (NGSS Lead States, 2013a) and the PISA science proficiency levels (OECD, 2017). The combination of functional scaffolds, student choice, and teacher support provided diverse student populations with the support they needed to build problem-solving skills while simultaneously showing proficiency in the science standard (Chu and Reid, 2012; Kahmann et al., 2022; Kirschner et al., 2006; Tomlinson, 2014). This differentiated approach supported both students and teachers because the teacher was able to address the unique needs of the individual rather than the students as a group; there was no need to teach toward the "middle of the distribution (Varavsky and Rayner, 2013)." Most students were able to choose the problem that aligned with their perceived needs, and the groupings allowed the teacher to provide targeted support for students working in groups with challenges that aligned with their own perceived level of abilities (Corno, 2008; Gregory and Chapman, 2012; Prast et al., 2015; Roy et al., 2003; Tomlinson et al., 2003).

Although there is limited prior evidence on how to use ability grouping within regular education classes (Lindner et al., 2021), this study shows how ability groupings can be implemented within "broader educational contexts" (Deunk et al., 2018) so that instruction is equitable and diverse students can be supported (Wilkinson and Penney, 2014). It offers an alternative to the work by Lou et al. (1996) who showed that student achievement increased when teachers evaluated student abilities, placed them into ability groups, and provided support. Unlike the work of Bikić et al. (2016) who found that support and scaffolds generally favored the average and lower-than-average ability students, this present study shows how differentiation supported a majority of students in high school biology classes regardless of their skills. In addition, the ability groupings used here do not place constraints on students' educational opportunities (OECD, 2012; Wilkinson and Penney, 2014); in fact, the ability groupings created through differentiation expanded students' opportunities with growth at a rate comfortable for the student. This study agrees that students need the support of the teacher to answer questions, ask guiding questions, and provide positive feedback (Corno, 2008; Vygotsky, 1978).

Overall, these findings help fill a research gap in how to differentiate for students learning to solve high school biology problems (Csapó and Funke, 2017, p. 20). Hopefully, this work will assist teachers who have "doubts and difficulties" in implementing differentiation for students (Kahmann et al., 2022, p. 2) and those who support them.

Implications

This study shows how scaffolded problem sets, choice, and individualized support can be used to differentiate for students learning to solve novel problems in general high school biology. This approach is more equitable than the one-size-fits-all approach to teaching problem solving because it addresses the needs of every student. Students can focus on problems that align with their present abilities – not problems that are too difficult or too easy for them to solve – and they can

sequentially build their problem-solving skills by working on problems that slightly exceed their present, perceived abilities. This approach supports the needs of individual students, but also the teachers, districts, and governmental organizations tasked with addressing the educational needs of all.

This is a novel approach, but it is readily available for teachers of any skill level. The first step is to consider the content standards in terms of what is required for students to learn in science, and then build scaffolded problem sets so that learners can choose the problem (or problems) that align with their perceived needs. For a teacher to start, they should build scaffolded problem sets with small, three-question assessments at the end of a sub-unit – providing students with three problem-solving tiers and asking them to choose the problem they can solve by themselves or with support. The teacher should observe how students respond, how they ask questions, what questions they ask, what happens to student motivation, how students persist, and what problem-solving level (or levels) students choose to solve. Teachers should make sure to ask students what worked and what didn't work with the tiered challenges. After the teacher reflects upon this work and makes adjustments (and hopefully collaborates with another teacher), they should try another tiered assessment the next week. (Be forewarned that some students may request even more difficult problems than is presented in the third tier.) This ongoing process of observing, collecting information, reflecting, and trying again is an iterative, systematic approach that can potentially result in improved learning outcomes, increased student agentic engagement (Reeve and Tseng, 2011) and enhanced differentiation skills for the teacher.

This iterative process takes time to learn and implement, and it requires teachers to be open-minded about its development both for themselves and the students. Since this process does not necessarily depend on resources provided by the school or community, it can be readily attempted in schools of any economic reality. Optimally, this approach could be developed and studied within teacher training schools.

Limitations of this Research

This is a novel, action-based research study conducted within one school with one teacher as researcher. There are no prior empirical studies from which to compare. The teacher as researcher was a participant in the process. To mitigate potential researcher bias, validation and triangulation strategies were integrated within the study design.

To validate the study design, the techniques shown here were developed and refined over a two-year period before the research study began. Over those two years, tiered challenges were presented to students, and students provided important and frequent feedback on what was working and what was not working with the problem-solving challenges. The teacher as researcher reflected upon the students' feedback and their own personal observations, and instituted changes, as appropriate, in response to this feedback. These findings were shared and discussed with students to verify their accuracy, and a continuing and iterative cycle for improvement continued as part of the research design. This development process strongly aligns with the characteristics of design-based research (e.g., Anderson and Shattuck, 2012).

As this research study emerged, refinements were made, as needed, to ensure that students of all abilities were provided with the potential for differentiated, individualized learning. A controlled experiment was not implemented for this study because the teacher could not ethically teach some students in a less-than-effective way to have both control and variable groups.

To mitigate researcher bias, the teacher as researcher reflected upon their own biases on an ongoing basis to ensure that the data analysis was separate from personal beliefs.

Triangulation was used to maximize the validity and reliability of these results (e.g., Ertesvåg et al., 2020). Quantitative and qualitative methods were used systematically using both Likert scale statements and open-ended questions. All data were coded and anonymized so that the five collaborating researchers working were blind to the subjects' identities. Statistical methods were used to validate the findings of the study, especially important due to the one teacher as researcher and the sample size.

This work lays the foundation for larger, controlled, statistical studies within a variety of cultural and pedagogical contexts. Research should extend beyond the boundaries of high school biology.

Methodology limitations for students

Students self-reported their data. Some students were second language learners and/or students who tended to struggle when learning at grade level. Several students asked for assistance when choosing their problem; help was given. The teacher reached out to students who acted uncertain about how to choose their problem. It is not known whether additional students were confused about alignment and did not ask for help. The impact of this limitation is considered minimal because the teacher was giving attention to struggling students, asking questions, and working to minimize student issues.

Research process limitations for students

1. Students needed time to learn how to choose problems that aligned with their abilities. The change from focusing on a grade to being asked to choose the problem for alignment was new and challenging to many students. Results for RQ1 and RQ2 show how students learned how to choose their problem, and how it took time to develop these skills. The impact of this limitation is minimal because the student's learning process became part of the research study. In future studies, it would be a mistake to ignore this aspect of the problem-solving learning process. Future studies need to incorporate time into the research timeline to allow

students to build the reflective skills to choose problems that align with their abilities

2. It is not known if students were affected by response bias. In the future, it would be helpful to offer students a private method for choosing their problems. The discomfort of choosing for some students was visible when selecting their problems from a common table.

Future Studies

This study revealed several large gaps in the empirical research for using differentiation to teach problem solving (Csapó and Funke, 2017, p. 20) and the use of ability groups for regular and special education classes (Lindner et al., 2021). The field of education would benefit from research in the following areas:

1. Under what contexts and in what frequency are the differentiated problem-solving challenges and student choice most beneficial for high school biology students? (It is recommended that the most recently created PISA proficiency scales in science be used).
2. Under what contexts can the instructional methods used in this study be applied to other subject areas and grade levels?
3. When students are engaged in tiered problem-solving challenges over time, what changes occur in students' self-efficacy, grit, and problem-solving abilities?
4. What are the costs/benefits of teaching problem solving with differentiated problem-solving challenges compared to the costs/benefits of using computerized, skill-building programs? How are sub-groups affected with each approach?

Conclusion

This study challenges the belief that students of all abilities should be presented with the same high school biology problems and expected to achieve the same results. The combination of functional scaffolds, student choice, and teacher support provided differentiated support for diverse students so that every student had the potential to build problem-solving skills and show proficiency in the science standards (Chu and Reid, 2012; Kahmann et al., 2022; McTighe and Brown, 2005; Tomlinson, 2014). These findings directly contradict the traditional and ineffective one-size-fits-all approach to teaching and learning (Valiandes, 2015), and they support the pedagogical approach of combining scaffolds and student choice to achieve problem-solving development. A majority of students learned how to choose the problem that aligns with their perceived abilities, and the teacher was able to provide on-the-spot support when students struggled. Students considered choice and alignment to be important or very important when they were learning to solve problems.

For those concerned with higher-ability students being under-challenged, this differentiated problem approach addresses that concern. For those concerned about supporting students with learning challenges or needing more support and scaffolding, this differentiated approach addresses that concern. For the teacher who is overwhelmed with trying to differentiate for diverse students, the instructional adaptations of tiers, student choice, and ability groups support the teachers to focus on helping students' on-the-spot, so that students are solving problems within their reach – not striving to build skills too many steps beyond their control (Varsavsky and Rayner, 2013). With student's abilities in heterogeneous classes ranging from those who struggle to learn, to second language learners and high achievers, this approach supports students as they improve their skills individually, while also working side-by-side in larger class groups. The ability groupings created through differentiation and choice do not constrain individual student growth; they enhance them (OECD, 2012; Wilkinson and Penney, 2014). The skills needed to solve each tiered problem provided feedback to the student, teacher, and parents about what individual students were able to achieve/not achieve with the differentiated support. This individualized information is not so readily available when students are assigned a list of problems, asked to solve all of them, and given a numerical grade for the number of correct answers. The scaffolds provide transparency into what each student knows and what they do not know when solving problems. This feedback is especially important for the students who did not master the problem-solving skills taught at earlier grade levels and need additional support. The scaffolded, problem-solving approach helps ensure that the intellectual growth of each student can be supported, even if the student has experienced lapses during their education timeline, struggled with their academic progress, or needs to be challenged beyond their grade level.

In conclusion, this study explored how differentiated instruction can be used to foster problem-solving skills in a general high school biology class. The findings suggest that when instructional strategies are tailored to students' varying readiness levels and learning needs, students become more engaged and better equipped to tackle complex, biology-related problems regardless of their initial ability level. This highlights the potential of differentiation not only as a tool for increasing students' knowledge but also as a meaningful strategy for promoting equitable science education. We would like to end this paper with a student's remark that captures the heart of the approach:

"With these methods, everyone is challenged. No one is left behind."

— 16-year-old student

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