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Fostering Student Engagement and Success in STEM Education: An AI-Driven Exploration of High Impact Practices from Cross-Disciplinary General Education Courses

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Abstract*— Due to the increase in data and software tools, the need for programmers and data analysts has risen in the United States during the 21st century. As a result, more students are enrolling in Computer Science, Information Technology, and Data Science programs nationwide. However, switching to online and blended learning and using cyberlearning tools have presented new challenges for student learning, retention, and program success. One way to overcome these challenges and improve student achievement is to implement evidence-based pedagogical strategies and innovative technologies within clear theoretical frameworks. Recent studies have shown that various Learning Engagement Strategies (LESs) in STEM education, such as gamification, active learning, feedback and assessment, and interactive multimedia, significantly increase student engagement and course completion rates. High-Impact Practices (HIPs), identified as crucial by Kuh in 2008, have become powerful tools for enhancing student involvement, retention, and completion in higher education. This article explores practices that can enhance student learning and success that have many benefits, including more robust relationships between students and faculty, cooperative learning, quick feedback, inclusive environments, and conflict resolution. The study uses NLP-based text analytics to investigate the application and impact of these High-Impact Practices (HIPs) across different disciplines. Firstly, it identifies the most prevalent HIPs in various General Education (Gen Ed) disciplines that impact student success. Secondly, it formulates AI-driven recommendations for cultivating a student-centric learning environment through HIPs within STEM education. The results of empirical analyses using course materials, survey data, syllabi, and pre/post-workshop surveys sourced from around 65 Gen Ed course at a small public university provides valuable insights into successful HIPs for STEM courses that can help instructors improve their online and blended course designs. By implementing these practices, educators can increase student engagement, retention, and completion rates across diverse student populations in Gen Ed STEM courses.

***Keywords*— High-Impact Practices; General Education, STEM education; Natural Language Processing.**

***JEET Category*—Research**

I. INTRODUCTION

THE diversity of students in higher education has broadened significantly in the past half-century encompassing a wide range of experiences, cultures, abilities, skills, and personalities, creating an opportunity to foster a diverse group of innovative thinkers and problem-solvers. The global lockdown of educational institutions in the recent past has profoundly impacted students' learning, resulting in disruptions in qualifications assessments and the use of suboptimal alternatives worldwide. To alleviate the negative consequences of this situation and to address the learning gap, universities have leveraged technology and remote communication. However, lingering questions exist on how to reach the most affected students.

The ubiquity of data and software tools in the current era has led to remarkable transformation across many sectors. This transformation has been notably characterized by the increasing demand for professionally skilled programmers and data analysts in the United States. Thus, the technological advancements in data-driven industries have catalyzed an augmented requirement for these professionals to navigate and make sense of this evolving landscape. As a result, higher education has seen a surge in enrollment in Computer Science, Information Technology, and Data Science programs nationwide. However, the recent shift to online and blended learning and using cyberlearning tools and technologies in Science, Technology, Engineering, and Mathematics (STEM) education has presented additional challenges regarding student learning, retention, and program success (Sharron, 2005). Implementing evidence-based pedagogical techniques and innovative technology in learning environments, guided by a well-defined theory of change, can effectively overcome these challenges and impact student success.

Recent research indicates that various Learning Engagement Strategies (LESs) used in STEM courses, such as gamification,

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active learning, feedback and assessment, and interactive multimedia resources, have impacted and enhanced student engagement and successful course completion (Narasareddygari et al., 2019; Desai et al., 2019; Ojha et al., 2022).

A. Importance of General Education Courses and High-Impact Practices in Higher Education

The concept of High-Impact Practices (HIP) was coined by Kuh in 2008, encompassing diverse components of undergraduate education such as learning communities, writing-intensive courses, collaborative assignments and projects, undergraduate research, diversity and global learning, service-learning and community-based learning, internships, capstone courses and projects, first-year seminars and experiences, and common intellectual experiences (Kuh, 2008). Since then, HIPs have emerged as a central strategy to improve student engagement, retention, and completion rates in higher education institutions, offering benefits such as better student-faculty relations, developing student cooperation, active learning, prompt feedback, and grievance resolution while improving inclusivity and accessibility.

The success and efficacy of HIPs stem from the multifaceted benefits, including fostering improved student-faculty relationships, cultivating collaboration among peers, promoting active learning, facilitating prompt feedback, and providing avenues for grievance resolution. Moreover, HIP initiatives contribute to developing inclusive and accessible learning environments, resonating with the evolving dynamics of modern education.

General Education (Gen Ed) courses are pivotal in equipping students with foundational knowledge and fostering critical thinking capabilities. They serve as a bridge, connecting various strands of knowledge and facilitating a comprehensive understanding of subjects. Gen Ed courses encapsulate a broad spectrum of subjects, and the HIP strategies incorporated within the higher education curriculum are imperative, signifying their accessibility and broad appeal across diverse faculties and disciplines.

The impact of HIPs, such as service learning, undergraduate research, and study abroad programs on Gen Ed courses at a liberal arts college, was examined by Kuh et al. in 2013. The research revealed that students who participated in HIPs had higher grades and were more likely to graduate in four years than those who did not. However, no statistical tests were reported in the study (Kuh et al., 2013). Therefore, HIPs represent a group of different techniques and designs for teaching and learning that benefit students from different background and their learning experiences. Through intentional program design and advanced pedagogy, student learning is enhanced, and educational gaps are reduced. The course's classification as a General Education course is a means of signaling to interested students the broad scope and accessibility of the subject.

B. Research Question

The different techniques and designs for teaching and learning engagement techniques and HIPs benefit students from diverse backgrounds and learning experiences to enhance learning and reduce educational gaps. This research project aims to determine the usage of HIPs in different disciplines of higher education, compare the benefits and impact of each HIP across various fields, and provide recommendations for successful HIPs for different courses/disciplines. The study uses NLP-based text analytics techniques to answer the following research question (RQ).

RQ: *What are the critical High-Impact Practices (HIPs) employed in General Education (Gen Ed) courses that can be adapted for STEM education to enhance student engagement and course outcome, fostering the development of a student-centered learning environment?*

The impact of HIPs on student learning is studied. The empirical analysis includes applying NLP-based data analytics techniques and sentiment analysis to evaluate course syllabi, a list of assignments (optional), and student survey data. The data required for this research is collected from around 65 Gen Ed course syllabi and other supporting documents in a small public university and pre/post-test surveys of 16 participants conducted at a Gen Ed HIPs Workshop at the University.

The results and inferences of this research could not only provide knowledge and insights about the successful LESs in STEM courses but also be helpful for the instructors to improve the online/blended course design. The study has the potential to contribute to the enhancement of Gen Ed courses' student engagement, retention, and completion rates, which will be beneficial for students from different backgrounds and learning experiences.

The remainder of the paper is organized as follows. The research motivation and detailed background knowledge gathered from the literature about the importance of HIPs are described in Section II. The HIPs assessment data collection and the study design are presented in Section III. The exploratory analysis of the HIPs assessment instruments, the results of the pilot study, and the inferences are presented in Section IV. The paper concludes with a description of future work in Section V.

II. Research Motivation and Background

Education is constantly evolving due to changing world dynamics, technology, the emergence of online platforms, student aspirations, and new forms of learning. With the shift towards online learning, educators face unique challenges, particularly in integrating many students and ensuring everyone receives equal attention. To guarantee student success, HIPs must be adapted with strategies in place to address and overcome potential challenges.

Brownell and Swarner examined the impact of HIPs on students from diverse backgrounds, demonstrating the importance of providing equal representation to learners from different ethnic, socio-economic, and cultural backgrounds to enhance their knowledge absorption and academic growth. Meanwhile, other researchers have focused on different approaches to teaching programming, including HIPs and their effects (Brownell & Swarner, 2009).

Researchers developed an instructional learning framework to foster greater learner engagement. This framework involves identifying instructional needs, defining goals and objectives, developing learning objectives, and summative assessment. Their study concluded that online instructors require improved approaches to increase student engagement, emphasizing facilitation, feedback, collaboration, and interaction (Czerkawski & Eugene, 2016).

A. High Impact Practices - Gen Ed Courses & STEM Majors

Research shows that some teaching practices have a higher impact than others used by instructors in various disciplines. These teaching practices, called HIPs, are now frequently utilized as metrics for measuring student learning and campus cultures that have promoted educational quality. Research from the National Survey of Student Engagement (NSSE) indicates HIPs have led to higher student learning and retention levels than traditional instruction. The Gen Ed courses predominantly use HIPs. Therefore, determining the extent to which undergraduate Gen Ed courses use HIPs and how these can be transformed into STEM education is an interesting research problem.

Recent research has shown that implementing LESs, such as gamification, active learning, interactive multimedia, and feedback mechanisms, has increased student engagement and completion rates in STEM education (Smith et al., 2021; Johnson & Smith, 2022). Moreover, the concept of HIPs, pioneered by Kuh, can promote solid student-faculty relationships, foster cooperative learning environments, and create inclusive educational settings that nurture academic success and conflict resolution. Kuh reported that student participation in HIPs positively correlates with persistence, performance, achievement, and intent to complete their current major (Kuh, 2008).

Ewumi et al. (2021) analyzed data from the National Survey of Student Engagement (NSSE) at two universities. They aimed to investigate the participation rates of first-year students and seniors in computer science and engineering in various HIPs. These practices promote meaningful interactions between faculty and students, encourage collaboration among students of diverse backgrounds, and encourage learning beyond the classroom. They used HIPs, including service-learning, learning communities, research with faculty, internship or field experience, study abroad, and culminating senior experience. They also evaluated the impact of these HIPs on course outcomes and compared the participation rates of different majors, such as civil, chemical, electrical, mechanical, and materials engineering. The study involved 674 participants. The results of the study indicated that *internships* (52%) and *culminating senior experiences (68%)* had the highest participation rates among seniors in the study.

Conversely, in their senior year, students do not engage in HIPs such as *service-learning (41%), learning community (59%),* and *study abroad* programs (68%), showing the lowest participation rates. First-year students showed a greater interest in participating in internships (76%), study abroad programs (47%), and culminating senior experiences (68%). These findings provide valuable insights for future research and have implications for student engagement and learning.

In 2021, Smith et al. conducted a systematic review of several studies to determine the impact of *gamification* on student learning outcomes in STEM fields. Their findings showed that incorporating game elements into non-game contexts can be a promising strategy for enhancing student engagement and motivation. This is particularly important in STEM education, where complex concepts can be challenging to understand. The study revealed that integrating gamified elements such as interactive quizzes, leaderboards, and simulation-based learning activities can significantly improve the learning experience. This evidence suggests that incorporating gamification practices from other General Education courses can potentially increase engagement in STEM education (Smith et al., 2021).

The research conducted by Johnson and Smith (2022) sheds light on the effectiveness of *active learning strategies* in STEM education. Their meta-analysis of multiple studies found that these strategies have a transformative impact on students, enhancing their conceptual understanding, critical thinking, collaboration, and problem-solving skills. The research demonstrates that active learning can be applied across various STEM disciplines. These findings have significant implications for the transformation of HIPs, as they suggest that active learning strategies from Gen Ed courses can be successfully adapted to improve student engagement and success in STEM contexts. The transformation of HIPs in STEM education revealed that incorporating practices from various educational fields can significantly enhance student engagement, learning outcomes, and overall educational experiences. Adopting a cross-disciplinary approach to shaping the future of STEM education is imperative. Thus, their scholarship provides a strong foundation for pursuing this transformation with conviction.

Smith et al. (2021) and Johnson & Smith (2022) reported many insightful approaches for enhancing STEM education in higher education. *Gamification* in STEM incorporates game-like elements to enhance engagement and accessibility, motivating active participation. *Active learning* methods in STEM, such as collaborative problem-solving and hands-on experiments, foster critical thinking and deeper comprehension. Adapting successful *teaching strategies from various disciplines* enriches STEM education by expanding the pedagogical toolkit. *Hybrid approaches* that combine gamification and active learning provide well-rounded, engaging learning experiences catering to diverse preferences. *Continuous assessment and feedback* through regular quizzes, formative assessments, and peer evaluations guide students' learning journeys and inform real-time adjustments in teaching strategies.

The impact of HIPs has been studied in STEM disciplines in the past. For example, the impact of various student engagement strategies such as active learning (Hodges, 2020), flipped classroom (Ryan & Reid, 2016; Maciejewski, 2016), critical thinking skills through inquiry-based learning (Rahmi et al., 2019), collaborative learning and problem-solving (Yunus, 2021), virtual lab learning with inquiry-based learning (Putri at al., 2021), inclusive learning (O'Leary, 2020), and service-learning and diversity (Collins, et al., 2019).

Incorporating effective LESs in a cyberlearning environment to promote student learning and engagement in introductory programming courses has been studied across different US institutions (Ramasamy et al., 2021). A meta-analysis of the effectiveness of the impact of different combinations of LESs, such as collaborative learning (CL), gamification (G), and social interaction (SI) embedded in a cyberlearning environment, on student understanding of programming concepts in an introductory programming course was studied. The studies showed that using LESs positively impacted student engagement and learning, especially when combining SI and G. The empirical results of another study by Ramasamy (2022) suggested that HIPs and collaborative teaching-learning practices mandated Bloom's taxonomy (Bloom, 1956) of more critical thinking at increasingly higher levels among students and improved the quality of learning.

B. Application of Natural Language Processing (NLP) Techniques for Processing Text Data

NLP is a core component of performing text mining operations on any document as it converts the unstructured text data into a cohesive, structured format. It can then make sense of the text and perform other operations such as similarity analysis, topic modeling, and machine learning. NLP-based text mining can be used for document analysis in keyword extraction, pattern identification, topic modeling, and other tasks that enable organizations to unlock valuable information hidden within their textual data. Therefore, it is pivotal in transforming unstructured text into structured, actionable insights, leading to informed decision-making and improved business processes.

Researchers in the past have extensively studied the application of NLP techniques in analyzing text documents. In their work on text summarization, Rahimi et al. used NLP techniques such as text mining, fuzzy and statistical text summarization, and text clustering to identify meaningful sentences and summarize the text. They found that text mining and text summarization are closely related and evaluated the effectiveness of their approach (Rahimi et al., 2017).

Agnihotri et al. worked on extracting useful information from text data using the stories data set from Project Guttenberg's William Shakespeare dataset. The frequent pattern mining technique is used to locate frequently occurring terms in documents and text. Statistical and probabilistic models were used for feature selection before applying machine learning techniques.

Academic documents often contain both graphical and textual content. Tamir Hassan developed methods for extracting both types of content directly from PDF files, facilitating machine data extraction (Hassan et al., 2009).

Agnihotri et al. extracted helpful information from text data using the stories dataset from Project Gutenberg's William Shakespeare. They used R as a Text Mining and Statistical Analysis tool and applied frequent pattern mining, statistical and probabilistic models, and machine learning techniques for feature selection (Agnihotri, 2014).

NLP-based text mining has been widely used for document analysis in keyword extraction, pattern identification, topic modeling, and other tasks that enable organizations to unlock valuable information hidden within their textual data. Therefore, it is pivotal in transforming unstructured text into structured, actionable insights, leading to informed decision-making and improved business processes. Therefore, we used the following Python tools and techniques for text preprocessing and analysis tasks. (i) Tokenization (Spacy library) to break down a phrase, sentence, paragraph, or an entire text document into smaller components like individual words or phrases, (ii) keyword extraction and summarization (Textrank tool), (iii) Parts of Speech (POS) Tagger to assign parts of speech to each word (and other tokens), such as noun, verb, adjective to attach linguistic (mainly grammatical) information to sub-sentential entities and (iv) Frequent Keyword Extraction (Rake - Rapid Automatic Keyword Extraction method) to find the most frequent words in the text file to determine the HIPs used. Due to the ongoing nature of the work and space constraints, more details are not included in this article. The data collection, experimental design, ML-based techniques, and the statistical inferences drawn from the analysis are discussed in the following sections.

III. Data Collection and Study Design of HIPs Assessment Data Analysis

Research shows that some teaching practices, a.k.a. HIPs, used by instructors in various disciplines have a higher impact than others. These HIPs are now frequently utilized as metrics for measuring student learning and campus cultures that have promoted educational quality. The findings from this study help us leverage appropriate HIPs in STEM majors. The extent to which HIPs are used in undergraduate Gen Ed courses in the three disciplines at a small public university was used for the study.

We investigated the HIPs used in Gen Ed courses across three disciplines, Humanities and the Arts (HU), Social and Behavioral Sciences (SB), and Natural Sciences (NS), to determine their positive impact on students' success and engagement. The number of Gen Ed course-related documents collected from 65 courses across three disciplines is shown in Table I.

TABLE I
NUMBER OF COURSES FROM DISCIPLINES EVALUATED

Disciplines	Number of Courses Studied
1. Humanities and the Arts (HU)	12
2. Social and Behavioral Sciences (SB)	24
3. Natural Sciences (NS)	29
Total	**65**

The multi-dimensional course-related data, including course syllabi and other optional course documents such as homework and reading assignments are used for the study. A certification survey submitted by the instructors is also used from the Gen Ed HIPs Assessment Workshop conducted to impart knowledge and estimate the widespread use of HIPs in college education. The pre-and post-test data were collected to quantify the impact of the workshop on the improved usage of HIPs in the courses.

Table II shows the 16 HIPs grouped into 4 categories and the category codes used for evaluation. The presence of any of these 16 different HIPs in four groups was identified by investigating the course-related documents submitted by instructors.

TABLE II
HIPS IDENTIFIED FOR THE STUDY AND THE CATEGORIES

HIP Category and (Code)	HIPs Identified for Study
1. Group Experiences (G)	(i) Collaborative assignments
	(ii) Common intellectual experiences
	(iii) Learning communities
	(iv) First-year experiences
2. Experiential Learning (E)	(i) Community-based learning
	(ii) Undergraduate research
	(iii) Real-world relevance
3. Interaction & Engagement (I)	(i) Hands-on activity
	(ii) Frequent interaction
	(iii) Sustained effort
	(iv) Constructive feedback
	(v) Critical reflection
4. Others (O)	(i) Diversity and global learning
	(ii) Writing
	(iii) Public demonstration of competence
	(iv) ePortfolios

The criteria for assessing HIPs and keywords using the numerical coding scheme defined by the Gen Ed committee experts are shown in Table III. Depending on how intensively these practices are used throughout the course, a numerical score is assigned - 2 for always, 1 for sometimes, and 0 for never to quantify and assess the incorporation of HIPs in the course.

TABLE III
NUMERICAL SCORES USED FOR ASSESSMENT OF HIPS

Criteria for usage of HIPs	Frequency	Score
Used throughout the course intensely	Always	2
Used sometimes during the course	Sometimes	1
Never used during the course	Never	0

Please note that, as the work is ongoing, the preliminary investigation results are presented in this article. The grading rubric, the keywords used to identify HIPs, and the semi-automated NLP-based algorithms used for assessment and evaluation are not detailed. Furthermore, it is crucial to recognize that the evaluation relies on the authors' comprehensive grasp of the contextual factors, which are inherently subjective.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

For this analysis, we utilize the descriptions of each HIP in conjunction with the associated key terms. We employ semi-automated Natural Language Processing (NLP) techniques to parse the text documents and estimate the usage of HIPs in the courses. The authors used NLP algorithms to find The average rate of HIPs reported in the different disciplines.

Table IV shows the proportions of different HIPs used in the descending order of usage in the different disciplines. The bar charts in Fig. 1 summarize (a) the numeric scores of the average % of HIPs shown in Table IV, (b) the average % of HIPs used consistently (score = 2) throughout the semester, and (iii) the average % of HIPs used sometimes (score = 1) in the courses. The results illustrate the distribution of HIPs across various disciplines, with *real-world relevance* having the highest average percentage at 38%. Frequent *interaction*, *constructive feedback*, and *writing* share the same average rate of 32%. On the other hand, *learning communities* and *first year experiences* are HIPs that showed the lowest implementation, both at 0%.

TABLE IV
AVERAGE RATE OF HIPS USED IN VARIOUS DISCIPLINES (%)

HIPs vs. Disciplines (Includes 65 Courses)	Average % of HIPs			
	HU	NS	SB	Avg
E_Real-world Relevance	46	39	33	**38**
I_Frequent Interaction	38	20	44	**32**
I_Constructive Feedback	52	22	34	**32**
O_Writing	52	16	41	**32**
G_Collaborative Assignments	38	3	44	**25**
I_Sustained Effort	38	7	13	**15**
I_Critical Reflection	38	3	11	**13**
E_Hands-on Activity	17	17	4	**12**
E_Community Based Learning	8	7	8	**8**
O_Diversity and global learning (needs review)	19	0	10	**7**
G_Common Intellectual Experiences	25	0	2	**5**
E_Undergraduate Research	6	0	10	**5**
O_Public demonstration of competence	8	0	4	**3**
O_ePortfolios	0	0	8	**3**
G_First Year Experience	8	0	0	**2**
G_Learning Communities	0	0	0	**0**

The chart underscores the variations in incorporating HIPs in the three academic disciplines, highlighting areas of potential improvement, and focusing on enhancing educational practices. Different disciplines prioritize various HIPs differently.

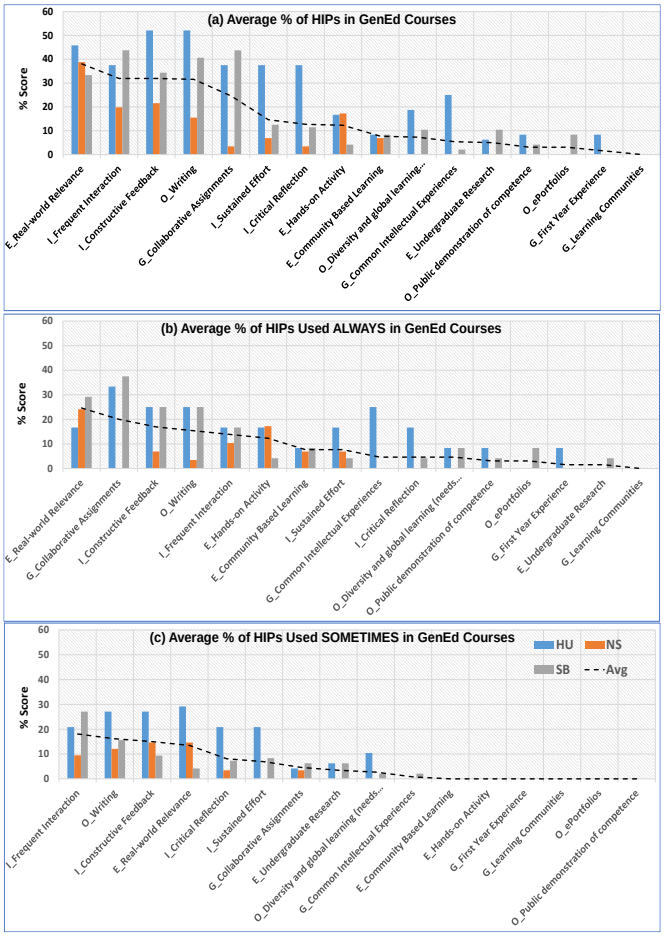

Fig. 1. Distribution of High-Impact Practices (HIPs) Across Disciplines: A Comparative Analysis of Average Percentages of HIPs used in Gen Ed Courses (a) Overall, (b) Always, and (c) Sometimes. Note: Prefix used for the four HIP categories: Group Experiences (G), Experiential Learning (E), Interaction and Engagement (I), and Others (O)

SB discipline emphasizes collaborative assignments, real-world relevance, and certain other practices. In contrast, HU and NS disciplines emphasize different approaches, such as constructive feedback, writing, and critical reflection.

These differences likely reflect the specific pedagogical and learning goals of each field. The results helped us understand the predominant use of various HIPs in the Gen Ed courses to gain more insights about student perceptions and identify interesting patterns and outliers. The Gen Ed Program aims to provide students with diverse knowledge and skills to help them become successful professionals, engaged citizens, and lifelong learners. Fig. 3 shows the scatter plots of the HIPs assessment scores for all HIPs in Gen Ed courses across the three disciplines.

To emphasize the benefits of using HIPs and measure the extent to which instructors use HIPs in their courses, a ***General Education HIPs Assessment Workshop*** was organized in the Summer of 2022. Sixteen instructors participated, and they were asked to submit the syllabi and the course-related documents before and after the workshop to assess the HIPs in these courses before attending the workshop and after the workshop to assess the impact that the workshop has created on the instructors in using the HIPs that they learned in the workshop sessions by experts. The participants completed a Qualtrics Survey before and after the workshop to compare the extent of HIPs they used in the courses before and after they completed the workshop. The results of the Qualtrics survey are illustrated in Table V.

TABLE V
PARTICIPANT RESPONSES OF HIPS USED BEFORE AND AFTER GEN ED WORKSHOP (N=16) (SCORES: YES=2, SOMEWHAT = 1, NO/NA = 0)

HIPs	Before Gen Ed Workshop %				AFTER Gen Ed Workshop %			
	Yes	Some what	No	NA	Yes	Some what	No	NA
Collaborative Assignments	37.5%	6.3%	43.8%	12.5%	63%	13%	25%	0
Common intellectual experiences	0%	6%	75%	19%	6%	25%	69%	0
Learning communities	0%	0%	81%	19%	6%	0%	94%	0
First-year experiences	13%	13%	50%	25%	25%	19%	56%	0
Community-based learning	13%	0%	69%	19%	19%	13%	69%	0
Undergraduate research	13%	6%	69%	13%	19%	6%	75%	0
Real-world relevance	31%	25%	31%	13%	63%	19%	19%	0
Hands-on activity	38%	13%	31%	19%	38%	19%	44%	0
Frequent Interaction	31%	31%	25%	13%	56%	25%	19%	0
Sustained effort	38%	6%	38%	19%	56%	19%	25%	0
Constructive feedback	19%	50%	19%	13%	69%	25%	6%	0
Critical reflection	31%	31%	25%	13%	81%	6%	13%	0
Diversity and global learning	38%	25%	25%	13%	44%	25%	31%	0
Writing	6%	50%	31%	13%	56%	19%	25%	0
Public demonstration of competence	19%	13%	50%	19%	25%	19%	56%	0
ePortfolios	6%	6%	69%	19%	13%	6%	81%	0

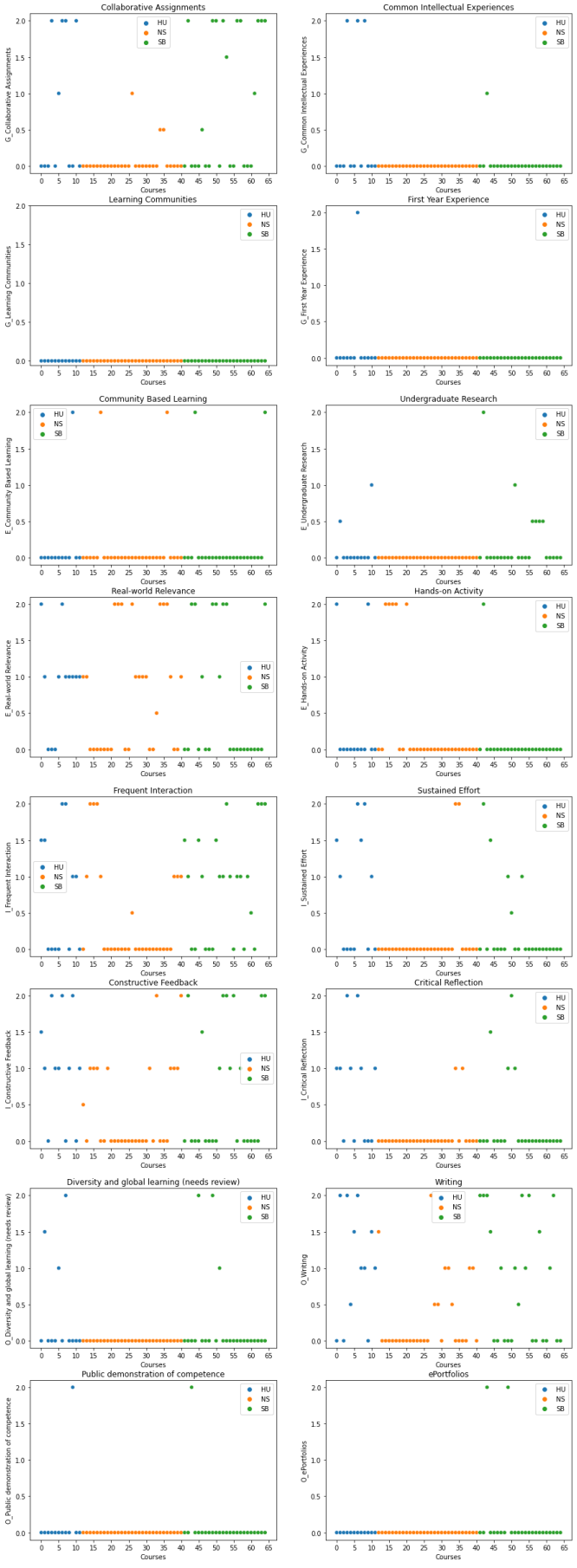

Fig. 3. Gen Ed Courses HIP Assessment Scores in HU, NS, and S Disciplines

Based on grouping similar responses of HIP usage, the assessment findings reveal the following:

(i) *HIPs with increased usage after the workshop:* Collaborative assignments, common intellectual experiences, learning communities, first-year experiences, community-based learning, undergraduate research, real-world relevance, frequent interaction, sustained effort, constructive feedback, critical reflection, and writing.

(ii) *HIPs with similar usage before and after the workshop:* Hands-on activities.

(iii) *HIPs with decreased usage after the workshop:* Diversity and global learning, public demonstration of competence, and ePortfolios. This decrease may be attributed to the fact that instructors started using other effective HIPs that they have learned in the workshop. It can be observed that the top three HIPs usage as measured after the workshop are *Collaborative Assignments* (63%), *Real-world Relevance* (63%), and *Critical Reflection* (81%).

The following inferences are made based on the results. Most HIPs experienced increased usage after the Gen Ed Workshop, indicating that the workshop ***positively impacted*** educators' adoption of these practices. The significant increase in *critical reflection* (from 31% to 81%) suggests that the Gen Ed Workshop had a powerful impact on promoting this practice. *Hands-on activity* remained stable in usage, suggesting that this practice was already well-integrated before the workshop. The decrease in *diversity and global learning* usage, *public demonstration of competence*, and *ePortfolios* highlight potential areas for further focus and improvement in future workshops. The high increase in *collaborative assignments* (from 37.5% to 63%) could be due to effective strategies shared in the workshop. The workshop's substantial impact on critical reflection usage implies that educators found The data contains ties with equal differences (C_{ties}=7.625). We use the normal approximation. The p-value of 0.0006223 ($P(x \leq 3.4217) = 0.9997$) indicates that the chance of type I errors in the workshop content is particularly relevant to enhancing this practice. Despite improvements, *learning communities, ePortfolios, and community-based learning* are less used, indicating potential areas for additional support or training. The stability of *hands-on activity* suggests using newer ones introduced through the workshop.

Critical reflection (50%) and real-world relevance (32.5%) were the most prominent increases. The average increase in HIPs usage after the workshop was approximately 28.27%. The average decrease in use was about 7.5%. The overall trend is positive, with more HIPs experiencing an increase than a decrease. These findings collectively suggest that the Gen Ed HIPs Workshop positively impacted the adoption and integration of various HIPs. Notable improvements were observed in *critical reflection, collaborative assignments,* and *real-world relevance*. However, areas still require attention, such as promoting *learning communities, ePortfolios,* and *community-based learning*. Therefore, the workshop encouraged educators to enhance their instructional strategies across various HIPs.

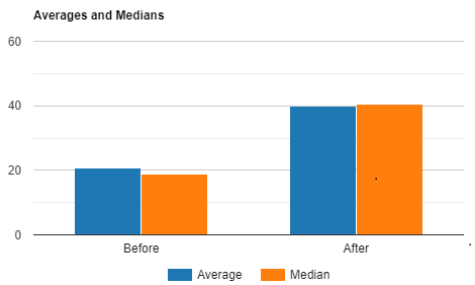

Fig. 2 Average and Median of HIPs before and after Gen Ed Workshop, (b) W-statistic: W+ = 120, W+ ~N(60,17.3889^2)

A. Statistical Analysis and Inferences:

Statistical tests are crucial to evaluate the impact of outcomes. While larger sample sizes are generally preferred, smaller studies can still offer valuable insights into the effects of High-Impact Practices (HIPs) on student learning outcomes. A small study by Gopalan et al. (2019) shows that service learning in general education courses positively affects student GPAs and personal/professional growth despite having a sample size of only 15 students. The findings from the statistical indicators are described below.

To analyze the statistical significance of the comparison between the pre-workshop and post-workshop HIPs usage responses, we used the ***Wilcoxin Signed-Rank-test***, using Z distribution (two-tailed) (Wilcoxin, 2017) (Table VI).

TABLE VI
WILCOXIN SIGNED-RANK-TEST, USING Z DISTRIBUTION (TWO-TAILED)

HIP	Before	After	Abs Diff	Rank - Abs diff	W-
Constructive feedback	18.75	68.75	50	+	14
Critical reflection	31.25	81.25	50	+	14
Writing	6.25	56.25	50	+	14
Real-world relevance	31.25	62.5	31.25	+	12
Collaborative Assignments	37.5	62.5	25	+	10.5
Frequent Interaction	31.25	56.25	25	+	10.5
Sustained effort	37.5	56.25	18.75	+	9
First-year experiences	12.5	25	12.5	+	8
Common intellectual experiences	0	6.25	6.25	+	4
Learning communities	0	6.25	6.25	+	4
Community-based learning	12.5	18.75	6.25	+	4
Undergraduate research	12.5	18.75	6.25	+	4
Diversity and global learning	37.5	43.75	6.25	+	4
Public demonstration of competence	18.75	25	6.25	+	4
ePortfolios	6.25	12.5	6.25	+	4
Hands-on activity	37.5	37.5	0	-	

The Wilcoxon signed-rank test is a non-parametric statistical test used to determine if there is a significant difference between paired or matched data. The two dependent samples non-parametric paired test compares the probability of getting higher value from *"before workshop"* with the probability of getting higher value from the dependent *"after workshop."*

The test results indicated that there is a significantly significant difference between *"Before Workshop"* (Median=18.8, n=16) and *"After Workshop"* (Median=40.6, n=16), Z=3.4, p < .001, r=0.9 as shown in Fig. 2.

The data contains ties equal differences (C_{ties}=7.625). We use

the normal approximation. The p-value of 0.0006223 ($P(x \leq 3.4217) = 0.9997$) indicates that the chance of type I error (rejecting a correct H_0) is slight: 0.0006223 (0.062%). The smaller the p-value, the more it supports H_1. *The test statistic:* Range of W is [0, 120], W+ = 120, W+ ~ N(60, 17.3889^2).

Test statistic *Z = 3.4217* (not in the 95% region of acceptance: [-1.96, 1.96]). The observed *effect size r = 0.88* is significant, indicating the large difference between the mean ranks.

Validation: Sample size=16 (sufficient for the normal approximation); Outliers are detected using the *Tukey Fence* method with k=1.5. The data set does not have any outliers. The Wilcoxon Signed-Rank test does not assume normality, assessed using the *Shapiro-Wilk* Test with a significance level of α=0.05; p-value=0.002827. This means that the data distribution is not normal, and the difference between the sample data and normal distribution is statistically significant.

The Wilcoxin paired rank test shows several HIPs, including *constructive feedback, critical reflection,* and *writing* showed significant positive changes in usage after the workshop. The absolute differences in these cases were 50%, indicating substantial increases. *Real-world relevance, collaborative assignments, frequent interaction, sustained effort,* and *first-year experiences* also experienced significant increases in usage, with absolute differences ranging from 12.5% to 31.25%. Several other HIPs, including *common intellectual experiences, learning communities, community-based learning, undergraduate research, diversity and global learning, public demonstration of competence,* and *ePortfolios,* showed positive changes but were not statistically significant.

These results provide insights into which HIPs experienced substantial improvements in use after the workshop, highlighting areas of impact for the intervention. The Wilcoxon signed-rank test helps assess these changes without relying on assumptions of normal distribution, making it a valuable tool for analyzing non-normally distributed data. Therefore, the RQ proposed could be answered using the empirical results performed in the research. It has been shown from the analyses that *constructive feedback, critical reflection, writing, real-world relevance, collaborative assignments, frequent interaction, sustained effort,* and *first-year experiences* experienced significant increases in usage.

By thoughtfully implementing these strategies into the STEM landscape, educators can create dynamic, engaging, and effective learning environments that resonate with the modern learner and equip them with the skills and knowledge needed to excel in STEM fields. Thus, integrating gamification, active learning, and evidence-based best practices from diverse educational contexts holds immense potential for transforming HIPs in STEM education.

V. Conclusion and Future Work

HIPs are powerful tools that enhance student involvement and success in higher education. HIPs can promote student learning and success by fostering stronger relationships between students and faculty, encouraging cooperative learning, providing quick feedback, creating inclusive environments, and facilitating conflict resolution. Our study used NLP-based text analytics to investigate the impact of HIPs across three different disciplines, focusing on the most prevalent HIPs in the three Gen Ed disciplines that impact student success. By analyzing course documents using NLP and text mining algorithms, we explored the impact of these practices in cultivating a student-centric learning environment through HIPs within STEM education. Even though the generalizability of the findings is limited due to the small sample size of 16 instructors who participated in the workshop, our empirical analyses provided valuable insights into the choices of successful HIPs for STEM courses, which can help instructors improve their online and blended course designs. Implementing these practices can increase student engagement, retention, and completion rates across diverse student populations in Gen Ed-based STEM courses. The impact of HIPs on learning outcomes is still being studied.

Creating syllabi that incorporate HIP-related task assignments can be challenging due to the limited availability of syllabi and the lack of suitable templates. The current approach is semi-automated, as the subjective nature of the assessment instrument requires expert intervention to validate the ground truth. To address this issue, we aim to develop an AI-powered tool that can automate syllabi construction by providing a template and recommendations for discipline-specific HIPs for instructors. This tool will use machine learning, text mining, and natural language processing techniques. A focus group of instructors will be trained to use a customized, easy-to-use tool to develop structured syllabi for their courses that assist without overwhelming the instructors. This will enable quantification and assessment of HIPs in each discipline and Gen Ed courses. With structured syllabi, the automation will be easy, and it will be possible to compare the benefits and impacts of different HIPs across disciplines, providing iterative recommendations for appropriate HIPs for various courses and disciplines.

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