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Exploring educational experiences that correlate with self-directed learning in college students seeking to pursue science, technology, engineering, math, and medical (STEMM) fields

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Educational experiences available to high school students have the potential to provide learning opportunities within science, technology, engineering, mathematics, and medicine (STEMM) that lead to student success in college and beyond. Therefore, the goal of our research was to identify whether participation in STEMM-specific outreach and pathway programs (OPPs), advanced placement/international baccalaureate (AP/IB), or dual enrollment correlate with self-directed learning (SDL) skills. Our population is composed of recent high school graduates matriculating into STEMM focused college programs. We collected responses from 339 students nationwide to assess their (1) experience with SDL, (2) the behavioral trait for SDL, and (3) the application of SDL in a newly developed situational judgment case. Our results demonstrate that those who have OPP experiences did not differ from their non-OPP counterparts regarding any aspect of SDL. However, dual enrollment significantly correlates with experience with components of SDL ($r = 0.206$, $p < 0.001$). Interestingly, AP/IB significantly correlates with the SDL behavioral trait ($r = 0.145$, $p < 0.05$) as well as the application of SDL skills ($r = 0.202$, $p < 0.001$), but not SDL experiences. This work identifies opportunities for improving the development of SDL within external and internal educational experiences for students interested in pursuing a career in STEMM.

KEYWORDS

self-directed learning (SDL), high school, outreach and pathway programs (OPP), advanced placement (AP), international baccalaureate (ib), and dual enrollment (DE)

1 Introduction

Self-directed learning (SDL) is a vital educational strategy, especially for students pursuing careers in science, technology, engineering, mathematics, and medicine (STEMM) fields. The concept of SDL was introduced by Knowles in 1975 and is composed of five components: (1) diagnosing one's learning needs, (2) formulating learning goals, (3) identifying human and material resources for learning, (4) choosing and implementing appropriate learning strategies, and (5) evaluating learning outcomes with or without the help of others (Knowles, 1975). Individuals who practice SDL take control of their learning, identify resources, and acquire knowledge independently. The ability to engage in SDL is paramount in rapidly evolving landscapes, such as STEMM, where technological advancements and data-driven insights are commonplace.

As students enter college, they face an abundance of new concepts and are expected to evaluate the credibility of ideas without relying on flawed or inappropriate sources. Moreover, success in STEMM fields is based on a continuous pursuit of knowledge, which requires skills that support lifelong learning (Loeng, 2020; Rillera Marzo and Marzo, 2018; Skrentny and Lewis, 2022). Therefore, it is essential to foster behaviors associated with SDL early in one's academic journey, preparing students to meet the demands of their chosen fields.

SDL is especially beneficial and necessary for navigating the complexities of STEMM subjects, where innovation and continuous learning are crucial for professional growth and advancement (National Academies of Sciences, Engineering, and Medicine et al., 2020). The behavioral trait of being a self-directed learner (SDL behavioral trait) is positively associated with work drive, sense of identity, self-actualization, and interest in science and math. In addition, the SDL behavioral trait is associated with higher grade point averages in U.S. middle school, high school, and college students (Lounsbury et al., 2009). The literature illuminates the relationship between SDL, academic achievement, and self-efficacy, as academic self-efficacy is one of the attributes present among self-directed learners (Cazan and Schiopca, 2014; Hood et al., 2020; Saeid and Eslaminejad, 2017). Academic self-efficacy is defined as the intrinsic belief that one will succeed in a task, which in turn affects other aspects of learning behaviors (e.g., initiation, time management, and motivation). Additionally, the "future time perspective," which is defined as the learner's ability to reckon with the future prospects of their goals based on current behaviors, was shown to significantly predict academic self-efficacy (Karataş et al., 2023; Saeid and Eslaminejad, 2017). Promoting SDL can directly impact self-efficacy and their subsequent achievement.

Students who practice SDL move beyond rote memorization and studying for a score; rather, students proficient in SDL analyze, process, and integrate materials into their existing knowledge with little guidance. Moreover, self-directed learners take on the responsibility of learning and become active participants in developing their thoughts, feelings, and actions necessary to achieve their learning goals. This ultimately promotes their academic and professional achievement. Indeed, academic success, as measured by grade point average and ACT scores, as well as cognitive factors such as verbal, abstract, and numerical reasoning, are associated with SDL (Lounsbury et al., 2009; Tekkol and Demirel, 2018). It is

also associated with academic self-efficacy, achievement motivation in students, and success in STEMM fields (Meng et al., 2019; Saeid and Eslaminejad, 2017). While SDL is entrenched within adult education, efforts currently exist within K-12 education to help students develop this critical skill (Alwadaeen and Piller, 2022; Bolhuis and Voeten, 2001; Stol et al., 2023; Voskamp et al., 2022).

1.1 Factors that impact SDL

While it is well established that SDL is important for adult learners, there is no clear understanding of what prepares individuals to engage in SDL. SDL is driven by behavioral factors such as personality traits, self-efficacy, and cognitive processes such as task switching, inhibitory control, and working memory (Cronin-Golomb and Bauer, 2023). It is unknown whether certain individuals innately express high levels of SDL readiness and the ability to apply SDL (SDL application), or if specific learning experiences improve SDL readiness. Lounsbury et al. utilized a large sample of middle school, high school, and college students and found the trait of being a self-directed learner had a positive relationship with grade-point-average. Furthermore, the SDL trait has a positive association with several other personality traits such as conscientiousness; emotional stability; extroversion; openness; agreeableness; optimism; work-drive; vocational interest- including interest in science, math, and medicine; and cognitive aptitudes (Lounsbury et al., 2009). The association between SDL and personality traits such as agreeableness, conscientiousness, intellect/imagination, extroversion, and emotional stability was also found among adult learners enrolled in health professional programs (Slater et al., 2017). Independent factors such as age and previous level of education also demonstrate an association with SDL in adult learners and adolescents (Slater et al., 2017; Uus et al., 2021). Indeed, an individual's ability to utilize SDL varies throughout their lifetime (Cronin-Golomb and Bauer, 2023). It is also possible that social determinants of learning, such as economic stability and social environment, can impact SDL as this has been associated with academic performance (Rasberry et al., 2019; Sanderson et al., 2021). Together, these indicate that a mix of personal and environmental factors plays a role in SDL. This interpretation is also supported by a recent systematic review of self-directed learning in undergraduate students (Wong et al., 2016).

1.3 Evolution of SDL and how it is assessed

The understanding of SDL has evolved due to variations in its implementation at differing educational levels and fields. This has led to a lack of standardized guidelines aimed at developing and assessing SDL skills among students. In response to this, Taylor et al. underwent a systematic review of SDL assessment in health professional programs (Taylor et al., 2023). They developed a seven-component SDL framework that builds upon Knowles's original conception of SDL after a review of the literature. This framework, while specific to health professions, can be adapted for broader use in STEMM education. We briefly elaborate on the framework

here; for a more complete discussion, please see the original sources (Knowles, 1975; Taylor et al., 2023).

Individuals must:

1. Take initiative of their own learning. This can be done independently or with others
2. Self-assess/diagnose their own learning needs. This leads to identifying gaps, developing self-awareness, and reflecting on what can enhance or limit their own growth
3. Formulate learning goals. They can work with others to develop a learning plan but are responsible for the planning
4. Identify resources. These resources can be material or human
5. Identify appropriate learning resources by appraising information resources for credibility and relevance
6. Choose and implement appropriate learning activities that develop and maintain competence and achievement of goals
7. Evaluate learning outcomes. This can be done individually or with the assistance of an evaluator's feedback on their information seeking skills. They should also evaluate learning results from formal and informal assessments and discover future learning needs

SDL has been assessed in a variety of ways. Self-assessment and perception-based methods are the most common (Cadorin et al., 2017; Taylor et al., 2023). However, other methods, such as knowledge- and reflection-based assessments, have been utilized. Moreover, SDL itself can be measured by exploring the SDL behavioral trait, readiness to apply SDL, and SDL application (Ricotta et al., 2022). Indeed, Taylor et al. (2023) found that it may be beneficial to measure SDL in multiple ways, as assessing multiple aspects of SDL was found to improve study quality (Taylor et al., 2023). The benefit may be due to an increase in the amount of data available or the use of an assessment less prone to social desirability response bias.

1.4 Educational opportunities that have the potential to promote SDL

Participation in formal educational programs such as Advanced Placement (AP), International Baccalaureate (IB), and dual enrollment courses (where high school students are enrolled in college or university courses) can significantly increase interest in STEMM careers and pave the way for entry into the STEMM field (Jewett et al., 2022; Smith et al., 2018). AP, IB, and dual enrollment are considered advanced offerings for high school students, but their innerworkings differ. Both AP and IB programs are designed to provide high school students with coursework that aims to develop critical thinking, analytical skills, and a deeper understanding of fundamental concepts. AP courses typically occur over a year and multiple courses can be taken at a time, while IB is a program that encompasses six courses across two years and is recognized internationally. Even though these programs have different structures, they have many similarities. For example, students who participate in AP and IB are typically high-achieving students (Warne, 2017), and prior research indicates that these students achieve similar graduation success at college (Schumacker, 2014). Students in both programs can take a subject examination

after completion and may be granted credit based on the policies of the institution of higher education they attend. While IB is a comprehensive program, both educational experiences are taught by high school teachers. In contrast, depending on specific state and districts' policies, dual enrollment may occur in a college or university setting alongside adult learners, and successful completion results in postsecondary credit. Due to the setting, individuals are expected to be more self-directed in their learning. Indeed, higher levels of self-directed learning skills are associated with academic success in college (Tekkol and Demirel, 2018).

1.5 Research focus

Participating in advanced offerings have been associated with college readiness and can improve pre-college competencies (An, 2013; Wyatt et al., 2015). However, opportunities to improve pre-college competencies exist outside the formal educational process. Taking part in OPPs focused on STEMM early in the educational process can foster a sense of inclusion and encourage students to continue to pursue STEMM in higher education (DuBois et al., 2011; Jung et al., 2023; Rocha et al., 2022a; Rocha et al., 2022b). However, it is unknown if participating in these programs is positively associated with behaviors linked to academic success, such as the components of SDL. We hypothesized that AP, IB, dual enrollment, and STEMM OPPs are potential opportunities for establishing SDL and associated skills in the academic life of high school students. It is further speculated that the aforementioned programs help to reduce achievement gaps and help students with successful college matriculation and completion.

In this study, we explore the following questions among matriculating college students:

1. What type of educational experiences correlate with SDL?
2. Are there student demographics that correlate with SDL?

2 Materials and methods

2.1 IRB approval

The Oakland University Institutional Review Board approved this study in August of 2022 (Protocol # 2022-346). All participants were informed of confidentiality and gave informed consent before participating in the study.

2.2 Recruitment

We recruited 339 first-year college students who graduated from a U.S. high school between September and October 2022 through Centiment LLC's data collection platform, as well as by word-of-mouth. All participants were screened to ensure interest in STEMM-related fields, and the data presented in this manuscript are part of a larger study.

Due to a technical error made when designing the survey attention check question, only 288 of the 339 participants were

TABLE 1 Demographics of the individuals enrolled in the study population.

Gender*	Percentage (%)	Number (N)
Female	54.3%	184
Male	43.1%	146
Non-binary	2.4%	8
Prefer not to respond	0.3%	1
Race/Ethnicity**		
AA/Black	33.6%	114
Asian	6.2%	21
Hispanic (any race)	28.6%	96
Native American	2.9%	10
Pacific Islander	0.6%	2
White	39.2%	133
Multi-racial	5%	19
Other	9.4%	32
Prefer not to respond	2.7%	9
Income		
< 25,000	24.0%	81
25,000–49,999	30.4%	103
50,000–74,999	17.1%	58
75,000–99,999	13.0%	44
100,000 or more	11.5%	39
Prefer not to answer	4.1%	14
First Generation College Student		
Yes	56.0%	190
No	43.7%	148
No answer	0.30%	1
Advanced Placement/International Baccalaureate (AP/IB)		
Yes	58.1%	197
No	41.9%	142
Dual Enrollment		
Yes	59.9%	203
No	40.1%	136

*One participant selected male and non-binary. **Individuals were allowed to select multiple fields. 5% of respondents are bi/multiracial:0.6% Asian and Native American, 1.2% African American and White, 1.2% Asian and White, 0.3% Native American and White, 0.6% African American and Asian, 0.9% Native American and African American, 0.3% Asian and Pacific Islander, and 0.3% African American, Native American, and White.

allowed to complete the situational case and the SDL scale by Lounsbury et al. (2009). As such, those analyses are focused on individuals that completed these sections.

2.3 Demographic information

Demographic information gathered from participants can be found in Table 1. Specific components of demographic information include race and ethnicity, gender, age, estimated

household income, number of individuals within the household, first-generation college status, and ZIP Code. For our analyses, individuals who self-selected Black/African American, Pacific Islander, Hispanic, and Native American were considered underrepresented minorities (URM) according to the National Science Foundation definition (National Science Foundation, 2023). Educational opportunities explored are 1) participation in AP or IB, 2) dual enrollment status in high school, and 3) OPP experiences. In this study, both AP and IB programs were considered as one variable due to the programs occurring in a high school setting, being taught by high school teachers, and similarities in student populations, outcomes, and requirements for students to achieve a certain score to qualify for college credit or being allowed to pass out of a college course. Moreover, the High School Longitudinal Study of 2009 recently updated by the National Center for Educational Statistics combines AP and IB program participants to report the results of their studies (Dalton et al., 2018). This differs from dual enrollment programs as they may occur in a college or university setting, successful completion leads to postsecondary credit, and most differently from AP/IB, are taught by college or university faculty.

2.4 Measuring OPPs

A survey was administered to respondents comprised of questions regarding the quantity of different OPP experiences (0, 1, 2, 3, and 4 experiences) and measuring SDL in three ways: the SDL behavioral trait (Lounsbury et al., 2009), SDL experiences, and SDL application (see section 2.5 and Supplementary material). Individuals were asked the following questions to assess OPP experiences:

1. Have you ever participated in a program or outreach activity geared at recruiting young adults, adolescents, or children into the science, engineering, technology, math, or medical fields?
2. Have you ever participated in science fairs outside of those that may have been required for school?
3. Have you ever participated in Math Olympics, Science Olympics, robotic clubs or competitions, or any other science, tech, engineering, math, or health-related educational competition?
4. Have you ever participated in an after-school, before-school, weekend, or holiday/summer break science, tech, engineering, math, or health-related program class or camp?

This allowed us to explore how increasing the number of OPP experiences impacted SDL. The type of OPP experience was not included as a factor in the analysis. The survey questions can be found in the Supplementary materials.

2.5 Measuring SDL

SDL is a complex process that involves a range of competencies, including self-assessment, goal setting, identifying resources, and evaluating outcomes. Multiple assessment methods should be used to measure SDL accurately. Indeed, Taylor et al. recently

published a systematic review where they explored the types of SDL assessments in healthcare education research (Taylor et al., 2023). Higher quality was associated with studies that utilized more than one assessment or those that were knowledge-based rather than perception-based (e.g., focus groups, reflections, SDL readiness surveys, etc.). Thus, we utilized the theoretical framework postulated by Taylor et al. and measured SDL attributes within the study population using three distinct approaches. Specifically, we used 1) SDL experience, 2) the SDL behavioral trait, and 3) SDL application. This approach improves the validity and reliability of the overall measurement, caters to different learning styles and backgrounds, provides richer data for analysis, and aligns the assessments with the theoretical framework of SDL. By using various methods, educators can gain a better understanding of a student's SDL abilities in different contexts and ensure that the assessments are based on a solid conceptual foundation. The relationship between the scales is illustrated in Figure 1. Moreover, all three scales were mapped to the SDL framework as shown in Figure 2.

2.5.1 SDL experience

A previously developed 5-item survey was used to identify specific aspects of SDL that students had experience with (Kemp et al., 2022). All five items map to the seven components of SDL [Figure 1 and (Taylor et al., 2023)]. The aggregated total of all responses was used to determine total experience with SDL. The maximum score an individual could receive was five.

2.5.2 The SDL behavioral trait

The self-directed learning scale by Lounsbury et al. was selected to measure SDL as a behavioral trait. This scale is validated for use with high school and college students. This 10-item scale with responses made on a 5-point Likert-type scale measures the SDL behavioral trait among adolescents and young adults (Lounsbury et al., 2009). Lounsbury found a Cronbach α of 0.87 in high school students and 0.84 in college students. The Cronbach's α calculated on these items for the current study of matriculating college students was found to be 0.87, which was expected given the similarity between populations. A composite variable was created that added all of the scores of the subcomponents together creating a scale from 10 (Strongly disagreed with participating in all 10 sub-components) to 50 (Strongly agreed with all of the components). We also mapped the Lounsbury scale to the seven components of the SDL framework (Figure 2), and explored the correlation between SDL experiences and the SDL behavioral trait among our participants. We found a weak, significant correlation between these two scales ($r = 0.283, p < 0.001$).

2.5.3 Situational judgment case validation and question selection

Although knowledge-based measures are good predictors of academic performance and achievement, research shows that performance measurements on situational judgment cases predict cognitive and related behavioral skills such as motivation, problem-solving, and coping (Cousans et al., 2017; Warwas et al., 2023). SDL is a good candidate to be tested via situational judgment cases due to these relationships (Lounsbury et al., 2009). Therefore,

we developed a representative situational case to assess the ability to apply SDL. Initially, two situational judgment cases with responses made on 5-point Likert-type items (central option available) were created. After validation, one case was dropped due to poor fit (see Supplementary materials for details on case development and validation). The Medical Education Research Study Quality Instrument guidelines were used for validating the case. This instrument identifies that theory, guidelines, experts, and existing instruments can be used to identify or refine survey instruments; the internal structure can be confirmed by reliability and factor analysis; and relevant evidence of relationships to other variables such as expert-novice comparisons and predictive correlation with other variables can be used for assessing validity (Cook and Reed, 2015). Below we briefly outline how the final case used for analysis in this study was developed and validated.

The situational judgment case was developed by three researchers (KK, DH, and ARN) and reviewed by experts. Twelve individuals with backgrounds in higher education, college administration, science, and medicine were presented with the case and asked to give their opinions as experts. The expert score was used to determine if each behavior was considered appropriate. The case was then mapped to the existing seven components of the SDL framework independently by two of the researchers (KK and ARN; See Supplementary Tables 1, 2). Two questions in the case did not sufficiently map to SDL components but were retained as they mapped to a related concept, self-efficacy (Hayat et al., 2020). Correlation matrix was constructed for the nine questions with six of the nine questions significantly correlated. All six of the retained items mapped to the SDL framework (Supplementary Table 2). The reliability of the final 6-item scale was found to be Cronbach's $\alpha = 0.75$.

A correlation was also run to assess how well the case aligned with the established SDL scales: the SDL behavioral trait and the SDL experience (Supplementary Table 3). This case had a significant, moderate correlation with the previously validated survey of SDL experience and a strong, significant correlation with the SDL behavioral trait ($r = 0.368, p < 0.001$ and $r = 0.557, p < 0.001$). A composite score was created for the judgment case and used for analysis. One participant was removed due to failure to respond to all of the questions. The final population for analysis was $N = 287$.

2.6 Neighborhood SES calculation

Neighborhood SES was calculated due to geographical location impacting educational attainment and opportunities (Banerjee et al., 2022; Levinson et al., 2021). ZIP Code information supplied by the subjects in the demographics portion of the survey was utilized to calculate the SES score for the neighborhood that the participants lived in based on U.S. census data. For details on this calculation and reasoning behind the measure see Hurse et al., 2023 (Hurse et al., 2023). Individuals' scores were normalized to their state SES metrics, arranged in ascending order, and partitioned into low or high SES groups (based on a median-split procedure). Nine individuals failed to provide their ZIP Code and were not included in the analysis involving this variable.

SDL Framework, Taylor et al, 2023	1. Take the initiative for one's own learning	2. Self-assess/diagnose one's own learning needs	3. Formulate learning goal	4. Identifying resources	5. Appraise information resources	6. Implement appropriate activities	7. Evaluate learning outcomes
SDL Scale, Lonsbury et al, 2009							
I regularly learn things on my own outside of class.	X	X	X	X		X	
I am very good at finding out answers on my own for things that the teacher does not explain in class.	X	X		X		X	
If there is something I don't understand in a class, I always find a way to learn it on my own.	X	X		X		X	
I am good at finding the right resources to help me do well in school.	X	X		X	X	X	
I view self-directed learning based on my own initiative as very important for success in school and in my future career.	X	X				X	
I set my own goals for what I will learn.	X	X	X			X	
I like to be in charge of what I learn and when I learn it.	X	X	X	X		X	
If there is something I need to learn, I find a way to do so right away.	X	X	X	X		X	
I am better at learning things on my own than most students.	X	X				X	
I am very motivated to learn on my own without having to rely on other people.	X	X	X	X		X	
SDL Experiences, Kemp 2022							
Identifying and synthesizing information relevant to your learning needs or desires	X	X	X	X		X	
Determining the credibility of sources in order to further your learning				X	X	X	
Reporting information to others that you have identified based on your learning needs or desires						X	X
Receiving feedback on your information-seeking skills and ability to assess information						X	X
Incorporating and improving information-seeking skills based on the feedback received regarding your skills	X	X	X			X	X
Situational Judgment Case							
Kiran has an exam in their chemistry class in two weeks. They are feeling nervous about the material and about how to prepare for the exam. Kiran has been reading the textbook and reviewing their notes. They recently took a practice quiz and did poorly. They are unsure how to proceed with the material. Kiran finds this frustrating because they aim to be a pharmacist. How would you rate the following behaviors on a scale regarding their usefulness to Kiran's future?							
Seek out videos and other materials on the subject and use this to prepare for additional practice questions provided by the professor	X	X	X	X		X (positive)	X
Memorize the correct answers to the practice quiz questions	X	X				X (negative)	
Review questions they get correct or incorrect to determine why they got them correct or incorrect	X	X	X			X (positive)	X
Seek feedback or help from the chemistry teaching assistant and/or the professor on the questions that they got incorrect	X	X		X	X	X (positive)	X
Set learning goals for the next two weeks and seek out materials and resources that can help them meet these goals and objectives	X	X	X	X	X	X (positive)	
Seek feedback from their teaching assistant or professor on the quality of sources they are using to learn the material	X	X		X	X	X (positive)	X

FIGURE 1 The Relationship between the SDL Measures and the SDL Framework. Pearson Correlations were run between the measures to determine the strength and direction of their relationship. All three measures map to the SDL framework. All figures were made using [Canva.com](https://www.canva.com).

2.7 Statistical analysis

All analyses were performed using IBM-SPSS statistics software (Version 29). A traditional threshold value of p-value of < 0.05 was used to determine statistical significance. These were uncorrected due to being planned comparisons in this exploratory investigation, but this decision is discussed as a limitation in this paper (see section 4.5). Pearson correlations were run between the three aforementioned SDL measures, the demographic variables, and the educational experiences. Two-sample independent proportions test were run to compare the SDL experience types between those who participated in AP/IB programs and those who did not and between

dual enrollment participants and those who did not participate in dual enrollment.

3 Results

3.1 Income has a weak positive correlation with SDL experiences

We first explored the correlation between SDL experiences and demographics. We found that while race, ethnicity, neighborhood SES, first-generation status, and gender did not correlate with SDL

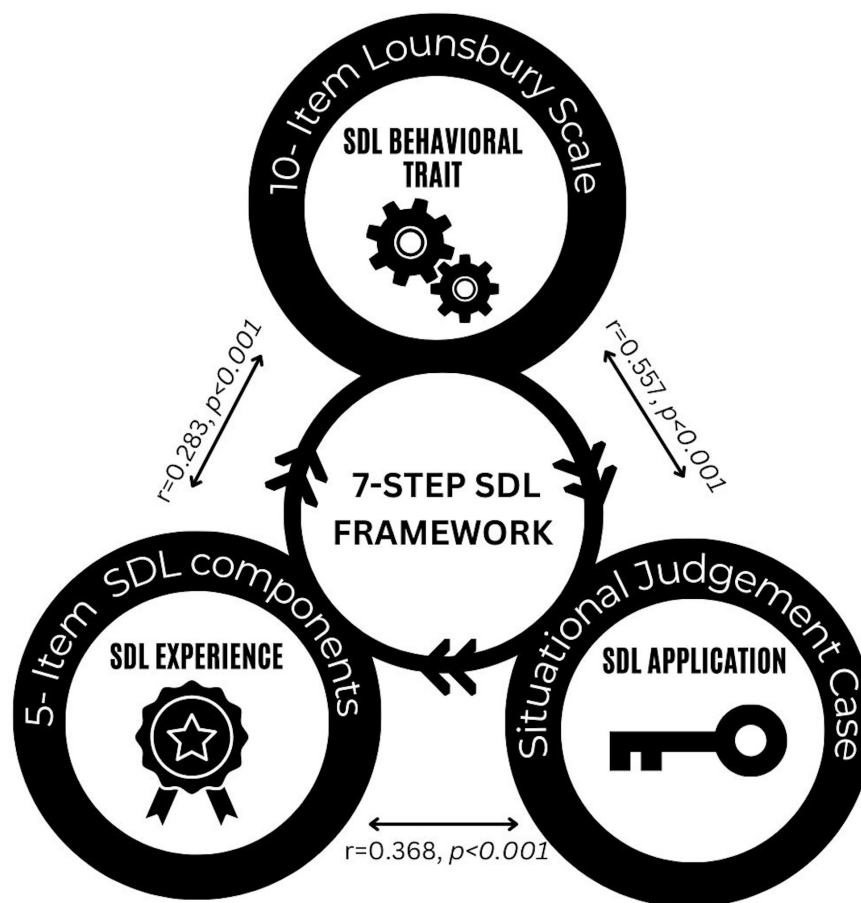


FIGURE 2

The SDL Behavioral Trait, SDL Experiences, and SDL Situational Case Were Mapped to the Seven Components of SDL Framework. The framework is shown at the top. The questions that map to the components for each measure are shown on the left. An "X" indicates the question maps to the component. All figures were made using [Canva.com](https://www.canva.com).

experiences, household income had a weak positive correlation with SDL experiences ($r = 0.116, p = 0.033$).

3.2 SDL experience correlates with dual enrollment, Not AP/IB or OPP

The relationship between education and SDL experience was then analyzed. There was a poor, non-significant correlation between the number of OPP experiences and participants' SDL experiences (Table 2). This was also true for AP/IB and SDL experiences. However, there was a weak, statistically significant correlation between components of SDL experienced by participants and dual enrollment ($r = 0.206, p < 0.001$).

We next explored if there were particular components of SDL that individuals who are dually enrolled are experiencing compared to those who were not dually enrolled. A higher proportion of those who were dually enrolled reported higher competencies in "receiving feedback on their information seeking skills" ($p = 0.044$; Table 3) and "incorporating and improving information-seeking skills based on the feedback" ($p < 0.001$; Table 3). Moreover, "reporting information to others" approached significance for those who were dually enrolled ($p = 0.051$; Table 3). While experience

with SDL did not correlate with AP/IB (Table 2), those who enrolled in AP/IB reported incorporating and improving information-seeking skills based on feedback at a higher incidence than those who were not enrolled in AP/IB ($p < 0.001$; Table 3).

3.3 The SDL behavioral trait correlates with AP/IB, not dual enrollment or OPP

Correlations were run to explore the relationship between the number of OPP experiences and the SDL behavioral trait. There was a poor, non-significant correlation found between these two variables (Table 2). Moreover, the relationship between AP/IB and the SDL behavioral trait was also explored. There was a weak, statistically significant correlation between the SDL behavioral trait and AP/IB ($r = 0.145, p = 0.014$). As the correlation between those who participate in AP/IB and those who report passing their AP/IB exam is very strong ($r = 0.963, p < 0.001$), we wanted to explore the relationship between the SDL behavioral trait and exam passage. The relationship becomes slightly stronger when focusing on those who report passing their AP/IB exams ($r = 0.159, p = 0.007$). In contrast, all correlations between the SDL behavioral trait and the other variables were statistically non-significant (Table 2).

TABLE 2 Correlations between SDL experiences, SDL behavioral trait, demographics, and educational experiences.

	SDL experiences <i>r</i> , <i>p</i> -value	SDL behavioral trait <i>r</i> , <i>p</i> -value
AP/IB	0.034, <i>p</i> = 0.537	0.145, <i>p</i> = 0.014*
Passed IB exam or received AP credit	0.063, <i>p</i> = 0.243	0.159, <i>p</i> = 0.007*
Dual Enrollment	0.206, <i>p</i> = < 0.001**	0.068, <i>p</i> = 0.248
Ethnicity	−0.01, <i>p</i> = 0.339	−0.012, <i>p</i> = 0.835
Gender	0.016, <i>p</i> = 0.766	0.089, <i>p</i> = 0.133
Income	0.116, <i>p</i> = 0.033*	0.032, <i>p</i> = 0.590
First generation	−0.050, <i>p</i> = 0.356	−0.009, <i>p</i> = 0.882
Number of OPP experiences	0.055, <i>p</i> = 0.310	0.040, <i>p</i> = 0.502
Race	0.049, <i>p</i> = 0.370	0.019, <i>p</i> = 0.744
Neighborhood SES	−0.032, <i>p</i> = 0.566	−0.030, <i>p</i> = 0.609
SDL Experiences	1	0.283, <i>p</i> < 0.001**

* *p* = < 0.05, ** *p* = < 0.001.

3.4 SDL application in a situational judgment case correlates with AP/IB participation

An analysis was run to assess how well the situational judgment case correlated with the various educational and demographic variables (Table 4). AP/IB participation had a weak and significant correlation with the situational judgment case ($r = 0.202$, $p < 0.001$). This increased slightly for those who passed their AP/IB exam ($r = 0.217$, $p < 0.001$). The other demographic factors were found to have a negligible, non-significant correlation with the situational judgment case (Table 4).

4 Discussion

Numerous advancements in science and technology have occurred over the past decade, with new concepts being introduced at an increasingly rapid pace (Author, 2019). Today's learners must practice self-directed learning to succeed in their professional pursuits, as they navigate a vast amount of information and build upon their existing knowledge. In this study, we used three measures of SDL, including a novel situational judgment case, to explore SDL in matriculating college students seeking to enter into STEM fields. We explored the impact of various educational and demographic factors on the varied aspects of SDL. We hypothesized that AP/IB, dual enrollment, and STEM OPP are potential opportunities for establishing SDL in high school students. Counter to our hypotheses, we found that OPP experiences did not correlate with the SDL behavioral trait, SDL experience, or SDL application in our novel situational case. Interestingly, while dual enrollment correlates with SDL experiences, it does not correlate with the other two measures of SDL. This is in contrast to AP/IB, which correlates with the SDL behavioral trait and SDL application, but not SDL experience. Our overall findings are summarized in Figure 3.

4.1 Educational experiences and SDL

While dual enrollment provides experiences with aspects of SDL, it does not appear to promote the development of the SDL behavioral trait. However, individuals who participate in AP/IB are more likely to possess the SDL behavioral trait and subsequently are more likely to apply SDL in a situational assessment. Both of these advanced programs intend to prepare students for future academic challenges; however, their populations and/or contributions to developing essential learning skills differ significantly. This could suggest that the structure and nature of the programs inherently support and draw different learners or aspects of learning, but this needs further research to clarify.

We were not surprised to find that participants who were dually enrolled tended to have more experience with performing self-directed learning. Self-directed learning (SDL) is a cornerstone of adult learning, and individuals taking college courses should have more experience with SDL as dual enrollment courses may sometimes occur in a collegiate learning environment. While enrollment in AP/IB does not correlate with SDL experiences, participating in AP/IB correlates with the behavioral trait of being a self-directed learner. This may indicate that those who are naturally higher in this trait may be drawn to AP/IB. Moreover, when given a situational judgment case that maps to components of SDL, only AP/IB participation correlates with performance on this measure. This may be because AP/IB select for individuals high in the SDL behavioral trait, and in turn, these individuals do better on the cases because they are self-directed learners. Suldo et al. found motivation and cognitive engagement increased AP/IB student success, which is similar to what is found in successful college students (Suldo et al., 2018). This may be further enhanced within our sample as we focused particularly on those interested in progressing to STEM careers and the rate of those that endorsed “taking an AP/IB course” and “passing the AP/IB course” is much higher than findings from the general population taking AP/IB courses. Interestingly, OPPs did not correlate with any measures, and this work identifies opportunities to improve the promotion of SDL in OPP educational exposures.

4.2 Demographics and SDL

We found SDL application and the SDL behavioral trait did not vary based on demographic factors such as neighborhood SES, income, race, and/or ethnicity (Tables 2, 4). These findings are similar to the results found when self-regulated learning was measured in college students (DuBois et al., 2011). Moreover, Tekkol and Demirel found income did not have a relationship with SDL skills in college students (Tekkol and Demirel, 2018). However, for our study, income does appear to impact SDL experiences among the respondents. Those with higher incomes may be able to gain additional opportunities that provide exposure to more SDL experiences. However, students from lower familial SES background, impacted by household income, possess a component called grit. Grit is a quality that motivates them to achieve; however, these individuals may lack critical resources such as access to mentors, knowledge of structural components, and favor with gatekeepers which are essential to academic success (Kundu,

TABLE 3 Percent of participants that report experiencing SDL.

	Dual Enrolled	Not Dual Enrolled	<i>p</i> value	AP/IB	Not AP/IB	<i>p</i> value
SDL Experiences						
Identify and synthesize information relevant to your own learning needs	37% (75)	29% (39)	<i>p</i> = 0.114	36% (71)	30% (43)	<i>p</i> = 0.268
Determine the credibility of sources	49% (100)	40% (55)	<i>p</i> = 0.110	44% (87)	48% (68)	<i>p</i> = 0.496
Report information to others	35% (71)	25% (34)	<i>p</i> = 0.051	28% (56)	35% (49)	<i>p</i> = 0.232
Receive feedback on information-seeking skills	41% (83)	30% (41)	<i>p</i> = 0.044*	38% (74)	35% (50)	<i>p</i> = 0.657
Incorporate and improve information-seeking skills based on feedback received	32% (64)	15% (21)	<i>p</i> < 0.001**	29% (58)	19% (27)	<i>p</i> < 0.001**

The percent of those responding that they experienced components of SDL are recorded above. The participants were divided into those that participated in dual enrollment or did not participate and again for those that participated in AP/IB and those that did not. A two-sample independent proportions test was run. **p* = < 0.05, ***p* = < 0.001.

TABLE 4 SDL application correlates with AP/IB participation.

	SDL Application
AP/IB	0.202, <i>p</i> < 0.001**
Passed IB exam or received AP credit	0.217, <i>p</i> < 0.001**
Dual Enrollment	0.068, <i>p</i> = 0.249
Ethnicity	0.001, <i>p</i> = 0.990
Gender	0.062, <i>p</i> = 0.298
Income	0.034, <i>p</i> = 0.570
First generation	0.008, <i>p</i> = 0.897
Number of OPP experiences	0.061, <i>p</i> = 0.301
Race	0.016, <i>p</i> = 0.784
SES	0.031, <i>p</i> = 0.605

***p* = < 0.001.

2017; Williams et al., 2019). Indeed, family income and SES has been shown to impact academic achievement (Suldo et al., 2018; Workman, 2022). Our data, however, reiterates the fact that students, regardless of demographic background, can possess the SDL behavioral trait and apply SDL. Beyond the current focus on SDL, factors such as agency, transitional knowledge, or interventions that promote a positive emotional experience are required for academic success in secondary education (Jury et al., 2017; Kundu, 2017; Williams et al., 2019).

4.3 Importance of SDL in high school and college

SDL has been identified as an educational asset since the 1970s. Knowles' seminal work on self-directed learning highlights its importance in educational settings. It emphasizes how SDL encourages students to take responsibility for their education and fosters critical thinking skills (Knowles, 1975). SDL is essential in high school and college to promote independence, critical thinking, and lifelong learning (National Science Foundation, 2023). SDL empowers students to explore their interests at their preferred pace. This results in developing problem-solving skills, adaptability, and efficient learning of new information and abilities. Our work finds participating in dual enrollment correlates with

SDL experiences; however, we propose that SDL experiences need to be promoted throughout high school and into college. Ways by which SDL are introduced and cultivated may need to vary as Uus et al. found SDL self-efficacy and SDL readiness vary based on age and year in school, geographical location, and gender in adolescents (Chen et al., 2022; Uus et al., 2021). A framework must be developed regarding the activities that constitute SDL and distributed to educators. A recent Dutch study found that the methods employed by teachers to develop self-directed learning, as well as an understanding of self-directed learning, varied. Moreover, the culture of the school impacted interpretations of SDL (Voskamp et al., 2022).

4.4 OPPs are Positioned to Incorporate SDL

Scholarship on OPPs shows that individual programs have been useful in promoting self-efficacy, a sense of belonging, and increasing retention of students in STEMM (Daniels et al., 2019; Kuchynka et al., 2022; Rocha et al., 2022a). However, it is unknown if OPPs promote pre-college matriculation competencies in adolescents. We became interested in exploring these competencies after identifying that high school students exhibited aspects of SDL due to participation in the Oakland University William Beaumont online enrichment program (Hurse et al., 2023). We have found OPP participation promotes perceptions of college readiness (publication in preparation). In fact, many of the skills learned from OPP experiences map to college readiness as defined by Conley (Conley and French, 2014). Due to this we were surprised to discover having additional OPP experiences did not correlate with SDL. Previous work illuminates a relationship between SDL, instruction method, and student interest. Schweder and Raufelder found that the incorporation of two self-directed intervals during the school year for German secondary students increased self-efficacy and interest throughout the school year (Schweder and Raufelder, 2022). It may be that specific types of OPP experiences promote SDL due to differences in instructional methods. It may also be that specific instructional methods employed during OPPs fail to engage with aspects of SDL. Many of the individuals in this study participated in multiple types of OPPs, which was not the focus of this investigation (see limitations section below). Thus,

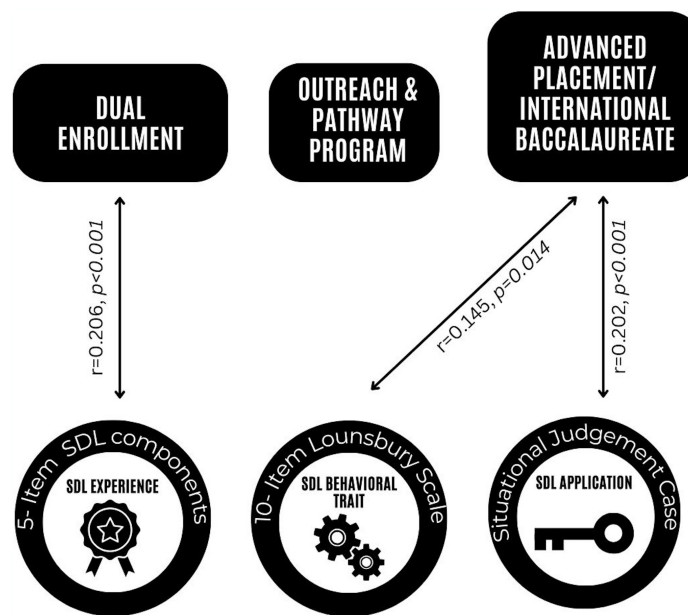


FIGURE 3

A Summary of the Study Findings. Correlations were run between the measures and the educational experience variables AP/IB, Dual Enrollment, and OPP to determine the strength and direction of their relationship. All figures were made using [Canva.com](https://www.canva.com).

the mechanism of instruction during OPP experiences may play a role in these findings and remains an area of future exploration and investigation.

Through this work, we have identified an opportunity to improve OPPs through the promotion of SDL related skills. OPPs are positioned to promote pre-college matriculation standards beyond subject matter knowledge. Incorporation of problem-based learning activities or research and design activities can be used to bolster SDL experiences. OPPs can also be used to emphasize the importance of SDL for college success and beyond.

4.5 Limitations

While our study has many strengths such as providing insights into rigorous SDL measurements and the relationship between SDL and various educational experiences, there are limitations. First, we did not evaluate how each of the individual educational experiences contributes to each of the seven components of the SDL framework. Moreover, the measures did not equally capture all seven components of the overall framework (Figure 2). We believe our use of multiple measures helps reduce this impact, but future studies call for a more focused approach to the different types of program structures.

We were unable to parse out the nuances between different types of OPPs, and AP/IBs given the diverse nature of these programs nationally. However, we do not see it as a major limitation because of the way educational research is studied. Student study populations typically have several experiences outside of formal education that they draw upon from their social, resistant, and navigational capital. These, among many others, could help them become self-directed, which they then would apply into their education and career aspirations (Strawn, 2003). Another

limitation of our study is that our groups are not mutually exclusive. A student may have experience in more than one program whether OPPs, AP, or IB. Although, the results are reliable, they may be partially confounded due to students having multiple experiences. While power is sufficient for the overall analysis, it is not for more advanced statistical techniques. Future studies could benefit from increasing sample sizes and integrating our insights statistically by employing a stepwise regression approach that inputs the most explanatory factors first.

Another limitation may lay in our method of calculating SES based solely on the students' provided ZIP Codes. While commonly used, this approach oversimplifies the complex nature of communities. Future research should consider a more multifaceted approach, exploring familial SES, neighborhood SES, and the SES of the area surrounding the school. These interconnected variables could allow researchers an even clearer picture.

5 Conclusion

The goal of our research was to assess self-directed learning among recent graduates matriculating into college who participated in various educational experiences. We found that in our population of students interested in pursuing a STEMM career, individuals enrolled in AP/IB have less experience with SDL, but participating in AP/IB correlates with the SDL behavioral trait and SDL application. This leads us to conclude that AP/IB may select for those with a predisposition towards SDL, while OPPs and dual enrollment do not. OPPs and dual enrollment both serve as ways to increase accessibility to all students. While we may recruit diverse candidates into the STEMM pathway through OPPs and dual enrollment, efforts must be made to ensure that

we are providing the experiences that will lead to their future success. This paper identifies an opportunity for the coalition of educators, community leaders, and industry professionals that seek to do this work to strengthen offerings to better prepare students for college and beyond.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Oakland University Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AN: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing. KK: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review and editing. CD: Data curation, Formal analysis, Software, Writing – review and editing. DH: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Visualization, Writing – review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2024.1393493/full#supplementary-material>

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