Jurnal Guru Dikmen dan Diksus
Volume 9 Number 1, 2026. Page 146-161
p-ISSN: 2655-481x, e-ISSN: 2723-6404

Siageng Learning as an Integrated Digital System for Chemistry Instruction during the COVID-19 Pandemic

Ageng Tri Rahayu
SMAN 6 Samarinda, East Kalimantan, Indonesia
Email: siagenglearning@gmail.com

(Received: June 10, 2022; Accepted: October 25, 2022; Published: June 30, 2026)

ABSTRACT

Pandemic-related distance learning required chemistry teachers to coordinate instructional resources, communication, and assessment through devices available to students at home. This descriptive practice study examined Siageng Learning, a teacher-developed website bringing together digital modules, instructional videos, an online chemistry class, and a digital test application at SMAN 6 Samarinda. Development followed the ASSURE sequence of learner analysis, objective setting, selection and use of methods and media, learner participation, and evaluation and revision. The system was implemented with 289 Grade X students. Evidence comprised the implementation account and descriptions of students' open responses concerning usability, navigation, presentation, content, compatibility, loading time, and functionality. The teacher reported favorable responses to the consolidated access arrangement, short chemistry videos, flipbook modules, online communication, and mobile-accessible tests. Independent activity was supported by a virtual class available during lesson periods, an arrangement termed asisimove. However, the record did not provide response frequencies, verbatim comments, coding procedures, system logs, or comparative achievement scores. Consequently, the findings support a description of perceived usability and instructional feasibility, rather than a causal claim of effectiveness or a verified unanimous response. The system illustrates how a teacher can coordinate multiple digital resources around a learning sequence. Recommendations concern transparent user evaluation, direct assessment of chemistry understanding, accessibility under limited connectivity, and sustainable support for maintaining the system.

Keywords: Siageng Learning; chemistry education; ASSURE; online learning; learning management system; digital assessment

INTRODUCTION

Distance learning required teachers to coordinate material, interaction, tasks, and assessment when students were working outside the classroom. Research on the pandemic identifies variation in teaching conditions, readiness, and adaptation, rather than a single experience shared by all schools (Daniel, 2020; Kaden, 2020; König et al., 2020). A learning resource that is available online is only one part of an instructional system. Students must also understand what to do, receive support when difficulties arise, and obtain feedback on their work.

At SMAN 6 Samarinda, the teacher developed Siageng Learning to consolidate the components of chemistry instruction in one website. The school account emphasized resources designed by the teacher, access through devices available at home, and the need for manageable

communication and assessment. The intervention addressed the organization of learning as well as the production of digital material. Research on online readiness and emergency remote teaching provides a context for these practical concerns (Al Mazrooei et al., 2022; S. K. Howard et al., 2021).

Chemistry presents a further challenge because learners need to connect observed phenomena, models of particles, and symbolic representations. Work on chemistry learning highlights these representational demands (Johnstone, 1991; Taber, 2013; Talanquer, 2011). A website can coordinate access, but coordination does not by itself demonstrate that students have understood those relationships. Appropriate explanation and assessment remain necessary.

The system combined E-Modul, instructional videos, E-Class, and GGT, or Gawai Gawe Tes, implemented through the SITEDI digital test application. The development account used ASSURE to connect analysis, objectives, media selection, use, participation, and revision (Smaldino et al., 2019). Independent online activity was accompanied by access to a virtual classroom during the lesson period. The teacher termed this arrangement asisimove to emphasize activity and support.

The study asks how the system was designed and used, what usability and instructional benefits were described, and what limits constrain claims about effectiveness. Its contribution is a documented account of a teacher-developed response to distance-learning needs. It does not compare Siageng Learning with another platform or establish a statistically measured achievement effect.

LITERATURE REVIEW

Instructional design and system coherence

ASSURE provides a planning sequence for connecting learners, objectives, methods, media, participation, and evaluation (Smaldino et al., 2019). Multimedia instructional guidance similarly emphasizes a relationship between a learning purpose and the design of material (Clark & Mayer, 2016). Following a design sequence can improve coherence, but the name of a model is not evidence that the resulting instruction is effective. Its use must be assessed through actual decisions and outcomes.

Teacher knowledge is important in relating technology to pedagogy and subject matter. Technological pedagogical content knowledge and reviews of its application provide a framework for examining this relationship (Mishra & Koehler, 2006; Voogt et al., 2013). Digital competence

also extends beyond operating a service (Falloon, 2020). In chemistry, the teacher needs to decide which representation and activity address a particular conceptual demand, then assess whether the student can use that knowledge.

Research on teachers' perceptions, lesson-planning expertise, technology-integration models, and educational digitalization underscores the role of pedagogical judgment (Akram et al., 2022; Backfisch et al., 2020; Tondeur et al., 2021; Wohlfart & Wagner, 2023). These sources support treating Siageng Learning as an instructional arrangement maintained by a teacher rather than as software acting independently. The study should therefore distinguish the platform's features from the guidance surrounding them.

Chemistry representations and explanatory material

Johnstone's analyses of science and chemistry learning draw attention to the relation between disciplinary organization and learners' processing demands (Johnstone, 1991; Johnstone, 2000). Later discussions of the chemistry triplet examine the meanings of macroscopic, submicroscopic, and symbolic representations (Taber, 2013; Talanquer, 2011). These perspectives justify careful selection of examples and explanation. They do not establish that every chemistry video or song makes the required conceptual connection.

A teacher-developed video can show a worked problem and explain how a symbol relates to a process. Short segments may help students revisit a difficult step, but segmentation should preserve the relationship among steps. Guidance on instructional video and a research synthesis on multimedia design address these design decisions (Mayer et al., 2020; Noetel et al., 2022). In this case, the described short videos and subtopic modules are therefore plausible supports whose learning value still needs direct assessment.

Multimedia design and affective appeal

Cognitive load theory and research on distracting details emphasize that learners have limited processing resources (Sundararajan & Adesope, 2020; Sweller, 2020). Music, illustrations, and animated effects may contribute to an instructional purpose, but they can also compete with explanation. Emotional-design research examines appeal and learning as related but distinguishable outcomes (Wong & Adesope, 2021). The present favorable accounts of chemistry songs do not demonstrate an independent memory or conceptual effect.

Generative learning considers students' construction of meaning through explanation and other representations (Brod, 2021; Fiorella, 2023). A review of activity-based learning further distinguishes purposeful processing from visible activity alone (Skulmowski, 2024). Watching, reading, or singing can be part of instruction, but an evaluation of chemistry understanding should ask students to explain and apply the concept.

Offering different media also should not be justified by assuming fixed learning styles that require matching to a preferred format. A review of learning-styles evidence questions that matching claim (Pashler et al., 2008). In this system, the defensible rationale for video and text is flexibility, complementary representation, and the ability to revisit material. No learning-style inventory or matching experiment was reported.

Online interaction and guided independent work

The community-of-inquiry account emphasizes the relationship among teaching, social, and cognitive presence in online learning (Garrison et al., 2000). Blended-learning scholarship and a broad review of online teaching also examine how activities are connected (Garrison & Kanuka, 2004; Martin et al., 2020). Although Siageng Learning combined independent activity with a virtual classroom, both could occur remotely. The arrangement should not be assumed to include physical classroom instruction during its pandemic implementation.

Research on engagement strategies and technology-supported student engagement distinguishes the presence of a digital service from meaningful participation (Bond et al., 2020; Martin & Bolliger, 2018). A visible online-status indicator may help a teacher identify access, but it cannot establish attention or comprehension. Questions, submitted work, and explanations provide different evidence. The present records describe monitoring functions without reporting a validated engagement measure.

Independent online study places demands on self-regulation. Reviews and research concerning online learning and hypermedia show why planning, monitoring, and help seeking matter (Azevedo & Cromley, 2004; Broadbent & Poon, 2015; Panadero, 2017). Keeping a teacher available during independent activity may support help seeking. However, the study did not quantify the number of help requests or test whether this arrangement improved self-regulation.

Usability and information system evaluation

Acceptance research distinguishes perceived usefulness and ease of use, and later models consider additional conditions affecting technology use (Davis, 1989; Venkatesh et al., 2003). Information-system success models also separate quality, use, satisfaction, and benefits (DeLone & McLean, 2003). These distinctions prevent favorable user impressions from being treated as proof of educational effectiveness. Ease of access may be necessary for participation while remaining insufficient for learning.

Learning-management-system scholarship provides a relevant account of organizing material and communication online (Bradley, 2021). In the present study, E-Class supplied several LMS-like functions, while SITEDI supplied test functions. Describing both does not establish their reliability, security, or comparative performance. Such properties require data beyond the feature descriptions and the teacher's summary of student responses.

Assessment, feedback, and sustained implementation

Formative assessment theory connects evidence of learning with instructional decisions (Black & Wiliam, 2009; Sadler, 1989). Feedback reviews further emphasize the purpose and content of information returned to learners (Hattie & Timperley, 2007; Wisniewski et al., 2020). A digital test can make administration convenient, but its items and scoring still determine what is measured. The availability of an application should therefore be evaluated separately from the validity of its assessment.

Motivation research also requires distinguishing positive experience from measured achievement (Bureau et al., 2022; J. L. Howard et al., 2021; Ryan & Deci, 2020). An attractive resource may support willingness to participate, yet an independent test is needed to determine what has been understood. The study does not provide either a validated motivation scale or numerical achievement comparisons.

Finally, teacher innovation depends on organizational support and opportunities to develop practice. Research on school leadership and professional development provides a basis for examining these conditions (Leithwood et al., 2020; Sims & Fletcher-Wood, 2021). The platform's sustainability requires attention to maintenance, workload, and resources, particularly when a rapid pandemic response becomes part of ordinary teaching.

METHODS

Design, setting, and participants

The investigation was described as a best-practice study using a product-oriented instructional-system design and qualitative descriptive analysis. Siageng Learning was implemented with 289 Grade X students at SMAN 6 Samarinda, East Kalimantan, during pandemic-related distance learning. Exact implementation dates, number of classes, duration of use, demographic characteristics, and recruitment details were not specified.

There was no randomized allocation or comparison group. The account describes product development and student responses, but does not present a pretest-posttest achievement dataset. The reported scope of 289 students is the implementation population; it is not treated as a verified number of returned questionnaires or coded comments.

Development and instructional arrangement

Development followed the ASSURE sequence: analyze learners; state objectives; select methods, media, and materials; utilize materials; require learner participation; and evaluate and revise. The teacher described identifying the resources students needed at home, designing digital materials and applications, implementing the system, and making revisions in response to feedback. The record does not contain a complete phase-by-phase development log or external product-validation assessment.

Asisimove combined independent learning through the website with teacher availability in a virtual classroom during scheduled chemistry lessons. Students could consult videos or modules and enter the virtual class to ask about a difficulty. The teacher also described monitoring online presence in E-Class and participation in virtual questioning. The exact virtual-meeting service, connection requirements, and individual time allocation were not reported.

Product components

E-Modul offered flipbook-style chemistry texts organized by subtopic. Instructional videos included explanations, worked examples, and chemistry songs, published through YouTube. E-Class provided the online chemistry classroom, while GGT supported digital testing through SITEDI. Both E-Class and SITEDI were accessed using individual five-digit tokens supplied privately; an automated WhatsApp reply was described as a means of retrieving access information.

The modules were intended to be read in a browser without requiring a separate download. This reduces the need to save a full file deliberately, but browser-based access still involves data transfer and potentially local caching. Actual storage use, data consumption, and loading performance were not measured. Product descriptions are therefore retained as access arrangements rather than quantitative performance claims.

Response framework and analysis

The user-evaluation framework included usability, navigation, graphic design, content, compatibility, loading time, and functionality. Its indicators addressed instructions, memorability, efficiency, reliability, satisfaction, ease of operation, presentation, understandable content, user friendliness, operation across devices, speed, and support for chemistry evaluation. The framework is summarized in Table 1.

Table 1. Framework for describing Siageng Learning user responses

Dimension	Indicators described in the study
Usability	Instructions, memorability, efficiency, reliability, satisfaction
Navigation	Ease of operation and finding resources
Graphic design	Images, text, symbols, and audio presentation
Content	Understandability, evaluation support, and user friendliness
Compatibility	Operation across available devices
Loading time	Perceived access speed
Functionality	Support for chemistry learning and evaluation

Source: Product-evaluation framework. The record contains no numerical scores, item-level responses, validated scale, or measured loading times. These dimensions organize the reported qualitative experience.

The teacher described qualitative analysis of students' open comments concerning practicality and effectiveness. The record does not provide the wording of response prompts, the number of comments, participant-level responses, a codebook, category frequencies, negative-case analysis, or verbatim extracts. Consequently, findings are reported as described experiences and perceived benefits. No percentage of satisfied students, scale reliability, significance test, or achievement effect was calculated.

RESULTS AND DISCUSSION

Consolidation of learning resources

Table 2. Components and reported functions of Siageng Learning

Component	Features described	Reported instructional function
E-Modul	Browser-based flipbook modules organized by subtopic	Material study and repeated reading
Instructional videos	YouTube explanations, worked examples, and chemistry songs	Explanation, review, and recall support
E-Class	Virtual chemistry class, assignments, communication, and online-status display	Interaction and access to teacher support
GGT / SITEDI	Mobile- and computer-accessible tests, doubtful-answer marker, individual tokens	Digital test administration

Source: Product and implementation descriptions. Functions and perceived benefits were reported by the teacher; comparative learning effects, complete user-response counts, and objective system performance were unavailable.

The implementation account indicates that the website provided an entry point to material, online-class functions, and testing. This potentially reduced the need for students to locate separate resources repeatedly. Students were described as finding the arrangement practical and easy to understand. These reports support discussion of perceived coordination, but the record does not compare navigation time or completion rates with the previous arrangement.

The central design contribution was connecting resources with a teaching sequence. Text and videos supported material study, E-Class supported communication and submission, and SITEDI supported assessment. This is consistent with instructional-system planning, in which components serve an explicit purpose (Clark & Mayer, 2016; Smaldino et al., 2019). The presence of those components does not establish that all intended objectives were achieved.

Videos, songs, and digital modules

The teacher reported that videos divided chemistry material into short subtopics, included worked examples, and could be watched again. Chemistry songs were described as helping students recall formulas and keywords and as making virtual sessions more enjoyable. The related published account of song innovation concerns multimedia in stoichiometry learning (Rahayu et al., 2020). It provides background to the teacher's design approach, rather than numerical outcome evidence for Siageng Learning.

Flipbook modules were described as attractive, modern, and easy to access, with audio used to enhance presentation. Students could read subtopic materials as an alternative or complement to video. These features support flexibility, but the study did not measure reading behavior or

compare text and video conditions. A claim that media were matched to fixed learning styles would exceed the evidence (Pashler et al., 2008).

The distinction between appeal and understanding is important in chemistry. A memorable song may retain a formula without establishing when or why it is used. Worked examples should connect procedures with the relevant concept and representation (Johnstone, 2000; Taber, 2013). The study lacks item-level evidence of these connections, so reported improvement in chemistry outcomes remains an unquantified teacher assessment.

E-Class and teacher availability

E-Class was described as supporting access to videos, assignments, notifications, and communication among users. Online-status displays helped the teacher identify users currently accessing the classroom. The teacher also remained available in a virtual meeting while students studied independently. The account suggests that students could seek clarification immediately rather than wait until a later lesson.

This arrangement is compatible with support for teaching presence and help seeking (Broadbent & Poon, 2015; Garrison et al., 2000). Nevertheless, online presence cannot confirm that a video has been understood, and no participation log or analysis of students' questions was supplied. The record supports an account of available interaction functions rather than a verified improvement in engagement.

Digital assessment through GGT and SITEDI

SITEDI was described as accessible through mobile devices and computers, with a layout students found clear, a doubtful-answer marker, and the same individual token arrangement used for E-Class. The teacher reported that it supported test administration and later dissemination for school end-of-semester assessment. The number of tests, number of school-wide users, and outcomes of this wider use were not specified.

Ease of administration and usefulness for evaluation are distinct from assessment validity. The study does not present the item bank, coverage of chemistry concepts, scoring reliability, or response behavior. Formative assessment requires interpreting evidence in relation to learning goals (Black & Wiliam, 2009; Sadler, 1989). A direct assessment of student explanation would help determine whether convenient testing supported meaningful diagnosis.

Reported user response and quality claims

The teacher summarized student responses as favorable across the product components and described broad acceptance. However, the absence of response counts and original comments prevents verification of a claim that every one of the 289 students responded positively. The implementation population cannot substitute for a questionnaire denominator. This limitation does not negate the reported experience; it defines the level of evidence available.

Perceived ease, satisfaction, reliability, and benefit should also remain separate. Technology-acceptance and information-system models provide a reason to distinguish these dimensions (Davis, 1989; DeLone & McLean, 2003). Statements that access was fast or the program reliable were not accompanied by measured loading times, error records, or device-specific results. Token-based access was described as simple, but no independent security assessment was reported.

Teacher innovation and implementation constraints

The teacher described dissemination to colleagues, support from the school, and opportunities to use the test application more widely. The account also identified substantial constraints: the need to generate ideas quickly, short development time, stress, financial resources, school and parental support, and continued assistance for students experiencing difficulties. These conditions qualify the interpretation of a teacher-developed system as easily transferable.

Sustainable implementation would require maintenance responsibilities, a manageable content-production schedule, and support for teachers' continuing learning (Leithwood et al., 2020; Sims & Fletcher-Wood, 2021). Those arrangements were not evaluated longitudinally. The system illustrates an adaptive response in one school, rather than a demonstrated low-cost or maintenance-free model for all schools.

Limitations and implications

The qualitative descriptive record lacks a clear response sample, original comments, systematic coding evidence, objective system measures, and a comparative achievement dataset. Claims of higher literacy, reduced stress, universal participation, and improved learning were not supported by separate measures. Conclusions therefore concern the reported practicality and perceived instructional value of the arrangement.

Future evaluation should retain anonymized comments and document how themes are derived, including difficulties and negative experiences. Usability testing should consider low-bandwidth access and different devices, while chemistry assessment should examine representations, explanations, and application. Feedback should be evaluated through its content and students' subsequent work (Wisniewski et al., 2020). A comparative study would be needed if the purpose is to estimate learning effectiveness rather than describe implementation.

CONCLUSION AND RECOMMENDATIONS

Siageng Learning brought digital chemistry modules, instructional videos, an online class, and digital testing into one website-based arrangement used with 289 Grade X students. The teacher described favorable user experiences and an instructional strategy combining independent study with access to virtual support. The evidence supports this account of coordination and perceived feasibility, with insufficient data to verify unanimous acceptance or a causal improvement in chemistry achievement.

Further use should preserve the relationship among objectives, resources, interaction, and assessment while improving the evidence supporting product quality. Teachers and school leaders should document user responses, assess chemistry understanding directly, monitor access difficulties, and allocate support for maintenance and content revision. Extending the system into ordinary classroom teaching is a reasonable development option whose benefits should be assessed rather than assumed.

REFERENCES

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*, Article 920317. https://doi.org/10.3389/fpsyg.2022.920317

Al Mazrooei, A. K., Hatem Almaki, S., Gunda, M., Alnoor, A., & Manji Sulaiman, S. (2022). A systematic review of K–12 education responses to emergency remote teaching during the COVID-19 pandemic. *International Review of Education, 68*(6), 811–841. https://doi.org/10.1007/s11159-023-09986-w

Azevedo, R., & Cromley, J. G. (2004). Does training on self-regulated learning facilitate students' learning with hypermedia? *Journal of Educational Psychology, 96*(3), 523–535. https://doi.org/10.1037/0022-0663.96.3.523

Backfisch, I., Lachner, A., Hische, C., Loose, F., & Scheiter, K. (2020). Professional knowledge or motivation? Investigating the role of teachers' expertise on the quality of technology-enhanced lesson plans. *Learning and Instruction, 66*, Article 101300. https://doi.org/10.1016/j.learninstruc.2019.101300

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability, 21*(1), 5–31. https://doi.org/10.1007/s11092-008-9068-5

Bond, M., Buntins, K., Bedenlier, S., Zawacki-Richter, O., & Kerres, M. (2020). Mapping research in student engagement and educational technology in higher education: A systematic evidence map. *International Journal of Educational Technology in Higher Education, 17*(1), Article 2. https://doi.org/10.1186/s41239-019-0176-8

Bradley, V. M. (2021). Learning management system (LMS) use with online instruction. *International Journal of Technology in Education, 4*(1), 68–92. https://doi.org/10.46328/ijte.36

Broadbent, J., & Poon, W. L. (2015). Self-regulated learning strategies & academic achievement in online higher education learning environments: A systematic review. *The Internet and Higher Education, 27*, 1–13. https://doi.org/10.1016/j.iheduc.2015.04.007

Brod, G. (2021). Generative learning: Which strategies for what age? *Educational Psychology Review, 33*(4), 1295–1318. https://doi.org/10.1007/s10648-020-09571-9

Bureau, J. S., Howard, J. L., Chong, J. X. Y., & Guay, F. (2022). Pathways to student motivation: A meta-analysis of antecedents of autonomous and controlled motivations. *Review of Educational Research, 92*(1), 46–72. https://doi.org/10.3102/00346543211042426

Clark, R. C., & Mayer, R. E. (2016). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning* (4th ed.). Wiley. https://doi.org/10.1002/9781119239086

Daniel, J. (2020). Education and the COVID-19 pandemic. *PROSPECTS, 49*(1–2), 91–96. https://doi.org/10.1007/s11125-020-09464-3

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–340. https://doi.org/10.2307/249008

DeLone, W. H., & McLean, E. R. (2003). The DeLone and McLean model of information systems success: A ten-year update. *Journal of Management Information Systems, 19*(4), 9–30. https://doi.org/10.1080/07421222.2003.11045748

Falloon, G. (2020). From digital literacy to digital competence: The teacher digital competency (TDC) framework. *Educational Technology Research and Development, 68*(5), 2449–2472. https://doi.org/10.1007/s11423-020-09767-4

Fiorella, L. (2023). Making sense of generative learning. *Educational Psychology Review, 35*(2), Article 50. https://doi.org/10.1007/s10648-023-09769-7

Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education, 2*(2–3), 87–105. https://doi.org/10.1016/s1096-7516(00)00016-6

Garrison, D. R., & Kanuka, H. (2004). Blended learning: Uncovering its transformative potential in higher education. *The Internet and Higher Education, 7*(2), 95–105. https://doi.org/10.1016/j.iheduc.2004.02.001

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81–112. https://doi.org/10.3102/003465430298487

Howard, J. L., Bureau, J., Guay, F., Chong, J. X. Y., & Ryan, R. M. (2021). Student motivation and associated outcomes: A meta-analysis from self-determination theory. *Perspectives on Psychological Science, 16*(6), 1300–1323. https://doi.org/10.1177/1745691620966789

Howard, S. K., Tondeur, J., Siddiq, F., & Scherer, R. (2021). Ready, set, go! Profiling teachers' readiness for online teaching in secondary education. *Technology, Pedagogy and Education, 30*(1), 141–158. https://doi.org/10.1080/1475939x.2020.1839543

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning, 7*(2), 75–83. https://doi.org/10.1111/j.1365-2729.1991.tb00230.x

Johnstone, A. H. (2000). Teaching of chemistry - logical or psychological? *Chemistry Education Research and Practice, 1*(1), 9–15. https://doi.org/10.1039/a9rp90001b

Kaden, U. (2020). COVID-19 school closure-related changes to the professional life of a K–12 teacher. *Education Sciences, 10*(6), 165. https://doi.org/10.3390/educsci10060165

König, J., Jäger-Biela, D. J., & Glutsch, N. (2020). Adapting to online teaching during COVID-19 school closure: Teacher education and teacher competence effects among early career

teachers in Germany. *European Journal of Teacher Education, 43*(4), 608–622. https://doi.org/10.1080/02619768.2020.1809650

Leithwood, K., Harris, A., & Hopkins, D. (2020). Seven strong claims about successful school leadership revisited. *School Leadership & Management, 40*(1), 5–22. https://doi.org/10.1080/13632434.2019.1596077

Martin, F., & Bolliger, D. U. (2018). Engagement matters: Student perceptions on the importance of engagement strategies in the online learning environment. *Online Learning, 22*(1), 205–222. https://doi.org/10.24059/olj.v22i1.1092

Martin, F., Sun, T., & Westine, C. D. (2020). A systematic review of research on online teaching and learning from 2009 to 2018. *Computers & Education, 159,* Article 104009. https://doi.org/10.1016/j.compedu.2020.104009

Mayer, R. E., Fiorella, L., & Stull, A. (2020). Five ways to increase the effectiveness of instructional video. *Educational Technology Research and Development, 68*(3), 837–852. https://doi.org/10.1007/s11423-020-09749-6

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record: The Voice of Scholarship in Education, 108*(6), 1017–1054. https://doi.org/10.1177/016146810610800610

Noetel, M., Griffith, S., Delaney, O., Harris, N. R., Sanders, T., Parker, P., del Pozo Cruz, B., & Lonsdale, C. (2022). Multimedia design for learning: An overview of reviews with meta-meta-analysis. *Review of Educational Research, 92*(3), 413–454. https://doi.org/10.3102/00346543211052329

Panadero, E. (2017). A review of self-regulated learning: Six models and four directions for research. *Frontiers in Psychology, 8,* Article 422. https://doi.org/10.3389/fpsyg.2017.00422

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest, 9*(3), 105–119. https://doi.org/10.1111/j.1539-6053.2009.01038.x

Rahayu, A. T., Nurhadi, M., & Amir, M. (2020). Song innovation in multimedia on stoichiometry chemical learning. *AIP Conference Proceedings, 2215*(1), Article 020019. https://doi.org/10.1063/5.0000863

Ryan, R. M., & Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary Educational Psychology*, *61*, Article 101860. https://doi.org/10.1016/j.cedpsych.2020.101860

Sadler, D. R. (1989). Formative assessment and the design of instructional systems. *Instructional Science, 18*(2), 119–144. https://doi.org/10.1007/bf00117714

Sims, S., & Fletcher-Wood, H. (2021). Identifying the characteristics of effective teacher professional development: A critical review. *School Effectiveness and School Improvement, 32*(1), 47–63. https://doi.org/10.1080/09243453.2020.1772841

Skulmowski, A. (2024). Learning by doing or doing without learning? The potentials and challenges of activity-based learning. *Educational Psychology Review, 36*(1), Article 28. https://doi.org/10.1007/s10648-024-09869-y

Smaldino, S. E., Lowther, D. L., & Mims, C. (2019). *Instructional technology and media for learning* (12th ed.). Pearson. https://www.pearson.com/en-us/subject-catalog/p/instructional-technology-and-media-for-learning/P200000001840/9780134287584

Sundararajan, N., & Adesope, O. (2020). Keep it coherent: A meta-analysis of the seductive details effect. *Educational Psychology Review, 32*(3), 707–734. https://doi.org/10.1007/s10648-020-09522-4

Sweller, J. (2020). Cognitive load theory and educational technology. *Educational Technology Research and Development, 68*(1), 1–16. https://doi.org/10.1007/s11423-019-09701-3

Taber, K. S. (2013). Revisiting the chemistry triplet: Drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. *Chemistry Education Research and Practice, 14*(2), 156–168. https://doi.org/10.1039/c3rp00012e

Talanquer, V. (2011). Macro, submicro, and symbolic: The many faces of the chemistry "triplet". *International Journal of Science Education, 33*(2), 179–195. https://doi.org/10.1080/09500690903386435

Tondeur, J., Petko, D., Christensen, R., Drossel, K., Starkey, L., Knezek, G., & Schmidt-Crawford, D. A. (2021). Quality criteria for conceptual technology integration models in education: Bridging research and practice. *Educational Technology Research and Development, 69*(4), 2187–2208. https://doi.org/10.1007/s11423-020-09911-0

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425–478. https://doi.org/10.2307/30036540

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge – a review of the literature. *Journal of Computer Assisted Learning, 29*(2), 109–121. https://doi.org/10.1111/j.1365-2729.2012.00487.x

Wisniewski, B., Zierer, K., & Hattie, J. (2020). The power of feedback revisited: A meta-analysis of educational feedback research. *Frontiers in Psychology, 10*, Article 3087. https://doi.org/10.3389/fpsyg.2019.03087

Wohlfart, O., & Wagner, I. (2023). Teachers' role in digitalizing education: An umbrella review. *Educational technology research and development, 71*(2), 339–365. https://doi.org/10.1007/s11423-022-10166-0

Wong, R. M., & Adesope, O. O. (2021). Meta-analysis of emotional designs in multimedia learning: A replication and extension study. *Educational Psychology Review, 33*(2), 357–385. https://doi.org/10.1007/s10648-020-09545-x