
Teachers' ICT Integration in Science Teaching and Learning Outcomes

Alfonso T. Pamisa Jr.¹, Jessica Joy D. Hinacay²

¹Southern de Oro Philippines College, Cagayan de Oro City, Philippines

²DepEd Cagayan de Oro City Division, Cagayan de Oro City, Philippines

ABSTRACT: ICT integration has become an essential factor of making teaching and learning in Science more effective. This study aimed to determine the teachers' level of ICT integration in Science classes and the pupils' level of learning outcomes. It also evaluated how ICT adoption by teachers impact pupils' academic performance in Science education. The respondents in this study were Grade 6 pupils from three sampled schools that have equal access to ICT randomly selected through Slovin's formula. The study employed a descriptive-correlational and causal research designs, utilizing a research-made questionnaires that underwent validity and reliability tests. Mean and Standard Deviation, as well as the Pearson Product Moment Correlation Coefficient and Multiple Linear Regression Analysis were used to analyzed data gathered. Results showed that level of ICT integration by Science teachers is high at the emerging and applying stages and low in infusing and transforming stages. Pupils' learning outcomes in Science is Very Satisfactory. A significant moderate positive correlation is identified between teachers' ICT integration and pupils' learning outcomes in Science. All stages of ICT integration are predictors of pupils' learning outcomes in Science. Thus, Teachers' ICT integration in Science is associated with the pupils' learning outcomes. As teachers use ICT more effectively, pupils tend to achieve better outcomes. It is recommended that teachers may keep abreast with the latest trends in ICT and its integration to improve the teaching and learning process.

KEYWORDS: applying, emerging, ICT integration, infusing, learning outcomes

I. INTRODUCTION

Educational developments using Information and Communication Technology (ICT) transformed traditional methods of teaching Science education alongside learning approaches. The modern education system uses ICT as its foundation because its applications extend beyond creating interactive classrooms. Since Science is primarily an experimental and inquisitive subject, it derives a great benefit from the opportunities that come with ICT. For example, virtual laboratories, simulations and data analysis software used by pupils help them to visualize complex Science concepts and have meaningful learning experiences (Hattie, 2019).

The demand for ICT to be integrated in Science education is due to its proficiency in making theory more practical. Most of the traditional methods in teaching are restricted in providing the learners with practical experience due to constraints such as resource or safety factors. As a result, ICT comes in to provide more engaging and safe ways of doing these hands-on activities. For example, virtual labs enable the pupils to do chemical reactions or study biological processes with minimal or no risk of being exposed to real experiments (Estriégana et al., 2019).

Moreover, the use of ICT in Science learning supports collaborative learning environments in which pupils collaborate on tasks while sharing information and performing output evaluation as one cohesive unit. The combination of scientific knowledge growth and teamwork development occurs within these environments, which are highly desirable in STEM (Science, technology, engineering and Mathematics) fields (Noroozi & Sahin, 2022). This technology enables the pupils to have more interactive and dynamic approach to Science learning through peer interaction and feedback of learned topics.

Several studies conducted have shown a positive effect of ICT on learning in Science. For instance, Alabidi et al. (2023) discovered that pupils who used interactive simulations had a better understanding of scientific concepts in a more abstract form. In addition, the study reported that educational apps and digital tools improve the pupils' performance in areas like physics and chemistry. These tools are not only used for learning but also for developing critical and problem-solving skills. The research investigated how curriculum integration of STEM subjects using a blended learning approach results in better academic achievement than a conventional instructional method.

Teachers' ICT Integration in Science Teaching and Learning Outcomes

Lim and Wardrip (2024) explained how ICTs in Science teaching create opportunities for every pupil to succeed. The research discovered that implementing digital resources reduces resource inequalities which affect Science education making it possible for all the pupils to receive high-quality Science education. In addition, (Tribble, 2024) stressed teachers serve as the essential factor for effective ICT utilization while teachers need training in technological pedagogical content knowledge for preparation. The benefits of using ICT in Science education are evident yet implementing it faces ongoing challenges. Science education benefits from ICT functions poorly because teachers need better training and schools need improved infrastructure (Vargas-Montoya, 2023). Additional research must take place to discover successful methods of integrating ICT into Science teaching which produces enhanced learning outcomes for pupils.

Teachers exhibit diverse methods of integrating ICT into Science instruction which depends on their personal skills alongside available resources and learning environment conditions (Bhat, 2023). Research into Science teaching practices based on ICT necessitates understanding because it helps explain alternative digital teaching methods suitable for different educational settings and learning outcomes.

This study follows the four stages of ICT integration starting from emerging to applying, infusing and transforming. The pupil-centered approach to deeper learning emerges through the infusing and transforming stages of education, whereas the emerging and applying stages form the foundation. Thus, Science education empowers the pupils to take an active role in their learning process, which supports the principles of autonomy and innovation (Faloye & Faniran, 2023).

This research examined ICT integration effects on Science teaching and learning results within the four stages of ICT implementation. The study analyzed how technology improves pupil engagement, understanding and achievement through its findings which were expected to be useful to teachers and policymakers. In addition, the study was related to the global focus on Science and technology education, in order to address the need to prepare pupils for a technological future.

This study was anchored on the four stages of UNESCO-UNEVOC International model for ICT development in education, which are Emerging, Applying, Infusing, and Transforming. These stages of the development of ICT integration described the process of their progression from the basic use of technology to the pupil-activated learning environments. This study found ICT to be an essential component of education, as its integration into the curriculum moves from technology as a tool that serves to transmit information to technology which brings transformative changes of educational methods to the best way.

Teachers' ICT integration ranges from basic use for static content presentation to more complex applications (Mohamed et al., 2021). The framework categorized ICT integration in schools, from the Emerging stage, where technology is primarily used for presentations with limited interaction, to the Applying and Infusing stages, where ICT is integrated into subject teaching for more participatory learning. The Transforming stage reflects ICT as a powerful tool for inquiry-based learning and real-life problem solving, addressing individual pupil needs more effectively.

As technology continues to evolve and become more advanced, pupils move from passive learning to an active involvement with the material (Itpartners, 2024). In early stages of development, ICT may enhance learning through improved lesson delivery, while in later stages it allows pupils to explore, collaborate and even develop solutions to complex problems.

The model is very useful to policymakers, curriculum developers and school administrators. Knowing the level of ICT development in each school, educational managers can in fact develop strategies for teacher professional development to move them to the next level (Sylvester, 2024). This systematic approach of integrating ICT in teaching ensures that it is not only used to improve individual lessons but also to change the education system. This is because ICT adoption in schools can be evaluated periodically to monitor progress, identify gaps and needed amendments to support teachers and learners (Tenaja & Oco, 2023). It is important to know the connection between ICT usage in education and pupil achievement results to allow analysis of better teaching approaches and enhanced pupils learning. As ICT is integrated more into teaching, it increases pupil interest, challenges critical thinking, and fosters group work (Msafiri et al., 2023). This framework describes in general how and what kind of support ICT needs to enhance learning processes, especially in Science where hands on, simulations and problem solving is vital.

Lastly, this framework provides the perfect guidance for schools, teachers and policymakers on how to effectively use ICT in Science education. Schools can use this framework to advance their technology adoption processes which leads to improved teaching and learning methods as well as enhance the achievement of pupils and the creation of learning environments ready for the future in Science subject.

II. METHODOLOGY

The research designs used in this study were correlational and causal research designs with content analysis. Bhat (2023) emphasized how correlational research design is used to examine the relationship between the independent variable to the dependent variable. This design enabled the interconnections of the relationships between the teachers' ICT integration in Science

Teachers' ICT Integration in Science Teaching and Learning Outcomes

to the pupils' learning outcomes. The research design helps identify patterns between the opportunities and challenges that Science teachers face when using ICT tools in educational settings.

Furthermore, the study employed causal research design to establish the existence of cause-effect relationships between ICT tool utilization and pupils' performance in Science. This aspect of the study aims to establish whether particular ICT intervention can enhance the learning outcomes of the pupils in measurable ways. The content analysis entails the systematic analysis of pupils' third quarter grades in Science. The grades are analyzed to identify patterns or trends that might suggest connection between the use of ICT and academic performance.

This section showed the study employed in collecting data for this research, each research questions was linked with the most suitable statistical analysis for the type of data and the kind of analysis to be made. The first and second research problems applied descriptive statistics. The Mean and Standard Deviation were used to summarize the data and present the results in a central tendency and variability of the data. The third research problem was analyzed using the Pearson Product Moment Correlation Coefficient. This statistical method helped to determine the degree and the type of the relationship between the two variables of the study. Finally, to address the fourth research problem, Multiple Linear Regression Analysis was carried out. This method helped to establish how the two variables impact each other, and determined the most important predictors.

III. RESULTS AND DISCUSSION

Problem 1. What is the level of ICT integration in Science among elementary teachers based on

- 1.1 emerging stage;
- 1.2 applying stage;
- 1.3 infusing stage; and
- 1.4 transforming stage?

Table 1. ICT Integration in Science

| Variables | Mean | SD | Description | Interpretation |
|--------------------|---------------------------------|--------------------------------|-------------|------------------|
| Emerging Stage | 3.17 | 0.54 | Agree | High Integration |
| Applying Stage | 2.70 | 0.54 | Agree | High Integration |
| Infusing Stage | 2.28 | 0.54 | Disagree | Low Integration |
| Transforming Stage | 1.86 | 0.54 | Disagree | Low Integration |
| Note: | 3.51-4.00 Very High Integration | 2.51-3.50 High Integration | | |
| | 1.51-2.50 Low Integration | 1.00-1.50 Very Low Integration | | |

Table 1 showcases the results of each stage of ICT integration in Science among elementary teachers. The variable, *Emerging Stage*, was rated the highest with Mean of 3.17 with SD=0.54, described as Agree and interpreted as High Integration. The data implied that the teachers have the idea and skills in utilizing and introducing technology to the teaching and learning process and activities in Science. The teachers can identify contents that may be use in their classes and can be use by the pupils in their studies. According to Dare et al. (2021) technology integration and utilization has been a practice by the teachers at school. They believe that it can arouse the pupils' interest. The challenge for them is to find more contents that will be suited to their lessons and activities.

Meanwhile, the variable, *Transforming Stage*, was rated the lowest with the Mean of 1.86 with SD=0.54, described as Disagree and interpreted as Low Integration. The data implied that the teachers have less activities dealing with the highest stage of utilizing technology in the school and even in connecting the pupils to their neighboring schools. This can be attributed to various reasons like restrictions for privacy and against abuse and even the availability of computers. According to Parveen and Ramzan (2024) restrictions for minor is built to protect them from unnecessary harm wherein they might not be able to fight and cope up with it leading to stress and even depression.

Problem 2. What is the level of pupils' learning outcomes in Science?

Table 2 on the next presents the pupils' overall learning outcomes in Science. 89 students which is 65.93% of the total, earned grades between 85% and 89%, interpreted as Very Satisfactory. The data implied that students are doing well and understand the concepts in Science resulting to the favorable learning outcomes. Additionally, 28 pupils (20.74%) achieved a grade between 80% and 84% (Satisfactory) and 16 pupils (11.85%) achieved the highest grade range of 90%–100% (Excellent). Among the pupils, only 2 (1.48%) achieved a score between 75% and 79% interpreted as Fairly Satisfactory and none of the pupils scored below 75%

Teachers' ICT Integration in Science Teaching and Learning Outcomes

(Needs Improvement). The results showed the registered overall Mean of 86.76 with SD=2.28 with the interpretation of Very Satisfactory.

The data implied that Science education benefits from a wide range of teaching methods, both those that use technology and those that do not. The good results could be due to effective lessons, active participation in class, using suitable teaching tools and teachers' ability to teach Science. According to Badshah et al. (2023), several factors such as teacher readiness, clear instruction and activities that fit the context all play a big role in pupils' learning outcomes. It appears that a flexible and holistic approach in teaching helps maintain and enhance student achievement in Science. Furthermore, the data implied that the pupils were able to achieve the second highest level of learning outcomes. This data further means that the pupils can either maintain the level of learning outcomes they receive or even aim for the highest level which is the outstanding level.

Table 2. Pupils' Learning Outcomes in Science

| Grading Scale | Frequency | Percentage | Mean & SD | Interpretation |
|---------------|------------|------------|-----------|-------------------|
| 90% - 100% | 16 | 11.85 | | Very Satisfactory |
| 85% - 89% | 89 | 65.93 | 86.76 | |
| 80% - 84% | 28 | 20.74 | (2.28) | |
| 75% - 79% | 2 | 1.48 | | |
| 74% and below | 0 | 0 | | |
| Total | 135 | 100 | | |

Note: 90% - 100%: Excellent 85%-89%: Very Satisfactory 80%-84%: Satisfactory
75%-79%: Fairly Satisfactory 74% & below: Needs Improvement

Additionally, the data further indicates that the majority of the pupils' learning outcomes in Science was at very satisfactory level. There are also pupils with learning outcomes level at satisfactory and fairly satisfactory level respectively. These pupils may need further assistance and guidance from their teachers as they may be experiencing difficulty. It is important that the teachers provide remedial activities to the struggling pupils so that they can have the chance to have the same level with their classmates. According to Harsch and Kendeou (2023) and well as Sucilestari and Ramdhani (2020) providing remedial activities for the pupils is an opportunity at the same time advantages for the teachers and the pupils. For the teachers, they can create research or innovation in conducting remedial classes at the same time help minimize or eradicate the struggles of the pupils. In the pupils' end, they may be able to master the topics and skills they struggled and be able to improve their knowledge and performance as a whole. This way of teaching and learning help to create an environment where everyone's needs are met.

Problem 3. Is there a significant relationship between the level of ICT integration in teaching Science and pupils' learning outcomes?

Table 3. Test for Correlation Between ICT Integration and Learning Outcomes

| Variables | r-value | p-value | Level of Correlation | Decision | Interpretation |
|--------------------|---------|---------|-------------------------------|-----------|----------------|
| Emerging Stage | 0.561 | 0.001 | Moderate Positive Correlation | Reject Ho | Significant |
| Applying Stage | 0.518 | 0.002 | Moderate Positive Correlation | Reject Ho | Significant |
| Infusing Stage | 0.541 | 0.001 | Moderate Positive Correlation | Reject Ho | Significant |
| Transforming Stage | 0.564 | 0.001 | Moderate Positive Correlation | Reject Ho | Significant |

Note: 0.91 - 1.00 Very High Positive Correlation 0.71 – 0.90 High Positive Correlation
0.51 – 0.70 Moderate Positive Correlation 0.31–0.50 Low Positive Correlation
0.00 – 0.30 Negligible Positive Correlation Significant when computed p-value <0.05

Table 3 shows the test for correlation between ICT integration and learning outcomes of pupils in Science. The independent variable is ICT integration in terms of Emerging Stage, Applying Stage, Infusing Stage, and Transforming Stage while the independent variable is on pupils' learning outcomes in Science.

Emerging Stage registered a computed r-value of 0.561 with computed p-value of 0.001. The computed p-value is less than the p-critical value at 0.05 level of significance. This imply that significant moderate positive correlation was registered between ICT integration and learning outcomes in Science when emerging stage is taken into account. Thus, the null hypothesis is rejected. During the Emerging Stage, the procedure for implementing information and communication technology (ICT) is began with the building of basic infrastructure, and schools begin to learn how to use the technology for the goal of education and instruction. Students have noticed that their teachers are using technology into their lessons at a high level, particularly in the field of Science.

Teachers' ICT Integration in Science Teaching and Learning Outcomes

In addition, this indicates that the students were presented with a variety of devices and technologies that have the potential to improve their capacity for thought and comprehension of the subject matter presented. With the incorporation of technologies into the classroom setting, both teachers and students have been inspired to work harder in their classrooms. Now more than ever, educators are beginning to recognize the advantages that come with incorporating various technology into the process of classroom instruction and education (Msafiri et al., 2023).

Applying Stage registered a computed r -value of 0.518 with computed p -value of 0.002. The computed p -value is less than the p -critical value at 0.05 level of significance. The data implied that significant moderate positive correlation was registered between ICT integration and learning outcomes in Science when applying stage is taken into account. Thus, the null hypothesis is rejected. In the applying stage, instructors make use of the information and communication technology (ICT) that is accessible to them in order to strengthen or enhance the tasks that are already in place within the leadership and curriculum, where it is being developed in certain disciplines.

The technology can be utilized by educators in the process of teaching and learning that they are responsible for. Integration of technology, particularly in the scientific field, is crucial. It is possible for teachers to simply monitor whether or not their students have understood the concept of the lesson that has been provided to them through the usage of videos. In the past, the utilization of technology has consistently been advantageous for both the instructors and the students. At the same time that it makes it easier for professors to create educational materials, it also makes it easier for students to research films on the internet for the purpose of reviewing them and getting clarifications (Sylvester, 2024).

Infusing Stage registered a computed r -value of 0.541 with computed p -value of 0.001. The computed p -value is less than the p -critical value at 0.05 level of significance. The data implied that significant moderate positive correlation was registered between ICT integration and learning outcomes in Science when infusing stage is taken into account. Thus, the null hypothesis is rejected. During the Infusing Stage, the use of information and communication technology (ICT) is carried out in a manner that is methodical, collaborative, and comprehensive. It is also included into the curriculum as well as other areas in order to improve both teaching and learning.

When it comes to the deeper employment of technology in the teaching and learning process as well as activities with students, teachers have a poor level of integration. This can be due to the fact that there are subjects that require additional instructional materials and strategies in addition to those that are based on technology, or that the teachers take additional time to adjust to the new technology. The utilization of additional instructional resources, such as those that are based on technology, requires teachers to undergo trainings and seminars in order to thoroughly comprehend and execute their utilization. In addition, the utilization of technology might sometimes necessitate additional time spent designing and preparing, which drive teachers to avoid its utilization (Bhat, 2023).

Transforming Stage registered a computed r -value of 0.564 with computed p -value of 0.001. The computed p -value is less than the p -critical value at 0.05 level of significance. The data implied that significant moderate positive correlation was registered between ICT integration and learning outcomes in Science when transforming stage is taken into account. Thus, the null hypothesis is rejected.

During the Transforming Stage, technology becomes fully integrated into the school, and it causes a change in the way that teachers instruct and acquire knowledge. As a result, the classes become more innovative, imaginative, engaging, and adaptable. The activities that teachers engage in that involve the complete incorporation of technology-based instructional resources into the activities that they engage in for teaching and learning are very few. This can be ascribed to the fact that even the computerization program in the department has not yet been fully implemented. This is because the purchase procedure takes a longer period of time and involves more processes, and there are also fewer money allocated for it by the department.

In contrast to the ease with which it may be implemented in private schools, public schools have a problem when it comes to the classroom facilities and even the number of students that need to be accommodated. Due to the fact that there are examinations that need to be completed online, which can have an impact on the students' performance as well as their chances since manipulating the computer is a struggle for them, public schools are doing everything in their power to ensure that students are proficient in the use of technology such as computers (Abdel-Salam, 2022).

Problem 4. Which of the independent variable impact/s the level of pupils' learning outcomes in Science?

Table 4 on the next page presents Regression Analysis if independent variables like emerging stage, applying stage, infusing stage, and transforming stage predict pupils' learning outcomes in Science. It is hypothesized that the four (4) predictors will be positively associated with learning outcomes. Results show that the 64.4% of the variance is explained by the four (4) predictors, $F= 36.953$, $p< .000$. Specifically, Emerging Stage ($\beta=0.5671$, $t\text{-value}=4.224$, $p\text{-value}< .001$), Applying Stage ($\beta=0.3673$, $t\text{-value}=4.103$, p -

Teachers' ICT Integration in Science Teaching and Learning Outcomes

value=0.001), Infusing Stage ($\beta=0.2558$, t-value=3.011, p-value=0.003), and Transforming Stage ($\beta=0.7856$, t-value=5.865, p-value=0.001) are positively associated with pupils' learning outcomes. It can be inferred that if the teacher is able to increase the ICT integration by 1% it will also increase the pupils' learning outcomes respectively. This suggest that teacher's ICT integration can have better pupils' learning outcomes in Science.

Table 4 demonstrates that all four levels of ICT integration (Emerging, Applying, Infusing and Transforming) are significantly linked to pupils' learning outcomes in Science, since all p-values are less than 0.05. This demonstrates that technology is important when it is properly used in any learning environment.

At the Emerging Stage, teachers use ICT to display videos or images to introduce Science topics. Even though there is not much integration at this point, it helps pupils learn by improving their visualization and interest. This suggests that using ICT in any way helps students relate abstract Science to things they can see and do (Abdel-Salam, 2022). It was clear from the data that schools could use easy and affordable technologies and still achieve good results. Having just a little ICT tools in the classroom can help students become more involved and understand better.

Table 4. Regression Analysis Between ICT Integration and Learning Outcomes

| Variables | UC | | SC | | t-value | Sig. (P-value) | Decision | Interpretation |
|--------------------|----------|----------------------|-------------------------------|--|----------------|-----------------------|-----------|----------------|
| | B | SE | B | | | | | |
| Constant | 0.7865 | 0.7766 | 0.7963 | | 5.477 | 0.001 | | |
| Emerging Stage | 0.5476 | 0.6754 | 0.5671 | | 4.224 | 0.001 | Reject Ho | Significant |
| Applying Stage | 0.5658 | 0.4549 | 0.3673 | | 4.103 | 0.001 | Reject Ho | Significant |
| Infusing Stage | 0.4668 | 0.4569 | 0.2558 | | 3.011 | 0.003 | Reject Ho | Significant |
| Transforming Stage | 0.8976 | 0.8978 | 0.7856 | | 5.865 | 0.001 | Reject Ho | Significant |
| | R | R² | Adjusted R² | | f-value | Sig. (P-value) | | |
| | 0.548 | 0.644 | 0.628 | | 36.953 | 0.000 | | |

Note: UC = Unstandardized Coefficients SC = Standardized Coefficients

Dependent Variable = Cognitive Engagement Significant when computed p-value <0.05.

At the Applying Stage, ICT is used more deliberately to help students learn by using digital quizzes, interactive PowerPoint presentations and simulations. At this point, students start to use technology to demonstrate their learning. According to Badshah et al. (2023), learners at this point start to work with information more actively which helps them remember the concepts. Using ICT with a clear curriculum at the applying stage helps students interact more and learn at their own speed which improves their Science performance.

At the Infusing Stage, ICT is used in more challenging and group activities. Pupils may carry out group investigations using online tools, produce digital stories or use apps to look at scientific data. Although the beta value is a little lower than the first two stages, it is still impactful which suggests that using ICT more deeply encourages critical thinking, creativity and teamwork (Faloye & Faniran, 2023). At this point, pupils both use and create information which demonstrates their move toward independent inquiry in Science.

The Transforming Stage had the biggest influence on how much pupils learned in Science. At this point, learning activities are completely changed, as ICT is now the main way students learn, create and connect with others locally or even internationally. Virtual experiments, online discussions and making digital Science portfolios are examples of what pupils might do. Rueda and Cerero (2019) pointed out that using ICT in a transformative way helps students learn how to solve problems and adapt. If ICT is used everywhere in the classroom, it helps students improve, become more independent and have more interesting Science lessons.

In conclusion, ICT integration has been continuously studied considering its availability as well as the reach it has. Teachers wanted to explore this area considering that the pupils spend more of their time on gadgets and surfing the internet (Safi, 2019). They want that the activities of the pupils will be diverted to more important and productive learning activities that may lead to their better knowledge and performance. However, there are challenges that makes the teachers hesitant to fully embrace the integration of ICT to their teaching and learning discussions and activities like the complexity of the procedures and rules that must be adhered to, as well as the capacity and capability of the educators to make use of technology, as well as their capacity to filter the exposure of the pupils to adult-related content and to protect them from bullying that is not essential.

On the other hand, there are websites that are extremely permissive and let the activities of minors be posted or published online. There are also websites that are extremely permissive and might potentially put the students' privacy at risk (Alabidi et al., 2023). Despite these concerns, the results of this study show that when ICT is used correctly and ethically, it can greatly improve pupils

Teachers' ICT Integration in Science Teaching and Learning Outcomes

learning outcomes in Science. Therefore, technical support, trainings and safety steps should be used together with ICT to make sure it helps rather than harm pupils.

IV. CONCLUSIONS

Based on the findings presented, the following conclusions can be drawn from the study:

1. Not all Science teachers have the knowledge or expertise to use advanced technology in integrating in the classes.
2. Pupils good learning outcomes in Science do not solely depend on technology.
3. Teachers' ICT integration in Science is associated with the pupils' learning outcomes. As teachers use ICT more effectively, pupils tend to achieve better outcomes.
4. All of the stages of ICT integration by the teachers give impact to the learning outcomes of the pupils in Science. Effective ICT integration at all stages of ICT integration contributes to better learning outcomes.

V. RECOMMENDATIONS

In light of the findings and conclusions outlined above, the following recommendations are presented:

1. Appropriate trainings and seminars may be provided to teachers to improve the ICT integration practices of teachers especially for the infusing and transforming stages of ICT integration.
2. Teachers may continue to support and enhance their teaching strategies that complement technology use to further improve pupils' learning outcomes in Science.
3. Teachers may sustain the use of ICT integration in Science effectively in their lessons as increased use of technology positively influences pupils' learning outcomes in Science.
4. School administrators along with the teachers may develop a structured ICT integration plan in Science that covers all the stages of ICT integration, ensuring consistent and effective use of technology to boost pupils learning outcomes in Science.

REFERENCES

- 1) Abdel-Salam, A. G., Hazaa, K., & Abu-Shanab, E. A. (2022). Evaluating the online learning experience at higher education institutions. *International Journal of Cyber Behavior Psychology and Learning*, 12(1), 1–23. <https://doi.org/10.4018/ijcbpl.298692>
- 2) Akram, H., Abdelrady, A. H., Al-Adwan, A. S., & Ramzan, M. (2022). Teachers' Perceptions of Technology Integration in Teaching-Learning Practices: A Systematic review. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.920317>
- 3) Alabidi, S., Alarabi, K., Tairab, H., Alamassi, S., & Alsahhi, N. R. (2023). The effect of computer simulations on students' conceptual and procedural understanding of Newton's second law of motion. *Eurasia Journal of Mathematics Science and Technology Education*, 19(5), em2259. <https://doi.org/10.29333/ejmste/13140>
- 4) Ali, Hakim & Rafique, Mariam & Hussain, Bashir. (2023). Effect of ICT Integration on Secondary School Students' Physics Achievement and Reasoning Skills. *Voyage Journal of Educational Studies*. 3. 383-398. 10.58622/vjes.v3i2.73.
- 5) Ambon, Josephine & Alias, Bity & Komariah, Aan & Mansor, Azlin. (2024). The impact of continuous professional development on teaching quality: a systematic review. *International Journal of Evaluation and Research in Education (IJERE)*. 13. 10.11591/ijere.v13i6.30427.
- 6) Asare, Samuel & Agyeman, Dwumfuo & Nyarko, Josephine & Opoku-Mensah, Nelson & Fokuo, Mary & Caroline, Owusu-Mintah & Asamoah, Richard. (2023). The Role of ICT in Teaching and Learning Mathematics at College of Education: A Systematic Review. 14. 2023. 10.7176/JEP/14-12-06.
- 7) Badshah, Afzal & Ghani, Anwar & Daud, Ali & Jalal, Ateeqa & Bilal, Muhammad & Crowcroft, Jon. (2023). Towards Smart Education through Internet of Things: A Survey. *ACM Computing Surveys*. 56. 1-33. 10.1145/3610401.
- 8) Bhat, Reyaz. (2023). The Impact of Technology Integration on Student Learning Outcomes: A Comparative Study. *International Journal of Social Science, Educational, Economics, Agriculture Research and Technology (IJSET)*. 2. 592-596. 10.54443/ijset.v2i9.218.
- 9) Buchholtz, N., Kaiser, G., & Schwarz, B. (2023). The evolution of research on mathematics Teachers' competencies, knowledge and skills. In *Mathematics education in the digital era* (pp. 55–89). https://doi.org/10.1007/978-3-031-31193-2_3
- 10) Dare, E. A., Keratithamkul, K., Hiwatig, B. M., & Li, F. (2021). Beyond Content: The Role of STEM Disciplines, Real-World Problems, 21st Century Skills, and STEM Careers within Science Teachers' Conceptions of Integrated STEM Education. *Education Sciences*, 11(11), 737. <https://doi.org/10.3390/educsci11110737>

Teachers' ICT Integration in Science Teaching and Learning Outcomes

- 11) Elmi, Hafiz & Ambiyar, Ambiyar & Huda, Yasdinul & Novaliendry, Dony. (2024). The Role of Information and Communication Technology in Interactive Learning. *Jurnal SAINTIKOM (Jurnal Sains Manajemen Informatika dan Komputer)*. 23. 193. 10.53513/jjs.v23i1.9549.
- 12) Estriégana, Rosa & Medina, Jose & Barchino, Roberto. (2019). Student acceptance of virtual laboratory and practical work: An extension of the technology acceptance model. *Computers & Education*. 135. 10.1016/j.compedu.2019.02.010.
- 13) Faloye, S., & Faniran, V. (2023). Integrating technology in teaching and learning practices: students' competencies. *South African Computer Journal*, 35(1). <https://doi.org/10.18489/sacj.v35i1.1111>
- 14) Goles, C., Sanchez, J. M., Sumalinog, G., Mananay, J., & Alejandro, I. M. (2024). Beyond the pandemic: The changing landscape of technology integration in higher education in Central Visayas, Philippines. *CTU Journal of Innovation and Sustainable Development*, 16(1). <https://doi.org/10.22144/ctujoisd.2024.262>
- 15) Goswami, S., Uddin, M. S., & Islam, M. R. (2020). Implementation of active learning for ICT education in schools. *International Journal of Innovative Science and Research Technology (IJISRT)*, 5(9), 455–459. <https://doi.org/10.38124/ijisrt20sep236>
- 16) Haarala-Muhonen, A., Myyry, L., Pyörälä, E., Kallunki, V., Anttila, H., Katajavuori, N., Kinnunen, P., & Tuononen, T. (2023). The impact of pedagogical and ICT training in teachers' approaches to online teaching and use of digital tools. *Frontiers in Education*, 8. <https://doi.org/10.3389/feduc.2023.1223665>
- 17) Hamoud, S. S., & Nzilano, J. L. (2024). Exploring Science teachers' beliefs and practices of ICT integration in secondary school teaching. *University of Dar Es Salaam Library Journal*, 19(1), 70–84. <https://doi.org/10.4314/udslj.v19i1.6>
- 18) Harsch, R. & Kendeou, P. (2023). Learning from refutation texts about scientific topics with analogical and causal explanations, *Contemporary Educational Psychology*, Volume 73, 2023, 102172, ISSN 0361-476X, <https://doi.org/10.1016/j.cedpsych.2023.102172>.
- 19) Hattie, J. (2019). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.
- 20) How important is technology in education? | American University. (2024, April 15). *School of Education Online*. <https://soeonline.american.edu/blog/technology-in-education/>
- 21) Ibrahim, E., Miri, F., & Koçiaç, I. (2024, February 15). An assessment of the integration of ICTs into teaching processes by Science teachers: The case of Albania. *Ibrahim | Journal of Technology and Science Education*. <https://www.jotse.org/index.php/jotse/article/view/2319/827>
- 22) Itpartners. (2024, August 16). How has technology changed education? | Tulane University. *Tulane University Online Master of Education - School of Professional Advancement*. https://masterofed-sopa.tulane.edu/articles/importance-of-learning/?utm_source=chatgpt.com
- 23) Janous, Y. E., El-Hassouny, H., Laafou, M., & Madrane, M. (2022). Effect of ICT on students achievements and motivation in life and earth Sciences subject. *Pegem Journal of Education and Instruction*, 12(4). <https://doi.org/10.47750/pegegog.12.04.11>
- 24) Kumar, P. (2024, March 27). The Role of ICT in Science Education • Teachers Institute. *Teachers Institute*. <https://teachers.institute/pedagogy-of-Science/role-of-ict-in-Science-education/>
- 25) Lagura, Romelyn. (2022). The Effectiveness of ICT Integration in Teaching Science Concepts. *American Journal of Multidisciplinary Research and Innovation*. 1. 11-20. 10.54536/ajmri.v1i3.322.
- 26) Laius, A., & Presmann, M. (2024). The Pre-service Teachers' Perceptions of Integrated Teaching, Inquiry Learning, using ICT and Real-life Examples in Science Classes. *Science Education International*, 35(2), 92–101. <https://doi.org/10.33828/sei.v35.i2.3>
- 27) Lamm, Alexa & Lamm, Kevan. (2019). Using Non-Probability Sampling Methods in Agricultural and Extension Education Research. *Journal of International Agricultural and Extension Education*. 52-59. 10.5191/iaee.2019.26105.
- 28) Lim, J., & Wardrip, P. (2024). Technology Integration as a Spectrum: integrating technology in early childhood classrooms. *Teachers and Teaching*, 1–19. <https://doi.org/10.1080/13540602.2024.2420137>
- 29) Mohamed Nowfeek, Mohamed Razeed & Mahrool, Farwis. (2021). The contribution of Integrated ICT in Teaching and Learning Practice: Teachers' Perspective. *International Journal of Multidisciplinary Research Review*. 8. 78-89. 10.22192/ijamr.2021.08.05.004.
- 30) Msafiri, M.M., Kangwa, D. & Cai, L. (2023). A systematic literature review of ICT integration in secondary education: what works, what does not, and what next?. *Discov Educ* 2, 44. <https://doi.org/10.1007/s44217-023-00070-x>
- 31) Ngodu, A., Ndibalema, P. M., & William, F. (2024b). Context-relevant strategies for ICT integration in teaching and learning Science subjects in Tanzania secondary schools. *Educational Technology Quarterly*, 2024(1), 20–37. <https://doi.org/10.55056/etq.704>
- 32) Noroozi, O. & Sahin, I. (Eds.). (2022). *Studies on Education, Science, and Technology 2022*. ISTES Organization.
- 33) Noroozi, Omid & Publication, Istes & Organization, Istes. (2023). *Technology-Enhanced Learning Environments in Education*.
- 34) Palomares-Ruiz, A., Cebrián, A., López-Parra, E., & García-Toledano, E. (2020). ICT Integration into Science Education and Its Relationship to the Digital Gender Gap. *Sustainability*, 12(13), 5286. <https://doi.org/10.3390/su12135286>

Teachers' ICT Integration in Science Teaching and Learning Outcomes

- 37) Parveen, N. D. S., & Ramzan, N. S. I. (2024). The role of Digital Technologies in Education: Benefits and challenges. Deleted Journal, 2(06), 2029–2037. <https://doi.org/10.47392/irjaem.2024.0299>
- 38) Rueda, M. M., & Cerero, J. F. (2019). Main barriers to ICT teacher training and disability. Research in Social Sciences and Technology, 4(2), 96–114. <https://doi.org/10.46303/ressat.04.02.7>
- 39) Safi, Abdul. (2019). ICT and Integration in Education: A Meta-analysis.
- 40) Schmitz, M., Antonietti, C., Consoli, T., Cattaneo, A., Gonon, P., & Petko, D. (2023). Transformational leadership for technology integration in schools: Empowering teachers to use technology in a more demanding way. Computers & Education, 204, 104880. <https://doi.org/10.1016/j.compedu.2023.104880>
- 41) Shemshack, A., & Spector, J. M. (2020). A systematic literature review of personalized learning terms. Smart Learning Environments, 7(1). <https://doi.org/10.1186/s40561-020-00140-9>
- 42) Sucilestari, Ramdhani. (2020). The Impact of Inquiry-Based Learning on Students' Critical Thinking Skills. 10.2991/assehr.k.200220.031.
- 43) Sylvester, R. (2024, November 22). Estonia's curriculum is one of the best — what can it teach us? *The Times*. <https://www.thetimes.com/uk/education/article/estonias-curriculum-is-one-of-the-best-what-can-it-teachus>
- 44) Tenaja, J. F. M., & Oco, R. M. (2023). Utilization of Social Media and Learners' Creative Writing Skills. *Asian Journal of Education and Social Studies*, 44(3), 1–14. <https://doi.org/10.9734/ajess/2023/v44i3961>
- 45) Tribble, D., & PowerSchool. (2024, July 15). The TPACK framework explained (With classroom examples). PowerSchool. <https://www.powerschool.com/blog/the-tpack-framework-explained-with-classroom-examples/>
- 46) Urbina, Santos & Villatoro, Sofía & Salinas, Jesus. (2021). Self-Regulated Learning and Technology-Enhanced Learning Environments in Higher Education: A Scoping Review. Sustainability. 13. 7281. 10.3390/su13137281.
- 47) Vargas-Montoya, L., Gimenez, G., & Fernández-Gutiérrez, M. (2023). ICT use for learning and students' outcomes: Does the country's development level matter? Socio-Economic Planning Sciences, 87, 101550. <https://doi.org/10.1016/j.seps.2023.101550>
- 48) Wale, B. D., & Bishaw, K. S. (2020). Effects of using inquiry-based learning on EFL students' critical thinking skills. Asian-Pacific Journal of Second and Foreign Language Education, 5(1). <https://doi.org/10.1186/s40862-020-00090-2>
- 49) Wangchuk, Nima. (2023). Impact of ICT integration in Science Classrooms at One of the Middle Secondary Schools. Journal of Humanities and Education Development. 5. 7-15. 10.22161/jhed.5.5.2.
- 50) Yilmaz, A. (2020). The effect of technology integration in education on prospective teachers' critical and creative thinking, multidimensional 21st century skills and academic achievements. Participatory Educational Research, 8(2), 163–199. <https://doi.org/10.17275/per.21.35.8.2>
- 51) Youssef, A. B., Dahmani, M., & Ragni, L. (2022). ICT use, digital skills and Students' Academic performance: Exploring the Digital Divide. Information, 13(3), 129. <https://doi.org/10.3390/info13030129>



There is an Open Access article, distributed under the term of the Creative Commons Attribution – Non Commercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>), which permits remixing, adapting and building upon the work for non-commercial use, provided the original work is properly cited.