

Exploring the Impact of Digital Divide on the Academic Performance of STEM Students in Hybrid Modality

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Abstract: This paper investigates the digital divide among undergraduate students enrolled in STEM programs at a satellite campus of a public university. A survey was conducted to collect data on access to technology, internet connectivity, socioeconomic status, and the use of digital educational materials. The results show that more than half of the respondents are from households classified as 'poor,' reflecting disparities in technology ownership and access. While most students own a smartphone, less than half have their own tablet or computer, and the majority rely on mobile data for internet connection. Using k-means clustering, three distinct student groups were identified, primarily distinguished by device ownership, frequency of computer use outside school, and proficiency in using digital tools such as email, social media, and office productivity software. The study found a slight but significant difference in academic performance (measured by general weighted average) between two clusters, corresponding to differences in access and digital proficiency. The findings highlight the need for targeted support programs, improved internet accessibility, and enhanced digital literacy training to address the digital divide and promote equitable educational outcomes in a hybrid learning environment.

Keywords: digital divide, STEM students, hybrid learning, academic performance, digital literacy

1. Introduction

STEM education, covering the disciplines of Science, Technology, Engineering, and Mathematics, has increasingly embraced technology-enhanced strategies over the years. The integration of digital tools such as e-books, multimedia materials, and mixed reality has become part of modern STEM pedagogy (Gattullo et al., 2022; Osadchyi et al., 2021; Yang and Baldwin, 2020). Moreover, post-pandemic, the utilization of these resources has increased together with the use of hybrid learning modalities, which combine face-to-face instruction with online learning (Singh et al., 2021). This offers students greater flexibility and access to a broader range of educational content. The hybrid model, in particular, has gained prominence as it allows educators to blend the strengths of traditional classroom teaching with the advantages of digital technology. However, while these innovations offer significant potential benefits, they also raise critical questions about equity and access, especially for students from rural areas who may not have the same level of access to digital resources as their urban counterparts (Talandron-Felipe, 2020).

In rural settings, where infrastructure may be limited and socioeconomic challenges more pronounced, the digital divide, defined as the gap between those who have access to modern information and communication technologies (ICT) and those who do not, poses a significant barrier to the effective implementation of technology-enhanced education (Lythreatis et al., 2022). Many students in these areas face difficulties in accessing reliable internet connections, up-to-date devices, and other essential technological resources. As a result, the very tools designed to enhance learning can inadvertently widen the achievement gap between students with different levels of access to technology (Talandron-Felipe, 2019). This issue is particularly important in hybrid learning environments, where students are

expected to engage with both online and offline components of their courses. For STEM students, whose education often relies on specialized software, online simulations, and digital collaboration tools, the impact of the digital divide can be especially detrimental.

The present study seeks to explore the digital divide among STEM students in a satellite campus of a university in a rural municipality and examine how this divide relates to their academic performance in a hybrid learning setting. The study will investigate key areas such as socio-economic status, access to technology (devices and connectivity), digital literacy, and the availability of support systems, all of which are critical to understanding the broader implications of the digital divide in STEM education. This paper aims to contribute to the ongoing discourse on educational equity, offering insights that could inform policies and practices aimed at ensuring that all students, regardless of their background or location, have the opportunity to succeed in a technology-enhanced, hybrid learning environment. Ultimately, this study seeks to highlight the importance of addressing the digital divide as a means of leveling the playing field for STEM students, thereby promoting a more inclusive and effective educational system. Specifically, the goal of this paper is two-fold: 1) identify groups based on digital divide profile of the STEM students and 2) look at the relationship of digital divide and their academic performance particularly in a hybrid setting of teaching and learning.

2. Digital Divide in STEM Education

Access to technology is crucial for STEM students in hybrid learning environments due to the specialized software and digital tools required for their studies. However, disparities in access lead to significant challenges. Research (Ong, 2020; Perez, 2023; Reisdorf et al., 2020) indicates that students lacking high-quality devices and reliable internet struggle to keep up, especially in courses requiring specific software that is not accessible on mobile devices or outdated computers. This disadvantage often results in poorer academic performance. Udeogalanya (2022) found that students frequently face issues like unreliable internet and the inability to afford necessary devices, further widening the performance gap. Talandron-Felipe's (2019) study on technology identity revealed that STEM students are eager to enhance their technological skills, but nearly half lack adequate access to necessary educational technology. This underscores the essential role of educational institutions in providing access to technology. Moore et al. (2021) further emphasized that students with reliable access to digital tools are better equipped to engage with complex STEM content, highlighting how the digital divide exacerbates inequalities, particularly for underrepresented groups.

Digital literacy is another key factor influencing STEM students' success in hybrid learning. It encompasses more than basic computer skills, including the critical evaluation of digital content, the use of specialized software, and online research (Le et al., 2022). Higher digital literacy, often found in students from higher socioeconomic backgrounds, correlates with greater success in hybrid STEM courses, as these students are better equipped to navigate digital resources effectively (Peng and Yu, 2022). Moreover, digital literacy is linked to mastering 21st-century skills and online learning success (Pepito and Acledan, 2022; Nurhayati et al., 2020). Addressing both access and digital literacy is essential for ensuring equitable educational outcomes in STEM fields.

In addition, household income significantly impacts digital inequality, affecting device ownership, stable internet access, and frequency of use (Talandron-Felipe, 2021). Students from low-income families face greater digital divides due to limited access to technology and lower digital literacy, directly influencing their academic performance in hybrid learning environments. Income and education levels are strongly linked to greater access to and use of digital technologies, emphasizing that poverty is a key driver of the digital divide. Economic barriers prevent low-income students from accessing necessary digital tools and services, widening the academic performance gap with their affluent peers. The lack of broadband access in lower-income households, due to affordability issues, exacerbates these challenges, especially in a hybrid learning environment where reliable internet connectivity is crucial. These disparities contribute to broader social exclusion and reinforce existing inequalities in

education (Reddick et al., 2020). Mubarak et al. (2020) also found that income disparity is a major driver of the digital divide, with lower-income groups having less access to digital technologies, limiting their ability to engage with ICT. This lack of access negatively affects educational outcomes, particularly in developing countries where basic needs may take priority over educational tools.

STEM students also face unique challenges in hybrid learning environments that can exacerbate the impact of the digital divide. One of the primary challenges is the need for hands-on learning and experimentation, which is often difficult to replicate in an online setting. While some online tools and simulations can partially address this need, students without access to these resources are at a distinct disadvantage. One major issue is digital literacy, as students with lower digital skills may struggle to navigate online learning management systems (LMS) effectively, which can hinder their academic success. Additionally, many students perceive an increased workload due to the combination of online and in-person components, leading to lower enthusiasm for technology-based learning. Discipline-specific challenges, such as integrating practical laboratory work into a blended format, add further complexity, particularly in fields where hands-on experience is crucial. Furthermore, students' ability to self-regulate and engage with the course material plays a critical role in their academic outcomes. High-achieving students tend to interact more frequently with LMS resources, but those with lower digital literacy might need to engage more, potentially reflecting inefficiencies in their navigation of these systems. These challenges underscore the importance of providing support to enhance digital literacy, manage workloads, and effectively incorporate practical elements into hybrid learning environments for STEM students (Capone, 2022; Le et al., 2022; Ryoo and Winkelmann, 2021).

3. Data Collection

An online survey was conducted among the STEM undergraduate students of a satellite campus of a public university in southern Philippines (see Table 1).

Table 1. *Distribution of respondents based on STEM undergraduate program*

Program	Computer Science	Civil Engineering	Computer Engineering	Cybersecurity
Responses	32 (63%)	15 (29%)	3 (6%)	1 (2%)

These students have been enrolled in their respective programs and have experienced hybrid learning modality for at least one school year.

The students provided information about their degree program, year level, and household income. They also answered questions on digital divide aspects including access to technology, their perception on their level of digital literacy and skills they are proficient in, and utilization of digital materials for their studies. To represent their academic performance, their general weighted average (GWA) in the last semester was obtained and categorized (i.e., excellent, very good, above average, average, passing, and below passing) based on the university's student handbook.

4. Findings

Among the 51 students who responded to the survey, 11 (22%) have experienced hybrid modality of learning for 3 years, 27 (53%) for 2 years, and 13 (25%) for a year.

In terms of academic performance, 9 (18%) respondents were categorized as 'very good' based on the prior semester's GWA, 29 (57%) were 'above average', 11 (22%) were 'average', and 2 (4%) were 'below passing'.

The identification of social class was based on their reported income as per Philippine Institute for Development Studies (PIDS) (Philippine News Agency, 2020). More than half of the respondents, 30 (59%), were classified as 'poor', 7 (14%) as 'low income but not poor', 5 (10%) as 'lower middle class', 3 (6%) as 'middle class', 3 (6%) as 'upper middle income', 2 (4%) 'high income but not rich', and 1 (2%) as 'rich'.

When it comes to ownership of devices, almost all of the respondents (88%) have their own smartphone while less than half have tablets and/or a laptop or desktop computer (please see Table 2). Those who do not have their own would have to go to computer rental shops when they need to do school work that requires a computer or they wait until it's their turn to use the computer laboratory in school during face-to-face classes. When asked how often they are able to use a computer on a weekly basis outside of the school, 28 (55%) responded 'never' compared to the 13 (25%) who responded 'daily', the remaining of the respondents said rarely (6%), several times (6%), and once a week (8%).

Table 2. *Ownership of device and access to internet at home*

Ownership and Access	Yes	No
Smartphone	45 (88%)	6 (12%)
Tablet	20 (39%)	31 (61%)
Laptop Computer	19 (37%)	32 (63%)
Desktop Computer	19 (37%)	32 (63%)
Internet Connection at Home	37 (73%)	14 (27%)

It is also important to note that only 18 out of the 37 with internet connection at home have broadband or fiber connection and the rest of them refer to 'internet at home' through their mobile data. Those without their own internet connection reported to use their neighbors', friends', relatives' or public Wi-Fi if available, otherwise, they go to internet cafés.

To identify groups among the respondents based on their answers to the digital divide questions, clustering technique was used. There was a total of 22 parameters and the responses were a combination of binary (yes or no) or rating using a Likert scale with normalized distance as part of the preprocessing.

The optimal number of clusters was determined to be 3 using the elbow method. After which, k-means clustering was applied. A total of 16 respondents (31%) were classified to cluster 0, another 16 respondents (31%) for cluster 1, and 19 respondents (38%) for cluster 2. The centroid chart for each parameter is shown in Figure 1.

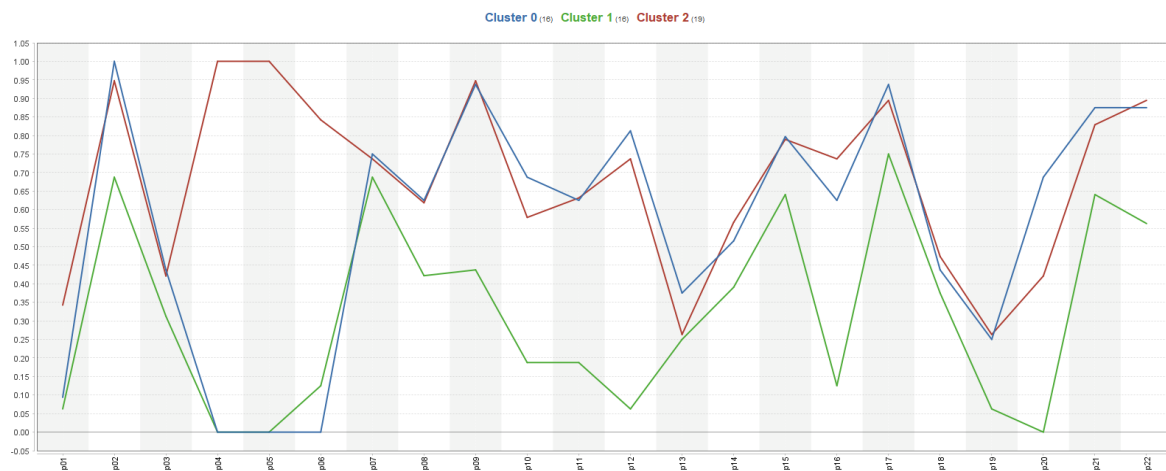


Figure 1. *k-means centroid chart of the clustering result*

This was helpful in understanding which parameters distinguish the clusters from each other. We can see that the prominent features that distinguish cluster 2 from cluster 0 and 1 are ownership of laptop (P4), desktop (P5), and frequency of using computer outside the school (P6). This distinction falls under the access divide among the students. For the distinction between cluster 0 and cluster 1, the features include proficiency in the use of email (P10), productivity tools (P11), and social media (P12). This distinction falls under the digital literacy and proficiency divide between these groups.

- Cluster 0 - limited device ownership and low frequency of computer use outside school.
- Cluster 1- higher digital literacy, particularly in email, productivity tools, and social media.

- Cluster 2 - better access to computers and more frequent computer use outside school.

Next, we looked at the academic performance of the respondents in the previous semester based on their general weighted average (GWA). We conducted a One-way ANOVA with post-hoc Tukey HSD Test. The f-ratio value is 3.588. The p-value is .0353. The result is significant at $p < .05$ suggesting that the one or more treatments are significantly different. The Tukey HSD test was used and a slight significant difference was found between cluster 0 ($m=2.44$) and cluster 2 ($m=2.09$), with Tukey HSD p-value of 0.046. Going back to the digital divide profile, there is an access divide between cluster 0 and cluster 2, with cluster 0 having smallest self-report rating for digital proficiency.

These findings link to Talandron-Felipe's (2019) study on technology identity, where STEM students showed eagerness to learn about technology but lacked sufficient access. This highlights the crucial role of educational institutions in providing technology access. Talandron-Felipe's (2020) study during the pandemic further emphasized this, categorizing students by their access to learning resources and prompting the university to implement support initiatives like ICT facility access, internet funding, and a tablet lending program. The study underscores the need for schools to consider the digital divide when designing instructional strategies and support policies for flexible learning.

5. Conclusion and Recommendation

This study highlights the digital divide among undergraduate STEM students at a satellite campus of a public university. The survey reveals that over half of the students come from low-income households, leading to disparities in technology ownership and access. While most students do own smartphones, fewer than half have their own tablet or computer, and many rely on mobile data for internet access. Clustering analysis identified three student groups, differentiated by device ownership, computer usage frequency, and digital proficiency. Academic performance, measured by general weighted average (GWA) in a hybrid learning environment, showed slight but significant differences between two clusters, linked to access and proficiency divides. The study suggests targeted support programs to address these issues, including providing affordable or subsidized access to essential technology, such as tablets or laptops, particularly for low-income students. Workshops and training sessions to improve digital proficiency in essential tools like email, social media, and office productivity software are recommended. Partnerships with telecommunications companies could enhance internet accessibility by offering affordable or subsidized packages, reducing reliance on mobile data. Ongoing monitoring of the digital divide's impact on student performance is essential to develop further interventions and ensure equitable access to education for all students.

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