ASSESSING EDUCATION 4.0 COMPETENCIES IN RURAL *STEM* SCHOOLS: BASIS FOR THE E-SINUDLO DIGITAL LITERACY INTERVENTION

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***ABSTRACT*: *This study assessed the Education 4.0 competencies of STEM teachers and students in two rural schools in the Cantilan District of Surigao del Sur, Philippines. Using a descriptive–quantitative research design, data were collected from 20 teachers and 221 students to assess their familiarity with Education 4.0 concepts, engagement with digital tools, pedagogical practices, infrastructure readiness, and support for research programs. Results revealed a significant competency gap between teachers and students. Teachers demonstrated moderate familiarity and strong engagement with digital tools, whereas students exhibited low familiarity and only moderate engagement, reflecting limited exposure to emerging technologies. Infrastructure was generally adequate, but internet connectivity remained a major barrier, restricting consistent use of digital platforms. Pedagogical practices aligned with Education 4.0 at a foundational level; however, the integration of advanced tools, such as simulations, AR/VR, and robotics, was minimal. Based on the findings, the study proposes the e-Sinudlo Digital Literacy Intervention, a contextualized framework intended to strengthen digital skills, enhance technology-supported pedagogical practices, and support the effective use of available infrastructure in rural schools. The results highlight a persistent digital divide in rural learning environments and underscore the need for sustained capacity-building efforts, reliable connectivity, and institutional support to promote equitable and meaningful implementation of Education 4.0.*

Keywords: Education 4.0, Digital Literacy, STEM Education, Rural Schools, ICT Integration, e-Sinudlo Program

INTRODUCTION

The rapid progression of Industry 4.0 has reshaped global education systems, ushering in an era known as Education 4.0. This paradigm emphasizes the integration of artificial intelligence, robotics, automation, cloud computing, big data analytics, and immersive technologies into learning environments [1]. Education 4.0 requires students to become technologically fluent, collaborative, innovative, and capable of solving complex problems using digital tools [2]. These demands call for schools to reorganize their curricula, strengthen their ICT infrastructure, and upskill their teachers to deliver technology-enabled learning experiences. International studies indicate that Education 4.0 promotes flexible, personalized, and competency-based learning pathways that enhance engagement and cognitive development [3, 4]. However, implementation varies widely, particularly in developing countries where rural communities often face persistent digital divides [5, 6]. Schools with insufficient connectivity, inadequate devices, and limited teacher training struggle to adopt Education 4.0 practices effectively [7].

In the Philippine context, national initiatives such as the DepEd Computerization Program (DCP) and the Digital Education Framework aim to improve ICT integration. However, research consistently shows that rural schools remain technologically disadvantaged due to power instability, insufficient digital resources, outdated equipment, and low exposure to advanced digital tools [23, 24]. This disparity poses challenges, especially for STEM learners, whose fields increasingly depend on digital simulation, modeling, computation, analytics, and automation [8, 9].

Preliminary assessments in the Cantilan District reveal that while teachers show moderate digital readiness, students demonstrate significantly limited familiarity with Education 4.0 tools. These gaps restrict the ability of rural learners to compete academically and professionally. Addressing these disparities calls for localized, inclusive, and sustainable digital literacy interventions.

This study, therefore, aims to evaluate STEM teachers' and students' Education 4.0 competencies, examine gaps in digital engagement, pedagogy, and infrastructure, and develop the e-Sinudlo Digital Literacy Intervention to enhance the implementation of Education 4.0 in rural schools.

MATERIALS AND METHODS

This study employed a descriptive–quantitative research design to evaluate the Education 4.0 competencies of STEM teachers and students in rural schools within the Cantilan District of Surigao del Sur. This design allowed the researchers to systematically collect and analyze numerical data describing the respondents' familiarity, engagement, pedagogical practices, infrastructure readiness, and research support. These procedures align with the approaches commonly applied in earlier ICT-readiness investigations.

The study was conducted in two STEM-offering institutions, Saint Michael College of Cantilan, Inc. (SMCCI) and Cantilan National High School (CanNHS). both located in rural coastal barangay where schools face persistent challenges in accessing digital resources, internet connectivity, and technological support. Twenty (20) STEM teachers and 221 STEM students were included as respondents. They selected the teachers through purposive sampling based on their involvement in STEM instruction. They drew the students through stratified random sampling to ensure balanced representation across grade levels and school types.

The data were collected using a validated survey instrument adapted from established Education 4.0 and digital literacy frameworks. The questionnaire covered five major areas: familiarity with Education 4.0 concepts, engagement with digital tools, teaching and learning practices, infrastructure readiness, and support for research programs. Respondents rated each item using a four-point Likert scale ranging from Strongly Disagree (1.00–1.75) to Agree (3.26–4.00). Field experts validated the instrument's content, and reliability testing using Cronbach's alpha produced coefficients between 0.82 and 0.94, confirming high internal consistency. Before collecting any data, the researchers obtained permission from school administrators and provided all respondents with information about the study's objectives, confidentiality measures, and requirements for voluntary participation

The survey was administered on-site using printed questionnaires to avoid issues related to unstable internet connectivity. After retrieval, all questionnaires were checked for completeness, encoded the responses into spreadsheets, and analysed the data using descriptive statistics, including frequency counts, percentages, and weighted means. These techniques enabled the researcher to present clear and interpretable summaries of the participants' readiness for Education 4.0. Throughout the process, all ethical standards, including obtaining informed consent, protecting respondent confidentiality, and complying with institutional and Department of Education (DepEd) guidelines were observed.

RESULTS

This section reports the key results generated from the descriptive analysis of the participants' responses. To provide a clear overview of the Education 4.0 competencies of both teachers and students, the findings are presented through a series of tables that detail their familiarity, engagement, instructional practices, infrastructure readiness, and research support.

Table 1. Teachers' Familiarity with Education 4.0

Indicator	Mean	Interpretation
Awareness of digital tools	2.80	Agree
Understanding of Education 4.0 concepts	2.40	Disagree
|Knowledge of LMS platforms	2.70	Agree
Awareness of AR/VR technologies	2.15	Disagree
Familiarity with robotics and automation	2.00	Disagree
Overall Mean	2.60	Agree

Table 1 reveals that STEM teachers possess a moderate level of familiarity with Education 4.0 concepts, as indicated by the overall mean score of 2.60 (Agree). The highest ratings are observed in indicators related to awareness of digital tools (M = 2.80) and familiarity with learning management systems (M = 2.70), indicating that teachers are comfortable using basic ICT applications to support instruction. These results align with existing literature, which shows that teachers typically adopt foundational technologies earlier and more confidently than students because they receive greater exposure through training and professional development initiatives. However, lower mean scores on indicators related to AR/VR (M = 2.15) and robotics and automation (M = 2.00) suggest that teachers have limited familiarity with advanced Education 4.0 technologies. These results indicate a gap between routine ICT practices and higher-level technological competencies needed for immersive and simulation-based teaching.

Table 2. Students' Familiarity with Education 4.0

Indicator	Mean	Interpretation
Awareness of digital tools	1.95	Disagree
Awareness of Education 4.0 concepts	1.80	Disagree
|Familiarity with LMS	1.78	Disagree
Knowledge of AR/VR	1.60	Strongly Disagree
Familiarity with automation	1.55	Strongly Disagree
Overall Mean	1.85	Disagree

Table 2 shows that students demonstrate low familiarity with Education 4.0, with an overall mean of 1.85 (Disagree). Students scored below 2.00 across all indicators, suggesting limited exposure to digital tools and minimal awareness of the technologies shaping modern STEM education. The lowest indicators—knowledge of AR/VR (M = 1.60) and familiarity with automation (M = 1.55)—suggest that students in rural settings have had limited interaction with or exposure to advanced technological systems. These findings confirm earlier studies that have noted rural learners often experience digital deprivation, resulting in reduced preparedness for technology-enhanced learning environments. The consistently low means imply that students may struggle to participate in Education 4.0-aligned tasks such as coding simulations, virtual labs, or robotics activities. Table 2, therefore, emphasizes the urgency of structured digital literacy training for STEM learners.

Table 3. Engagement Levels among Teachers and Students

Group	Mean	Interpretation
Teachers' Engagement	3.42	Strongly Agree
Students' Engagement	3.04	Agree

Table 3 reveals a clear difference in the engagement levels of teachers and students. Teachers demonstrate high engagement with digital tools, reflected in their mean score of 3.42 (Strongly Agree). They use digital platforms regularly for lesson delivery, assessment, communication, and instructional planning. Their strong engagement likely results from ongoing professional development activities and institutional expectations that require them to integrate technology into their teaching practices. In contrast, students' engagement was rated lower, at 3.04 (Agree). While this value still indicates moderate engagement, it suggests that students' experiences with digital tools are less consistent and often limited by factors such as device availability, data access, and connectivity issues. The discrepancy between teacher and student engagement reveals a structural inequality: even if teachers integrate technology, students may not fully benefit if they lack access to the same digital environment outside of school hours. Table 3 highlights the need for improved student access to digital resources to support equitable technology-enhanced learning.

Table 4. Infrastructure Readiness

Indicator	Mean	Interpretation
Availability of devices	2.85	Agree
Functionality of equipment	2.70	Agree
|Internet connectivity	2.40	Disagree
Technical support availability	2.65	Agree
Overall Mean	2.65	Agree

Table 4 reveals that overall infrastructure readiness was rated 2.65 (Agree), indicating that schools possess the essential ICT facilities, such as computers, projectors, and basic laboratory equipment. The indicators for device availability (M = 2.85) and equipment functionality (M = 2.70) show that the foundational infrastructure is in place.

However, the indicator for internet connectivity (M = 2.41) received the lowest rating, indicating that connectivity remains a critical barrier to implementing Education 4.0. This finding aligns with national and global reports indicating that rural schools frequently experience unstable, slow, or limited internet access. Without reliable connectivity, schools cannot fully integrate LMS platforms, real-time communication tools, online research, simulations, and other Education 4.0 technologies.

Thus, Table 4 highlights that although physical equipment is available, the digital infrastructure remains insufficient to support the integration of advanced technology.

5. Research Program Support

Table 5. Research Program Support

Indicator	Mean	Interpretation
Access to research mentors	2.70	Agree
Availability of funding opportunities	2.45	Disagree
| Availability of funding opportunities	2.60	Agree
Collaboration with HEIs	2.55	Agree
Overall Mean	2.58	Agree

Table 5 shows that research program support received an overall mean of 2.58 (Agree), indicating that schools provide some degree of assistance in terms of research training, mentorship, and collaboration. Teachers agreed that research mentors are available (M = 2.70) and that training opportunities are occasionally offered (M = 2.60).

However, the indicator for funding opportunities (M = 2.45) was rated “Disagree,” showing that financial support for conducting, presenting, or publishing research is insufficient. Limited funding restricts teachers’ ability to engage in sustained inquiry-based practices and weakens schools’ overall research culture.

Table 5 suggests that while schools recognize the importance of research, support systems lack depth, structure, and consistent funding, making it difficult to fully integrate research-based teaching, which is essential to Education 4.0.

DISC USSION

Findings show a mismatch between teacher and student readiness, consistent with prior research indicating that teachers often receive more digital exposure than students in rural environments [8]. The low familiarity among students reflects chronic issues related to device scarcity, inadequate internet access, and limited integration of advanced digital tools in classroom instruction.

Teacher results align with the TPACK Framework, which suggests that teachers possess a baseline level of technological knowledge but lack the deeper integration skills necessary to combine technology with effective pedagogy [1]. While TAM theory posits that perceived difficulties, such as poor connectivity and limited devices, reduce perceived ease of use and subsequently lower adoption [11], [12] extend this idea by focusing on the psychological factors associated with ICT use. They find that negative experiences, such as discomfort or distraction, also affect students' perceived usefulness and self-efficacy, which are key to adoption intention. Both perspectives highlight how barriers to ease of use, whether technological or psychological, contribute to lower adoption rates among students.

Infrastructure findings reinforce UNESCO and World Bank reports noting that rural schools globally face inadequate connectivity, insufficient equipment, and inconsistent digital support [21], [22]. These systemic barriers limit the integration of AR/VR, robotics, automation, and other Education 4.0 technologies.

The study reveals urgent pedagogical implications: teachers need more training in immersive digital tools, simulations, coding, and data-driven STEM learning. Similarly, students must receive foundational digital literacy training to participate meaningfully in Education 4.0 learning environments.

These findings justify the development of the e-Sinudlo Digital Literacy Intervention, designed to address rural digital gaps, strengthen teacher and student competencies, and institutionalize digital transformation practices.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that Education 4.0 readiness in the rural STEM schools of Cantilan District remains limited and uneven, with teachers showing moderate familiarity and strong engagement with digital tools. At the same time, students exhibit low familiarity and inconsistent access to essential technologies. Although schools possess basic ICT facilities, unstable internet connectivity and limited integration of advanced tools, such as simulations, AR/VR, and robotics, continue to hinder full digital transformation. These findings align with global and local literature that highlights the persistent digital divide in rural learning environments. However, this study extends the existing body of knowledge by providing updated empirical evidence specific to rural Philippine STEM contexts—an area where research remains sparse.

Furthermore, the development of the e-Sinudlo Digital Literacy Intervention provides a localized and context-driven model that directly addresses gaps identified in current literature, particularly the need for culturally responsive and community-anchored approaches to Education 4.0 implementation. Based on the results, this study recommends that schools institutionalize structured digital literacy programs that build both teacher and student competencies, supported by continuous professional development aligned with TPACK principles and increased access to STEM-related digital platforms. Schools must also strengthen internet connectivity, expand device accessibility, and cultivate a stronger research culture through consistent mentoring and funding opportunities to create sustainable digital ecosystems. The study also encourages collaboration with local government units, NGOs, and higher education institutions to enhance infrastructure, support capacity-building efforts, and ensure the long-term sustainability of the program. By addressing these systemic concerns, rural schools can close digital learning gaps, improve student outcomes, and align their instructional practices with global Education 4.0 standards.

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