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Exploring the readiness of high school physics students for project-based hybrid learning in the Sultanate of Oman

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Abstract

This study investigates the preparedness of school students in grades 9-12 to engage in physics project-based hybrid learning within the Sultanate of Oman. Using survey methodology, the research employed the online learning readiness scale and self-directed learning readiness scale following an evaluation of the questionnaire's reliability. A total of 383 physics students participated in the electronic survey conducted across 11 educational governorates in Oman, and descriptive statistics were employed for the analysis. Most participants, predominantly from grade 9, were situated in the Muscat Governorate, consistent with the targeted research population. The findings indicate a generally moderate level of readiness among school physics students (grades 9-12) for engaging in project-based hybrid learning. The study enhances the comprehension of student readiness dynamics amid evolving educational methods, specifically in physics project-based hybrid learning in the Sultanate of Oman.

Keywords: project-based learning, hybrid learning, online learning, physics education, self-directed learning readiness scale

INTRODUCTION

Physics students should possess the capability to apply their acquired knowledge for problem-solving within the subject. However, a significant proportion of classroom instruction tends to emphasize subject mastery over proficiency in problem-solving (Retno et al., 2019). However only a restricted proportion of students demonstrate the capability to utilize physics problem-solving strategies (Prahani et al., 2021). It has been established that the improvement of students' competence in solving physics problems necessitates the implementation of innovative learning models that are specifically designed and put to practical use. To enhance the overall quality of education, additional research may be warranted, particularly in the realm of relevant physics learning linked to the enhancement of physics problem-solving abilities. It is imperative for students addressing physics challenges in high school physics classes to adopt student-centered teaching strategies such as problem-based learning (Docktor et al., 2015). Said et al. (2023) concluded that there is a need to prioritize project-based learning (PjBL) in physics. Emafri et al. (2020) uncovered that PjBL represents an effective method for instructing physics to students with advanced capabilities. Fadilah (2019) recommends PjBL as a viable choice for larger courses. By involving students in collaborative investigations of real-world problems, PjBL facilitates active and profound learning (Belwal et al., 2020; Gendjova & Yordanova, 2009; Hong Sharon Yam et al., 2010; Papanikolaou & Boubouka, 2010). The performance and engagement of students in physics studies experience a substantial impact through the adoption of PjBL (Araujo et al., 2021; Bobroff & Bouquet, 2016; Makkonen et al., 2021)

In light of this, the evolution of the Internet and mobile platforms has created opportunities for hybrid learning, which combines both online and in-person interactions between educators and students. The COVID-19 pandemic has accelerated the integration of technology into physics education, underscoring the need for adaptive and flexible teaching strategies. As indicated by Mufida et al.'s (2021) study, the utilization of virtual laboratories and e-modules in physics instruction during the COVID-19 crisis significantly impacted student achievement. Particularly crucial for high school students, these online resources offered

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Contribution to the literature

- This study adds valuable insights into the assessment of students' preparedness for hybrid learning environments. Shedding light on the unique challenges and opportunities that may arise in the intersection of project-based and hybrid learning modalities.
- The findings provide a nuanced understanding of how readiness for physics project-based hybrid learning may vary across different stages of secondary education. This grade-specific approach enhances the applicability of the findings to educators and stakeholders catering to students in these grade levels.
- The findings can inform curriculum development and instructional strategies tailored to the distinct requirements of physics education in grades 9-12. This acknowledges the nature of physics education and how project-based hybrid learning may align or differ from traditional instructional methods in this subject.

diverse avenues for honing their physics problem-solving skills during a challenging period. After the COVID-19 pandemic, the Sultanate of Oman, akin to numerous other nations, embraced online and hybrid learning solutions to ensure educational continuity while prioritizing the safety of both students and educators.

In alignment with the objectives outlined in Oman's Vision 2040, the Omani government has placed a high priority on enhancing the education system. The commitment of the Sultanate of Oman's government to continual improvement in the educational sector is unwavering, with a focus on implementing significant enhancements. Unfortunately, students in the Sultanate of Oman face difficulties across various domains, with science being particularly notable among these challenges. As per evaluations conducted at both the national and international levels, the academic performance of students in Oman falls short of government targets, particularly in the field of science (Al-Amri et al., 2020). This shortfall may be attributed to various factors, including the content of science curricula and instructional methodologies. In the initial phases of Oman's primary education system, fundamental scientific principles are introduced, incorporating physics into the science curriculum for grades one through eight. From grades nine and ten onward, physics evolves into a distinct curriculum mandatory for all students. Following this, students are provided with the choice to elect physics as a subject in grades eleven and twelve. Belwal et al. (2020) presented evidence of the impact of instructional strategies, notably PjBL, in Oman. The findings of the study align with the objectives outlined in Oman's Vision 2040 and the nation's capacity-building goals, which strive to implement innovative methods for lifelong learning and student development. Unfortunately, there remains a lack of sufficient research to date that demonstrates the effectiveness of this learning technique within Omani educational contexts (Al-Balushi, 2016). Ambusaidi et al. (2022) underscored the imperative for the Sultanate of Oman to increase investment in preparing emerging science graduates with 21st century skills, enabling them to meet the demands of the global economy. This objective can be realized by highlighting the transformative impact of technological advancements on scientific hybrid learning, which holds the potential to significantly influence the academic performance of Omani students. To effectively teach physics in Omani schools, there is a requirement to integrate instructional methodologies with technology. The incorporation of technology into physics PjBL holds promise for enhancing educational quality and meeting the evolving needs of modern students in a rapidly changing technological landscape. However, it is crucial to assess students' readiness for PjBL in a blended environment. The primary objective of this study is to ascertain how students in grades 9-12 in the Sultanate of Oman perceive their level of readiness for physics project-based hybrid learning.

Research Problem & Questions

The research problem originates from the suboptimal academic performance observed among high school students in Oman, particularly those in grades nine through twelve, within the field of physics. The difficulty arises from the presentation of theoretical content without employing effective teaching strategies or sufficient digital tools, rendering it challenging for students to grasp concepts or solve problems in physics. Consequently, this study aims to assess the preparedness of students for learning physics in a hybrid environment by incorporating PjBL. To potentially implement PjBL in a hybrid setting, it is essential to examine the readiness of physics students for both PjBL strategy and online learning. The primary goal of the study is to investigate the extent to which physics students are ready to apply PjBL in a hybrid learning environment. Consequently, two research questions have been devised. The initial question focuses on students' preparedness for hybrid learning, while the subsequent one centers on their readiness for implementing PjBL, outlined, as follows:

1. To what extent are students in grades nine through twelve prepared for the hybrid learning approach in the field of physics?

2. To what extent are students in grades nine through twelve prepared for PjBL approach in the field of physics?

Research Importance

This study holds significance as it contributes to the existing educational literature by expanding our understanding of hybrid learning and advocates for the adoption of PjBL in physics education. Furthermore, the project aims to provide established teaching strategies and methodologies, specifically focusing on the implementation of PjBL in a hybrid context, which can be valuable for individuals engaged in teacher preparation and training. The findings of the study are anticipated to inspire educators and stakeholders to integrate this approach into classroom practices.

THEORETICAL FRAMEWORK

Project-Based Learning

PjBL is an educational methodology that places a strong emphasis on active student involvement and learning through hands-on, real-world projects. In PjBL, students engage in active exploration and inquiry-based learning, acquiring both information and skills in a collaborative setting. Unlike conventional classroom instruction, which tends to present material passively, PjBL encourages students to actively participate in their learning process (Harris et al., 2015). This approach involves learners expressing their acquired knowledge by creating personally meaningful artifacts, which could take the form of a poem, drama, or multimedia presentation (Harel & Papert, 1991; Kafai & Resnick, 1996). Additionally, students typically exert greater control over the content they study, fostering sustained interest and promoting a heightened sense of responsibility for their learning (Grant, 2002). The increased autonomy enables students to "tailor their assignments to align with their skills and interests." Consequently, the creation of artifacts through PjBL provides learners with the opportunity to showcase their diversity in terms of interests, skills, and learning preferences (Grant, 2002). According to Larmer et al. (2015), a challenging problem, sustained inquiry, authenticity, student voice and choice, reflection, critique and revision, and a public product are the fundamental elements of Gold Standard PjBL. The extent to which a project adheres to the principles of Gold Standard PjBL depends on these design elements and their representation within the project. The goal of the Gold Standard PjBL is to include the top research-based, classroom-tested project design elements and teaching strategies. The major objective for both teachers and students is to improve their teaching skills toward the Gold Standard PjBL for teachers, and for students to learn in-depth and develop the skills necessary for success in life (Larmer et al., 2015). In a PjBL approach, the teacher's function has been described in a variety of ways, including as a conductor, coach, or a facilitator. In addition to creating educational materials to PjBL strategy by implementing a variety of teaching practices. These practices involve planning, standard alignment, building the culture, managing activities, scaffolding, assessing, and coaching (Larmer et al., 2015).

As highlighted by Sivia et al. (2019), significant distinctions exist between training modules employing PjBL and those that do not. Specifically, the non-PjBL module allocated noticeably more time to independent and teacher-directed tasks compared to PjBL module, which emphasized research, critique, collaboration, and questioning. Moreover, in PjBL module, the teacher's focus centered more on monitoring the progress of each project, whereas in non-PjBL instruction, the emphasis was on ensuring the accuracy of responses from students working in groups. In PjBL approach, students are assigned tasks that replicate real-world problems. PjBL empowers students by placing them in control of their learning process, prompting them to formulate and address questions rather than merely responding to inquiries posed by a teacher or textbook (Sahli, 2017). This approach is versatile and can be implemented across various academic disciplines, fostering active, student-directed learning. The incorporation of real-world problems is integral to sustaining students' interest and motivation in the learning process. For teachers to effectively embrace this departure from traditional teaching methods, they must be prepared and capable of understanding their role in the instructional process. For these initiatives to yield effectiveness, it is crucial to emphasize that learning is not only a passive acquisition of information but an active process of knowledge production. The successful implementation of PjBL entails various factors, including scaffolded education, assessments that are less structured and time-intensive, instructional methods avoiding oversimplification, and a classroom environment that fosters inquiry, risk-taking, and a mastery orientation (Sahli, 2017). A recent examination of teachers' perspectives on PjBL revealed that educators reported higher satisfaction with both their teaching strategies and outcomes when utilizing PjBL (Sahli, 2017).

The efficacy of PjBL in imparting advanced physics knowledge to students has been substantiated in the research (Emafri et al., 2020). There is a strong recommendation for secondary schools to incorporate PjBL paradigm (Suastra et al., 2019). The application of PjBL approach has a discernible impact on the critical thinking abilities of high school students across various physics courses. For example, PjBL paradigm influences the critical thinking skills of high school students in topics related to energy (Fadilah, 2019) and static fluid learning materials (Hamdani, 2020).

Implementation of PjBL necessitates students to employ their comprehension of electromagnetic waves and optics from the curriculum to address real-world problems (Makkonen et al., 2021). The application of a PjBL model, grounded in the process skills approach, to the topic of momentum and impulse has been shown to enhance students' critical thinking abilities (Suastra et al., 2019). Additionally, as reported by Bonanno et al. (2018), a majority of educators and students expressed the view that the air quality experiment instrument, equipped with instructions, air quality indicators, and digital test data, should be integrated into PjBL. There is a recognized need for a practical module utilizing PjBL technique to assist students in reinforcing their scientific skills (Rahmad et al., 2019). PjBL demonstrates effectiveness in classrooms with a substantial student population, as indicated by Fadilah (2019). However, it is imperative to investigate the influence of PjBL when supplemented by additional media, such as virtual labs, visual media, or other audiovisual tools.

Hybrid Learning

Hybrid learning, also known as blended learning, has gained popularity as an educational approach (Olapiriyakul & Scher, 2006). This method involves the integration of traditional classroom instruction with online learning (Graham et al., 2013). The terms of hybrid learning and blended learning are often used interchangeably, Hinterberger et al. (2004) differentiate them. They define hybrid learning as utilizing technology in distance education, while blended learning involves merging traditional and modern pedagogical practices. A considerable number of students, 133 to be exact, express high enthusiasm for utilizing digital technology as a learning tool (Adri, 2020). It's essential to recognize that blended learning, often referred to as hybrid learning, extends beyond the simple combination of online and in-person instruction. The thoughtful selection of the most suitable environment for implementation holds equal importance to the fundamental integration process (Simarmata et al., 2018). The instructional approach included three weekly class meetings, a lecture-style format, assigned homework, and a group project submission (Gedik et al., 2013).

An assessment of course delivery requirements revealed that students sought an interactive and stimulating learning environment that could facilitate their learning through meaningful interactions, comprehensive feedback, guidance, and collaboration with peers. To manage a large class, the face-to-face (F2F) course instructor required a flexible learning environment for distributing materials, conducting various tasks, facilitating discussions, promoting collaboration, and easily monitoring students' progress. Improved engagement and communication were identified as additional essential components.

Furthermore, the collaborative mobile-learning science module on nutrition in science, designed for a Malaysian Secondary School, comprises five online courses, a F2F module orientation meeting, and a final F2F session (DeWitt et al., 2013). The study's findings indicate that students actively engaged with the course content, the instructor, and their peers in the discussion forum, highlighting how internet-based communication tools contribute to collaborative learning and offer advantages in science education (DeWitt et al., 2013). DeWitt et al. (2013) developed the collaborative mobile-learning module on nutrition in science based on the social constructivist learning theory and the First Principles of Instruction by Merrill (2002).

Following the global impact of the COVID-19 pandemic, hybrid learning has garnered widespread popularity, prompting numerous studies to investigate its impact on physics education (Herayanti et al., 2020). Despite the challenges posed by the pandemic affecting individuals across various domains, teachers and students quickly resumed their educational activities by implementing emergency remote learning systems (Selvaraj et al., 2021).

The findings of a quasi-experimental study demonstrated that blended learning has a significant positive effect on students' understanding of physics (Sivakumar & Selvakumar, 2019).

In this paper, hybrid learning refers to formally integrating F2F and online learning through technology to enhance the overall educational experience through PjBL implementation.

METHODOLOGY

In the research, a quantitative approach involving the administration of a questionnaire was employed for data collection. The questionnaire incorporated the self-directed learning readiness scale (SDLRS) and the online learning readiness scale (OLRS) to evaluate the preparedness of physics students for engaging in PjBL within a hybrid learning environment in Oman.

Research Population

The Sultanate of Oman comprises 11 educational governorates, each housing multiple public schools for both female and male students. These governorates are identified as Muscat, Dhofar, Musandam, Buraymi, the Dakhiliyah, the North Batinah, the South Batinah, the South Sharqiyah, the North Sharqiyah, the Dhahirah, and the Wusta. **Table 1** presents the study's target population, detailing the distribution of physics students from grade 9 to grade 12, as reported in the school year 2020/2021 by the statistical team. The statistical data was collected from the website of the educational portal of the Sultanate of Oman, https://home.moe.gov.om/?GetLang=en.

Table 1. Distribution of physics students in educational governorates in Oman (2020/2021)

Educational governorate	Number of physics students in grades 9-12
Muscat	26,854
North Batinah	24,334
Dakhiliyah	21,573
South Batinah	17,215
Dhofar	11,567
South Sharqiyah	11,041
North Sharqiyah	9,665
Dhahirah	8,110
Buraymi	2,857
Wusta	1,382
Musandam	1,163
Total	135,761

Research Sample

A sample size of 383 appears to be adequate for a population of 135,761 physics students in grades 9-12, as illustrated in **Table 1**, considering a 5.0% sampling error and a 1.0% risk factor. Guided by Krejcie and Morgan's (1970) recommendations, the appropriate sample size of 383 was determined, considering factors like population size, desired confidence level, and margin of error. This selection aligns with their guidelines, ensuring statistical reliability and confidence in the research findings.

Survey Instrument

In this study, a quantitative instrument took the form of an electronic survey designed through Google Forms. Leveraging Google Forms for its renowned flexibility in constructing online surveys, the primary objective was to systematically gather and structure data. SDLRS and OLRS used in this study on students' readiness for hybrid PjBL were carefully adapted. A careful adaptation process has been undergone to ensure their relevance and appropriateness for assessing the readiness of students for engaging in PjBL within a hybrid learning environment. The adaptation process involved several key steps as illustrated in the following sections for each scale. A comprehensive literature review was conducted to identify instruments with established reliability and validity. SDLRS and OLRS, chosen based on their alignment with study objectives, underwent scrutiny of their constructs. Expert consultation and pilot testing were employed for refining survey items, incorporating feedback. Ethical considerations were prioritized throughout the adaptation process. Construct validity was ensured through a detailed comparison with the original instruments. The adapted surveys, thus refined, were utilized as a reliable and valid means of assessing students' readiness for PjBL in a hybrid environment.

The survey design was a fusion of online learning readiness (OLR) survey instrument by Watkins et al. (2004) and SDLRS developed by Guglielmino and Paul (1977). The survey, structured on a 5-Likert scale, encompassed a total of 67 items and was distributed across 11 educational governorates in Oman. Its purpose was to assess students' readiness for PjBL in a hybrid setting. The survey categories are, as follows:

Table 2. Cronbach's alpha coefficients

Questionnaire	Items number	Overall Cronbach's alpha
OLR survey	27	0.847
SDLRS	40	0.917

1. OLR survey instrument, as developed by Watkins et al. (2004), was utilized in this study. Permission has been granted by the authors to utilize the instrument; however, caution has been advised in the interpretation of the results. This instrument, comprising 27 items, was aimed to assess students' preparedness for online learning as a component of hybrid learning. The survey items were rated on a 5-point Likert scale (1=completely disagree; 2=strongly disagree; 3=not sure; 4=strongly agree; & 5=completely agree). Watkins et al. (2004) asserted that their examination of the initial and modified instrument does offer substantiation indicating that the questions consistently measure the intended scales derived from the e-learning literature. As a result, forthcoming iterations of the e-learning readiness self-assessment could offer practitioners and researchers a valid and reliable tool for gauging learners' readiness for success in the online classroom. The validity and reliability of the instrument were established through assessments of its construct, content, and criterion. The adaptation of this questionnaire drew from OLRS, encompassing constructs such as technology access, online skills, motivation, ability to use online audio/video, the Internet discussions, and importance to your success (Watkins et al., 2004). In assessing the reliability of OLR questionnaire for this study, a pilot study involving 30 students, distinct from the final sample, was conducted. Cohen et al. (2007) recommended a minimum sample size of 30 for statistical analysis, aligning with the central limit theorem. The calculated Cronbach's alpha coefficient, depicted in **Table 2**, stood at 0.847, signifying a satisfactory level of reliability.
2. SDLRS instrument by Guglielmone was utilized to assess students' preparedness for PjBL. SDLRS proves to be a superior instrument as it encompasses both attributes and skills, coupled with a more substantial foundation in the existing literature. Furthermore, extensive evidence supporting its construct, content, and criterion reliability and validity is prevalent in the literature (Maltby et al., 2000). Consequently, for the specific objectives outlined in this study,

Table 3. Profile of respondents (n=383)

Demographics		n	%
Gender	Male	186	48.6
	Female	197	51.4
Grade	9	106	27.7
	10	101	26.4
	11	85	22.2
	12	91	23.8
Educational governorates	Muscat	79	20.6
	North Batinah	62	16.2
	South Batinah	49	12.8
	Dakhiliyah	57	14.9
	South Sharqiyah	28	7.3
	North Sharqiyah	28	7.3
	Buraymi	15	3.9
	Dhahirah	17	4.4
	Dhofar	28	7.3
	Wusta	10	2.6
	Musandam	10	2.6

SDLRS was considered the most appropriate instrument for obtaining a precise measurement of readiness for self-directed learning. SDLRS questions, totaling 40 items, were categorized into self-management (SM) (13 items), learning desire (12 items), and self-control (SC) (15 items) (Stewart, 2007). Recognizing that self-directed learning (SDL) is a key outcome of PjBL, optimal SDL readiness becomes crucial for maximizing the benefits of PjBL experiences at advanced learning levels. Respondents in this study were tasked with rating statements related to SDLRS on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) through a questionnaire. The reliability of SDLRS questionnaire was assessed, yielding an overall Cronbach's alpha coefficient of 0.917, signifying highly acceptable reliability, as presented in **Table 2**.

RESULTS & DISCUSSION

Data analysis was performed using descriptive statistics in SPSS version 22. The mean and standard deviation were calculated for both the respondents' demographics and all constructs within the questionnaire. This analysis aimed to examine the readiness of physics students in grades 9-12 to embrace PjBL strategy within a hybrid learning environment.

Respondents' Profile

Table 3 provides a summary of the demographics of the 383 respondents. Among the total population, males constituted 48.6%, and females constituted 51.4%. The distribution across grades showed that 27.7% of the respondents were in grade 9, and 22.2% were in grade eleven. To determine the number of participants to be sampled in each educational governorate in Oman, proportional and stratified simple random sampling techniques were employed, considering the varying sizes of strata (Sekaran & Bougie, 2013). Notably, a significant portion of the respondents originated from Muscat Governorate, accounting for 20.6%, while participants from Wusta Governorate and Musandam Governorate collectively represented 2.6% of the respondents. According to the context of proportional and stratified simple random sampling techniques, these portions reflect the distribution of participants across different governorates in a manner that aligns with the population proportions. In proportional sampling, the goal is to ensure that the sample reflects the same proportions as the entire population. In this case, Muscat Governorate is justified by its larger population size within the overall population. Similarly, Wusta Governorate and Musandam Governorate are reflective of their smaller population proportions as presented in **Table 1**. The demographic findings played a pivotal role in supporting the study's objective of examining students' readiness for physics project-based hybrid learning in grades 9-12 in the Sultanate of Oman. The gender distribution, with a balanced representation of males (48.6%) and females (51.4%), enabled an exploration of gender-based variations in readiness. Likewise, the distribution across different grades (e.g., 27.7% in grade nine and 22.2% in grade eleven) allowed insights into readiness variations across educational stages. The inclusion of respondents from diverse governorates, notably Muscat (20.6%), facilitated the examination of potential regional differences. Proportional sampling techniques enhanced the study's external validity, ensuring representative samples in each educational governorate. These demographic insights, combined with the proposed statistical analysis, supported a nuanced understanding of readiness levels, aligning with the study's objective to inform targeted educational interventions for grades 9-12 students in Oman.

Students' Readiness for Online Learning

The key distinction between hybrid learning and online learning lies in the extent of F2F interaction. Hybrid learning integrates both traditional classroom elements and online components, fostering a blended approach. Online learning, on the other hand, is conducted entirely through digital platforms, allowing for more flexibility but without the physical classroom experience. However, in this study the survey on students' readiness for online learning was utilized for examining their readiness for hybrid learning. This is due to shared digital literacy skills, technological proficiency, and self-directed learning requirements. Both modalities demand time management and flexibility. Assessing students' preferences and skills through an online readiness survey is relevant for designing effective hybrid experiences.

Table 4. Results of students' readiness for online learning

Dimension	M	SD	Level
Technology access	3.48	0.980	Medium
Online skills	3.61	0.745	Medium
Motivation	2.93	1.018	Medium
Online audio/video	3.44	0.813	Medium
Internet discussion	3.35	0.727	Medium
Importance to your success	3.35	0.693	Medium

Note. M: Mean & SD: Standard deviation

While nuances exist, the overlap in essential skills and attitudes makes the online readiness survey a valuable tool. The survey assessed respondents' readiness for online learning across six dimensions: Technology access, online skills, motivation, online audio/video, the Internet discussion, and importance to your success.

Table 4 presents the mean scores and standard deviations for each of these six subscales. The mean scores for each factor were calculated by dividing the sum of responses to the component's items by the quantity of factor items. Evaluation criteria categorized means in the range of 1.00-2.30 as low, 2.31-3.70 as medium, and 3.71-5.00 as high. The results, as depicted in **Table 4**, indicate that respondents' average scores across the various dimensions, measured on a 5-point Likert-type rating scale, ranged from 2.93 to 3.61. This suggests that most students exhibited intermediate levels of readiness for online learning. Consequently, it implies that in PjBL scenarios, students possess a moderate level of technology access concerning the implementation of hybrid learning.

Based on the results of the requirements analysis, students are at a medium readiness level for PjBL approach in terms of their OLR. These results also support previous research that examined the possibilities of using appropriate technology for pedagogical approaches, such as a plan to enhance engagement and communication between students and teachers by fusing social media and mobile messaging with in-person instruction (Zhai et al., 2019). Technologies have allowed educators and learners to search for materials for their studies, use topic-specific search engines to locate pertinent information, and therefore have some degree of learning flexibility. To provide students with relevant and interesting learning experiences, educators must focus on building the infrastructure necessary to enable hybrid and blended learning techniques (Arano-Ocuaman, 2010; Singh et al., 2021). Students in the hybrid curriculum showed greater satisfaction with the usage of technology to assist and enhance their learning when compared to those in the traditional program (Arano-Ocuaman, 2010). Student conversations were enhanced by PjBL with the help of e-learning, and the learning environment seemed to be quite pleasurable (Widyaningsih & Yusuf, 2020). By completing online activities, students gained preparation and knowledge that enabled the application of scaffolding in a meaningful inquiry (Kurniawan et al. 2019). Learning is positively impacted by the integration of PjBL model with Telegram Messenger (Pratama & Prastyaningrum, 2019).

According to Alias et al. (2013), students benefited from the creation of a physics curriculum and its integration with technology in a secondary school setting. The learning expectations that teachers set for their students during distance learning physics can be influenced by a variety of factors, including the characteristics and backgrounds of each student, the school's capacity to facilitate online learning activities, the learning environment, and the local conditions in each location (Mufida et al., 2021). Using online video lectures can improve e-learning initiatives (Ozan & Ozarslan, 2016; Rozal et al., 2021). Videos need to be provided to make PjBL method more appealing to students who use it. It has been shown that PjBL with YouTube presentations as a capstone project increases student learning achievement in cognitive domains, where the experimental physics class performs better than the control class (Rozal et al., 2021). The results of the poll support the notion that social media, mobile messaging applications, movies, and online resources are often used by physics students.

Hybrid learning amplifies the effectiveness of PjBL in physics by amalgamating traditional and online components. Employ virtual labs, simulations, and collaborative platforms to foster both individual exploration and teamwork. Integrate self-paced online modules to establish a solid foundational knowledge base and apply real-world scenarios within virtual environments to enhance the comprehension of concepts. Conduct hybrid meetings for project updates and guidance, catering to diverse learning preferences and employing a range of assessment methods, blending traditional evaluations with online techniques. Allow adaptable online project submissions to accommodate varying schedules. Leverage technology tools such as 3D modeling and coding platforms to enhance the depth and complexity of projects, ensuring a dynamic and comprehensive physics education.

In general, the outcomes of the present investigation indicate that students in grades 9 to 12 within Omani public schools demonstrated a moderate degree of preparedness for engaging in online learning in the field of physics. Therefore, educators should assess students' OLR before introducing physics hybrid learning for several crucial reasons. Firstly, understanding students' readiness for online learning ensures they possess the necessary technological skills and access, preventing potential barriers to effective participation. Secondly, evaluating OLR allows educators to tailor instruction to students' digital proficiency, ensuring a smoother transition to hybrid learning environments. Additionally, assessing readiness helps identify areas,

Table 5. Results of students' readiness for project-based learning using SDLRS

Dimension	M	SD	Level
Self-management (SM)	3.28	0.664	Moderate
Desire for learning (DL)	3.52	0.620	High
Self-control (SC)	3.43	0.562	Moderate

Note. M: Mean & SD: Standard deviation

where students may need additional support or resources, promoting a more inclusive and equitable learning experience. Ultimately, exploring OLR is integral for educators to design hybrid learning strategies that effectively meet the diverse needs of students in the ever-evolving educational landscape.

Students' Readiness for Project-Based Learning Using SDLRS

The findings from the analysis of SDLRS were interpreted based on the criteria established by Klunklin et al. (2012), which categorizes scores into the highest level (4.50-5.00), high level (3.50-4.49), moderate level (2.50-3.49), low level (1.50-2.49), and the lowest level (1.00-1.49). In **Table 5**, mean and standard deviation details for the three constructs of SDLRS are provided, with mean ratings ranging from 3.28 to 3.52. The respondents exhibited the highest level of desire for learning (3.52), while SM received the lowest rating with a mean value of 3.28. **Table 5** indicates that students generally demonstrated moderate levels of both SC and SM. However, they exhibited a strong desire to learn (DL). In summary, the overall student preparedness for PjBL is at a medium level. In other words, students seem to be somewhat prepared for PjBL.

Before implementing physics PjBL, educators should evaluate students' readiness using the self-directed learning readiness (SDLR) assessment. SDLR gauges learners' ability for self-guided education, aligning with the independence needed in PjBL. This evaluation ensures students possess vital skills and motivation for effective participation. SDLR, focusing on SM, learning desire, and SC, assists educators in offering targeted support, enriching PjBL experience. Identifying students' readiness levels allows educators to address weaknesses, reinforce self-directed learning skills, and establish a conducive learning atmosphere. Considering SDLR enhances the success of PjBL, fostering well-prepared and empowered students. While the application of SDLRS scale to evaluate students' preparedness for PjBL may not be conventional, the outcomes suggest its viability, supported by previous research. SDLRS, designed for assessing learners' readiness for self-directed learning, can be modified and employed to gauge students' readiness for PjBL. Many of its constructs closely correspond to the skills and attributes conducive to success in PjBL environments, showcasing the adaptability and potential utility of SDLRS in this context.

Engaging in PjBL endeavors, typically characterized by self-discovery, encourages students to chart their paths. Stewart (2007) asserts that Guglielmone's SDLRS stands out as the most effective instrument for gauging SDL readiness due to its comprehensive coverage of both qualities and skills, coupled with a robust theoretical foundation. Moreover, extensive literature provides ample evidence of its construct, content, and criterion reliability and validity (Maltby et al., 2000). Importantly, employing such assessments enables educators to systematically enhance SDL skill levels to align with specific PjBL tasks. In PjBL settings, these measurements can also identify and support students who may be more vulnerable (Stewart, 2007). Also, SDLRS instrument was employed to evaluate the readiness of secondary school students, as evidenced by Kan'an and Osman (2015), who examined the correlation between the achievement of secondary science students and their readiness for self-directed learning using SDLRS. Students with prior PjBL experience ought to be better equipped to participate in SDL than other students (Stewart, 2007). The findings show that students' strong DL drives their participation in PjBL activities. Although their levels of SC and SM are moderate. Sohmen (2020) assessed the extent to which PjBL participants applied their SDL abilities. The results demonstrated the significant time, cost, and quality efficiencies that a PjBL model offers for 21st century educational performance in rapidly evolving technological environments. These findings demonstrated that improving students' preparedness for online learning as well as PjBL using SDLRS is essential for implementing PjBL in physics in a hybrid context. Reflective talks led by teachers increased student participation and cooperation during PjBL (Sormunen et al., 2020). When integrating PjBL with the Learning management system (LMS) LMS Moodle as an instructional e-platform, students' achievement of critical thinking skills and self-regulated learning SRL is higher than when using traditional learning methods (Sudianto et al., 2019).

In general, for this study, the results of SDLRS suggest that students in grades 9 through 12 in both male and female schools in the Sultanate of Oman are moderately prepared for PjBL. Therefore, physics educators should assess students' SDLR before implementing physics PjBL. SDLR evaluates learners' capacity for self-guided education, aligning with the independent exploration required in PjBL. This assessment ensures students possess essential skills and motivation for effective engagement. SDLR's focus on SM, learning desire, and SC also aids educators in tailoring support, enhancing PjBL experience. By identifying students' readiness levels, educators can address weaknesses, strengthen self-directed learning skills, and create a conducive learning environment. Considering SDLR optimizes success of PjBL, promoting well-prepared and empowered students in the process.

CONCLUSIONS

Hybrid learning provides a dynamic platform for the implementation of PjBL in the field of physics. This study aimed to evaluate students' readiness for engaging in PjBL within a hybrid setting. A total of 383 physics students spanning grades 9-12 from eleven educational governorates in Oman participated in an online questionnaire. The survey incorporated OLRS and SDLRS. The findings indicated a moderate level of readiness among students for project-based hybrid learning. Consequently, it is crucial to assess students' readiness before introducing PjBL in physics within a hybrid context to ensure they possess the essential technological skills and exhibit self-directed attributes, contributing to effective educational outcomes. While the primary emphasis of the study was on physics students in public schools, there is the potential for the research to be extended to include physics students in private schools in the future. Additionally, the study's environment is considered analogous to other scientific domains such as biology and chemistry, suggesting that the findings could be applicable to diverse settings. Moreover, for broader utilization of SDLRS in evaluating readiness for PjBL, adjustments to certain statements or the inclusion of specific questions on collaborative work, teamwork, and problem-solving within a project-based context may be necessary for researchers. This research can unveil innovative and effective pedagogical approaches that harness the benefits of integrating PjBL with digital technologies, advancing the field of physics education. Future research initiatives could delve deeper into developing and organizing a pedagogical module that combines PjBL with physics education in a hybrid learning setting. This exploration is essential for understanding how the collaborative interactions among PjBL, LMSs, and electronic applications can enhance the educational journey in physics, ultimately leading to improved learning results.

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