Journal of Pedagogical Research
Volume 8, Issue 4, 2024
https://doi.org/10.33902/JPR.202427454

Research Article

Socio-scientific issues-based electronic-learning material reveals a high incorporation of lifelong learning, ethical, and sustainability issues

Rinalyn G. Magtibay

Batangas State University, The National Engineering University, Philippines (ORCID: 0009-0005-4963-1836)

This study aims to develop an SSI-based electronic learning material [e-LM] that will respond to the current educational landscape. Socio-scientific issues are utilized in the e-LM recognizing it can be useful in resolving societal issues and assisting learners in developing scientific habits of mind. A Mixed-method research design was employed in the development and validation of an SSI-based e-LM. Brain DeCor e-LM Framework, an SSI-based e-LM design framework highlighting lifelong learning, ethical, and sustainability issues in situations became the basis of SSI-based e-LM development. Its salient features such as the priority SSIs, e-LM design structure, appropriate teaching strategies, and suitable teaching approaches became the basis for its development. It was validated by five science facilitators considering the salient features and found out, they were highly incorporated. The study recommends its implementation on the intended participants. Furthermore, implementing the developed e-LM was also suggested to be validated considering the e-collaborative activity assessment and the result of student participant's reflection time assessment. The student performance in science achievement will denote the effectiveness of the developed e-LM.

Keywords: Brain DeCor e-LM Framework; Electronic learning materials; Ethical issues; Lifelong learning; Socio-scientific issues; Sustainability issues

Article History: Submitted 29 March 2024; Revised 26 July 2024; Published online 2 October 2024

1. Introduction

The Science teaching landscape significantly transformed after the pandemic. The introduction of flexible instruction further provides an opportunity leading to Education 4.0. The use of electronic learning materials became advantageous. Due to the pandemic's after-effects, science education became vital in creating awareness and environmental consciousness (Pietrocolla et al., 2021; Rogayan & Dantic, 2021). Socio-scientific issues [SSIs] utilize experiential knowledge as their core in dealing with science teaching situated with societal issues. According to previous works (Erduran, 2020; Genisa et al., 2020), incorporating SSIs in science teaching assists students in developing scientific habits of mind. It also supports sound decisions when students try to resolve societal issues. In Magtibay and Nueva Espana (2024) study, environmental issues were the most occurring SSIs identified in analyzing science course curricula in higher educational institutions. On the other hand, lifelong learning, ethical issues, and sustainability issues were "mostly no

Address of Corresponding Author

Rinalyn G. Magtibay, PhD, Batangas State University, The National Engineering University, JPLPC, Malvar, Batangas, Philippines.

✉ rinalynmagtibay@g.batstate-u.edu.ph

How to cite: Magtibay, R. G. (2024). Socio-scientific issues-based electronic-learning material reveals a high incorporation of lifelong learning, ethical, and sustainability issues. *Journal of Pedagogical Research, 8*(4), 220-234. https://doi.org/10.33902/JPR.202427454

occurrence at all" in their findings. These identified SSIs became their suggested priority SSIs to be situated in science teaching to ensure a balanced SSI situation. Sustainability issues are one of the predominant themes for SSI-based learning, raised by scientific and technical advancements as mentioned by Amos and Levinson (2019) in their study. English and Carlsen (2019) also cited that lifelong learning issues were analyzed with education leading to sustainability. SDGs intend to mold a holistic approach, and as the priority SSIs become more interrelated, the significance of ethical issues from the global perspective is becoming progressively evident (van Den Hoven, 2019).

1.1. SSI-based Teaching

SSI-based teaching is one of the significant holistic approaches to conveying effective science teaching. It aims to connect the classroom set-up to real-world learning. It includes practices in socio-scientific reasoning and a culminating exercise synthesizing primary ideas and practices. As Sadler et al. (2017) used, Information and Communications Technology [ICT] became very beneficial in search of the main issue and allowed learners to reflect on their views and perceptions. The application of technology became an advantage in situating SSI in science teaching, promoting the use of current issues in society.

A teaching strategy shows the plans of the teacher's technique to facilitate the teaching-learning process in the classroom. As SSI-based teaching is applied, an appropriate teaching strategy is deemed needed. In today's era where digitalization has become a part of the learning landscape, innovative teaching strategies will comprehend the forward-thinking learning styles. Electronic brainstorming has become a highly relevant and prevalent platform of learning. As Maaravi et al., (2021) mentioned in their study, it boosts creativity and generates innovative ideas. Correspondingly, Al-Samarrae and Hurmuzan (2018) described that this technique involves utilizing online resources and tools to facilitate conversation. In their study, this strategy was coined as "brain-netting" by Magtibay and Nueva España (2024). They described this as involvement in sharing ideas, and linking their thoughts and experiences through available technology resources. E-collaboration or collaborative learning in the digital space is also a versatile strategy that can complement other approaches. It involves learners forming groups and working together towards a common objective. The flexible learning approach supports e-collaborative learning, realizing it can be performed in person and in an online modality. Online platforms provide a conducive workspace where learners can freely collaborate. From Blau et al.'s (2020) point of view, successful integration of e-collaboration requires a combination of in-person and online modalities. This validates the idea that incorporating e-collaboration in flexible learning can be advantageous.

Another strategy that supports SSI-based teaching is discovery learning. By engaging in discovery, learners take ownership of their learning experience (Bruner,1961). Exploration is a fundamental aspect of human learning, as emphasized by Bruner (1971). Lastly, reflective thinking as a cognitive process involves evaluating thoughts and experiences. According to De Leon-Pineda and Prudente (2022), it is a sequential thought process that revolves around one's beliefs, behavior, and relationships with others. They also emphasized that reflective thinking evaluation is crucial for learners. It helps them reflect on their thoughts, comprehend their experiences, and enhance their performance in Science.

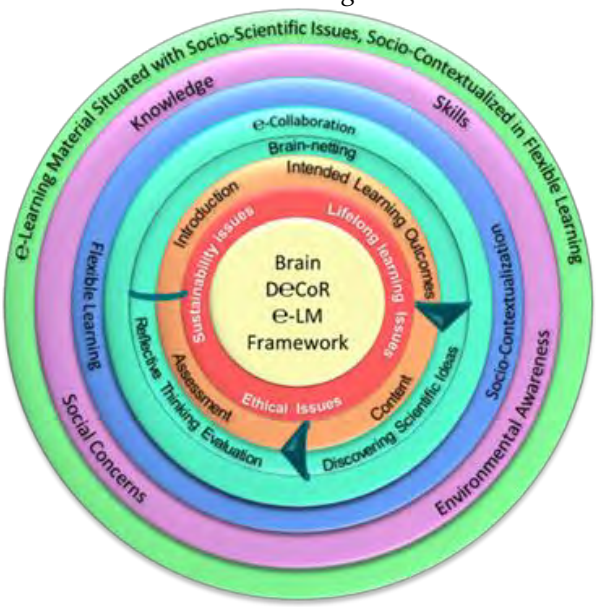
A suitable teaching approach is also necessary for the implementation of SSI-based teaching. As the academe is still in the post-pandemic phase, the flexible learning approach would be beneficial to grasp the demands of the curriculum. Realizing that learners are digitally inclined while learning institutions are after the modality with flexibility, this approach will support SSI-based teaching. Another approach that can be significant in SSI-based teaching is the use of the learner's previous knowledge through socio-contextualization. This allowed them to reorganize their conceptual understanding of the content using their involvement with the related issue. They are given a chance to construct their knowledge by discovering, exploring, and realizing the

significance of the science concept. Picardal and Sanchez (2022) noted that this approach could improve learners' science achievement while Belen and Caballes (2020) found that it also leads to greater understanding, engagement, and satisfaction among learners.

1.2. Background

Magtibay and Nueva España (2024) developed a framework called Brain DeCoR e-LM Framework. Their proposed framework considered SSIs to be prioritized, and applied with appropriate teaching strategies, and suitable teaching approaches. They highly suggested their developed framework be applied to e-LM in the current set-up recognizing its support in socio-contextualization and flexible learning instruction. This study will be adapting this framework as it responds to the current needs in the academe. Socio-contextualization assists learners in claiming their discovered concept, becoming a part of their learning. Additionally, flexible instruction supports the learner's comfort in the process while blending with the academic demand for flexibility.

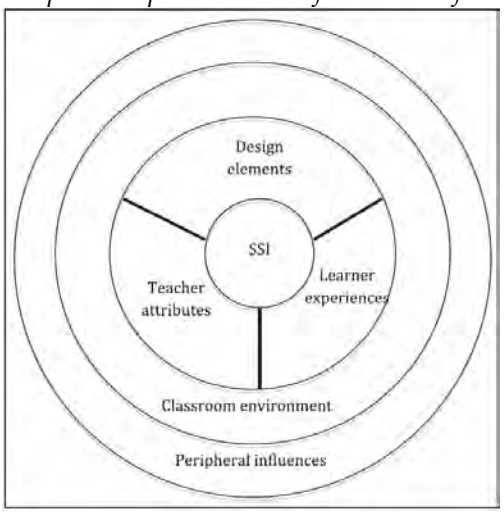
Figure 1
The Brain DeCoR e-LM Design Framework Structure



Note. Adopted from Magtibay & Nueva España (2024).

The Brain DeCoR e-LM Framework structure is illustrated in Figure 1 showing its salient features. The priority SSIs: lifelong learning, ethical issues, and sustainability issues; appropriate teaching strategies: brain-netting, discovering scientific ideas-collaboration and reflective thinking evaluation; e-LM component: Introduction, intended learning outcomes, content, and assessment; and suitable teaching approaches: flexible learning and socio-contextualization. The Brain DeCoR e-LM Framework will be more on assisting the e-LM development focusing on the socio-contextual SSI situation in flexible learning instruction. The current need to complement flexible learning and socio-contextualization was also highlighted in the Brain DeCoR e-LM Framework. The situated cognition theory (Brown et al., 1989), the discovery learning model (Bruner, 1961), and inquiry-based learning (Pappas, 2014) were also instructional designs considered in e-LM development.

Figure 2
Graphical representation of SSI-based framework developed by Presley et al. (2013)



The Brain-DeCoR e-LM Framework is in contrast to the Presley et al. (2013) SSI-based framework which was designed to map SSI-based instruction. Its Organizational outline was utilized in the initial need assessment of the framework leading to its framework design structure. To comply with the current academic demand, the Brain-DeCoR e-LM Framework was designed from curriculum analysis considering not only Presley et al. (2013) design elements, learning experiences, and classroom environment but also including teaching practices, instructional materials, and assessment tools analyzed. Considering these insights, Brain DeCoR e-LM became more relevant in the current educational set-up.

Figure 3
SSIBL model developed by Levinson et al. (2018)

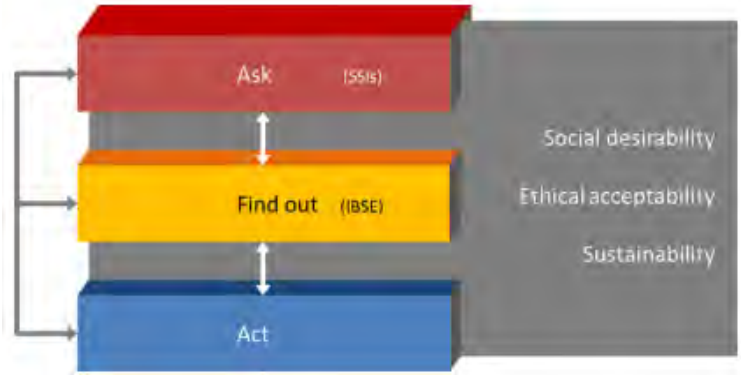


Figure 3 shows the SSIBL model developed by Levinson et al. (2018). SSIBL framework, as a tool for improving teacher practices, directly focuses on inquiry-based learning, enaction, and framing of solutions to enact changes. This framework focuses on three pillars namely: citizenship education, socio-scientific issues, and inquiry-based science education. This framework differed from the Brain DeCoR e-LM Framework. It focused mainly on inquiry-based learning and did not consider diverse teaching strategies and approaches that are very relevant in the new setup. In addition, the flexibility of the Brain DeCoR e-LM Framework made this more appropriate for the varying demands of the learning process, applied in the e-LM development.

1.3. The Aim

This study aims to develop an electronic learning material adhering to the Brain DeCoR e-LM Framework (Magtibay & Nueva España, 2024) Specifically, this study intends to address the following questions:

RQ 1) How can the electronic learning material SSI-based be developed adhering to the salient features of the Brain-DeCoR e-LM Framework?

RQ 2) How the developed e-LM will be validated?

This study will substantially contribute to science teaching modified landscape. The trend of SSI-based learning is very timely. The flexible learning approach supports the post-pandemic academic grasping of the learner's digital nature. The socio-contextualization approach consequently promotes linkage with learners' prior knowledge, enabling them to apply it to their real-world applications. The development of an SSI-based electronic learning material that is socio-contextualized for flexible learning instruction will aid science facilitators in adapting SSI-based teaching. Showing how the e-LM will be developed will hopefully encourage science facilitators to situate SSI in science teaching.

Students' lifestyle depends greatly on digitalization, and smartphone technology is almost inseparable from them, as shared by Dalaila et al. (2022). The SSI-based electronic learning material in 21st-century learning in the Industrial Revolution era (Dalaila et al., 2022) is very appropriate, hence the Brain-DeCoR e-LM Framework will be performed in this study. As an e-LM will be presented in this study, this will guide science facilitators to situate SSIs and suitably implement them considering the appropriate teaching strategies approaches, and priority SSIs. There is a need for an SSI-based e-LM in teaching science to support socio-contextualized academic learning in digital space. Lastly, the science facilitators will validate the developed SSI-based e-LM to ensure adherence to the design framework's salient features.

2. Methodology

2.1. Research Design

A mixed-method research design was employed in the development of an SSI-based e-LM. Qualitatively, a narrative approach was performed to showcase how each salient feature of the design framework is incorporated into the e-LM development. In validating the developed e-LM, a quantitative research design was employed. Using the validated instrument, the incorporation of the salient features of the developed e-LM was measured.

2.2. The Setting of the Study

The study was conducted at one of the state universities in the province of Batangas, Philippines. In the course of the development phase, a post-pandemic education setup was applied. Flexible learning instruction in a cyclical scheme is being implemented utilizing Google Classroom as its learning management system [LMS]. Google Meet was utilized as a means for video conferences at the university. The study considered the Microbial and Food Biotechnology course specifically the content dealing with the Application of Biotechnology on Milk, Dairy, and Bread Products.

2.3. Instrument

The salient features of the Brain-DeCoR e-LM Framework (Magtibay & Nueva España, 2024) became the guiding post for the development. This includes the following: (1.) Priority SSIs: lifelong learning issues, ethical issues, and sustainability issues; (2.) E-LM design structure: introduction, intended learning outcomes, content, and Assessment; (3.) Teaching strategies: Brain-netting, Discovering scientific ideas, Reflective thinking evaluation, and e-collaboration; (4.) Teaching approaches: flexible learning and socio-contextualization

The instrument utilized in this study is the Evaluation Instrument for the Developed e-LM. It underwent face and content validation with field experts in science education who are knowledgeable in developing electronic learning material. A document referring to the designed e-LM framework was attached during validation. The content of the instrument was found acceptable to validators. From the dichotomous manner of rating, whether the salient feature is present or not, it is suggested to devise into scaling rate. The teaching approaches, design

structure, priority SSIs, and teaching strategies served as the components of the instrument. Given in Table 1 are their brief descriptions of the instrument components.

Table 1
Evaluation of Instrument Components in Analyzing the e-LM Salient Features

Components	*Description*
Teaching approaches	Flexible learning in blended modality is adopted while contributing to a conducive learning environment. Provide approaches that promote and stimulate socio-contextualization in the given activities.
Design structure	The design structure of the institution includes Introduction, ILOs, Content, and Assessment are all provided while situating the priority SSIs
Priority SSIs	The priority SSIs identified in data gathering are those that are present in the science courses.
Teaching and Assessment strategies	The teaching strategies are systematically designed and suited to the priority SSIs identified and found appropriate

The validators of the developed e-LM assessed these components in the evaluation process. The instrument was presented on a four (4) point rating scale (Musau, 2018) where 3 is the highest, and 0 is the lowest with adjectival ratings: highly incorporated (3), moderately incorporated (2), lowly incorporated (1), and not incorporated (0). The validators' ratings were computed for their mean and corresponding adjectival interpretation was given.

2.4. Research Procedure

Brain-DeCoR e-LM Framework served as a map in the e-LM development phase. The e-LM was structured based on the salient features of the framework. The inclusion of the identified priority SSIs was remarkable. The details of the e-LM design structure were discussed. The appropriate teaching and assessment strategies and approaches for SSI situations were designed in the e-LM developed. The flexibility of instruction was ensured by merging the e-LM structure with the blended learning modality.

The Science courses offered at the senior year level were the chosen course for the e-LM to be developed. The intended e-LM users are expected to be well-acquainted with the flexible learning implementation in the Institution. They may be more familiar also with the SDGs, which were incorporated into the e-LM development. The Science courses offered for the first semester on the third-year level, BIT Food Technology, were evaluated. Microbial and Food Biotechnology, the only Applied Science Tool [AST] course, was chosen. Application of Biotechnology on Milk, Dairy, and Bread Products was selected from the topics listed in the course outline. This topic portrayed Science applications that the anticipated student users may appreciate more if the designed framework for SSI is situated.

In the e-LM development, the end user was first identified. Salient features of the e-LM were introduced in the segment "Foreword" of the e-LM. SDGs were introduced to familiarize learners with each goal. The "know-how" of QR code scanning was given to ensure learners independently explore QR code scanning. Designed SSI icons for SSI situations were presented. Relevant SSIs with the chosen topic were also carefully studied and embedded in the development process. Considering the end user's available resources for flexible instruction, e-collaborative activity was deliberately structured.

The e-LM was validated after its completion. This guaranteed that the designed salient features of the Brain DeCoR e-LM Framework were incorporated in the developed e-LM. In the validation process, the developed SSI-based e-LM was presented to the five validators and the validation instrument. Validators of the developed SSI-based e-LM were the science facilitators of the Institution. They teach science courses in the institution and are also well-versed in developing science course learning materials. Their knowledge of learning material development contributes to validating the developed SSI-based e-LM.

2.5. Data Analysis

The development phase covered the narrative approach in analyzing salient features and presenting the developed e-LM framework. Meanwhile, in the validation phase, the developed e-LM was validated using the four-point scoring criteria shown in Table 2.

Table 2
Scoring Criteria for the Incorporation of Salient Features on the Developed e-LM

Score	*Scoring range*	*Adjectival Interpretation*
0	0.0	Not incorporated
1	0.1 - 1.0	Lowly incorporated
2	1.1 - 2.0	Moderately incorporated
3	2.1 - 3.0	Highly incorporated

Note. Adapted from Musau (2018).

As responses of validators were collected, the mean average on each criterion of the salient feature was computed and analyzed using the adjectival interpretation.

3. Result and Discussion

The developed e-LM is where the salient features of the Brain-DeCoR e-LM framework were applied. The facilitator and learner are the end users of the electronic learning material situated with SSI.

The e-LM is designed to be flexible and can be accessed through smart mobile devices. The e-LM includes a QR code, allowing quick access to supporting materials and e-collaboration within the class. Additionally, the Institution's LMS, Google Classroom, supports the e-LM and serves as a repository for learners' output during flexible learning activities, such as Brain-netting activities, e-collaborative learning, and reflective thinking evaluations.

The Brain DeCoR e-LM Framework with its salient features is applied to the Microbial and Food Biotechnology course (AST 101) of BIT Food Technology. Microbial and Food Biotechnology, a three-unit course, is a pure lecture offered every first semester at a third-year level.

3.1. Unlocking the e-LM Key Features

To fully utilize the e-LM, it is essential for facilitators and learners first to acquaint themselves with its salient features. These features are conveniently explained in the "Forewords" section of the e-LM. SSI icons are affixed on the e-LM to serve as a cue of the SSIs' situation. Table 3 shows their representations.

Table 3
SSI Icon and Its Representation in the e-LM

SSI Icon	*SSI representation*	*Description*
	Lifelong learning issues	It symbolizes brighter learning brought by the knowledge gained and the moral considerations applied in a sustainable initiative affecting our daily lives.
	Ethical issues	It symbolizes the scale for morality, equality, and ethical decisions for the betterment of society.
	Sustainability issues	It symbolizes the different sustainable development goals if dealing in general with the SDGs.
To be represented also by a particular SDG icon	Sustainability issues	A particular icon for the specified SDG may be used

Furthermore, the design of QR codes was created in the e-LM, as shown in Table 4.

Table 4
Design of QR codes in the e-LM

Design of e-LM QR codes					
Video clippings		For e-book references		Activities	

QR codes with different designs were made in developing e-LM to signify different references such as video clippings, activities to be conducted, and e-book references. This e-learning feature of the e-LM was found to improve communication between the teacher and learner as cited by Hernando and Macias (2022). They added that the QR-code approach of presenting a learning material gained high acceptance and usability, reducing learners' cognitive burden.

3.2. Development of e-LM and Its Salient Features

3.2.1. Inclusion of the Identified Priorities SSIs

The Brain DeCoR e-LM Framework prioritizes situating the SSIs: lifelong learning issues, ethical issues, and Sustainability issues (Magtibay & Nueva España, 2024). Shown in Figure 4 is an example portion of the e-LM content structure developed with the inclusion of the identified priority SSI.

Figure 4
Inclusion of SSI in Content Structure in the e-LM

Note. Excerpt from a Content structure highlighting the SDG and ethical-related issues SSIs.

The e-LM content is illustrated with the SSI icon- SDG 2 and ethical issues. As the content is presented, it is suggested to be situated with the SSIs on the right side. SDGs intend to mold a holistic approach, and as the priority SSIs become more interrelated, the significance of ethical issues from the global perspective is becoming progressively evident, as mentioned by van Den Hoven (2019). As ethical issues are situated, other priority SSIs, the SDGs, and lifelong learning issues will also be situated in some instances in the e-LM. Yenni et al. (2017) supported this inclusion of SSI in learning material, noting that an SSI-based teaching material motivated learners, significantly impacting their scientific literacy specifically in science content.

3.2.2. Details of the Design structure of the e-LM

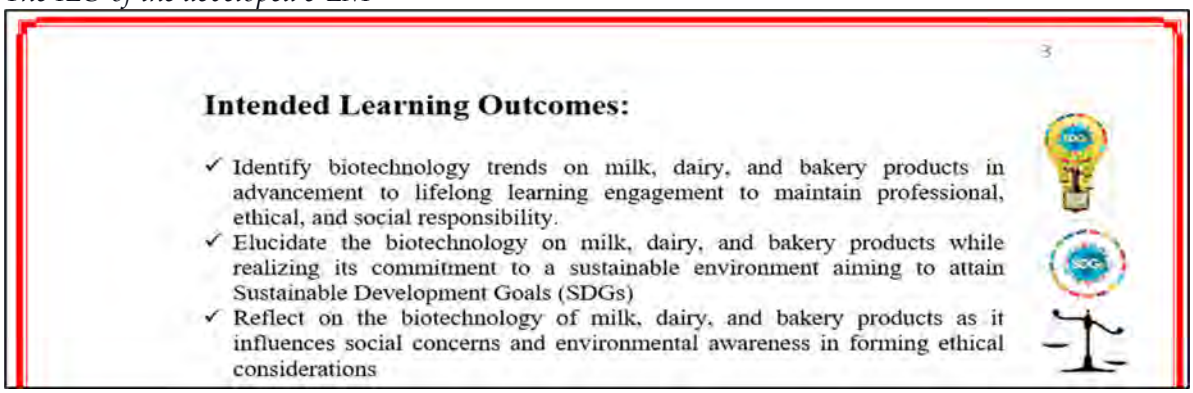
The IM design structure provides suitable teaching and assessment strategies as suggested in the Brain DeCoR e-LM design framework. The e-LM design structure and its corresponding teaching and assessment strategies are summarized in the following.

Introduction. The introduction part of the e-LM begins with a short statement about Biotechnology. It eventually leads to the discussion of milk, dairy, and bread products. Brain-netting aids the facilitator in relating the course topics to the learners' daily experiences, linking them to their future careers. This portion provides interest and motivation to the learners.

Learners who participate in brain-netting view their fellow learners' shared ideas. They also learn from it, realizing they have the same experiences and sometimes far more than their peers. In the end, the facilitator will summarize the ideas shared, making them appreciate the topic's significance when applied to their personal life. The Introduction situated with priority SSIs will make the learning progression more authentic for learners' advances (Talen, 2016). Baytelman and Constantino (2017) validated that an introduction to a learning material can provide higher levels of moral reasoning provided it has well-organized knowledge. A well-planned introduction in the developed e-LM intends to improve the learners' moral reasoning.

ILO. The ILOs present what the learners should attain after completing the e-learning material as presented in Figure 5.

Figure 5
The ILO of the developed e-LM



The first ILO is linked with lifelong learning issues, the second ILO with sustainability issues, and the third one with ethical issues.

Lifelong Learning issues are prioritized in the ILOs of the e-LM and intend to create engagement to maintain professional, ethical, and social responsibility to the learners (Magtibay & Nueva España, 2024). Likewise, in the study of English and Carlsen (2019), these SSIs were mentioned to support scientific literacy, adult learning, and academic endeavors. Ethical Issues in the ILOs dealt with character and value improvement. Controversial issues are expected to be explored, dealing with moral reasonings, which the learner will attempt to resolve. Sustainability issues are prioritized in the ILOs of the e-LM to achieve a sustainable environment. Furthermore, SDGs encourage learners to be abreast with a learning outcome that promotes sustainable development.

Content. The content structure of the e-LM presents the course content. Discovering scientific ideas in studying content will help the learners claim their knowledge and relate SSI to their personal lives. This portion also encourages learners to develop skills and challenges them to e-collaborate.

One sample is Discovering Scientific Ideas Activity designed for a group of learners. It includes QR codes to access related references and videos in the e-LM. The e-LM also provides an activity sheet with a soft copy available in Google Classroom. Learners can use it for a Google document task during an online session.

Lifelong Learning issues are situated in the content of the e-LM, which captures learners' life experiences as a part of their learning process. The application of daily experiences of the learners that are socio-contextualized aids in understanding the science lessons. Ethical Issues on the content of the e-LM presents the ramifications of learners' decisions. These SSIs will recognize learners' moral situations while relating them to science and the ethical pathways in pursuing progress. Sustainability issues expressed in SDGs are prioritized in the content of the e-LM to promote sustainable practices relating to scientific ideas through procedures or processes. These

SSIs allow the content to be abreast with contemporary issues on sustainable processes or resolutions.

Assessment. This is also known as the "Reflection Time" at the end of each topic. This feature encourages reflective thinking and allows learners to assess their learning experiences This assessment also connects learners to their personal and societal contexts. By utilizing reflective thinking strategies, learners can reflect on their learnings and deepen their understanding thoughtfully.

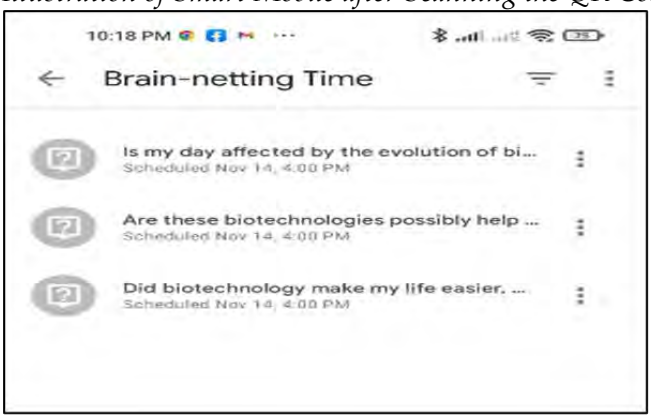
At the assessment, lifelong learning issues deal with learners' practical learnings, and SSIs are expected to be evident and presented in their culminating experiences in science. Ethical Issues will be considered in the assessment. These SSIs encourage learners to enhance their moral reasoning when dealing with the dilemmas of SSIs. Resolving moral issues with science will play a significant role in this component. Sustainability issues in the assessment will encourage learners to propose a sustainable solution while dealing with societal development. Considering SDGs, proposed solutions will be expected to be given into focus. SSIs attempt to evaluate practical learnings, inspire learners to improve their ethical judgment, and recommend a sustainable solution while dealing with societal growth (Magtibay & Nueva España, 2024).

3.2.3. Designing Appropriate Teaching and Assessment Strategies for SSIs

Appropriate teaching and assessment strategies ensure that the inclusion of priority SSIs in the e-LM design structure is implemented properly.

Brain-netting. The brain-netting process begins with open-ended questions relating to the learner's experiences. This activity is readily available in Google Classroom and accessible through smart mobiles. By scanning the QR code, the screen displays the related queries (see Figure 6).

Figure 6
Illustration of Smart Mobile after Scanning the QR Code for Brain-Netting



Enough time is given to learners while contemplating the open-ended questions in brain-netting. They can view the answers of their peers. This activity creates connections with their experiences. Maaravi et al., (2021) shared that it boosts creativity and generates innovative ideas.

Discovering Scientific Ideas. In discovering scientific ideas, learners actively participate while the facilitators offer scaffoldings to achieve the learning goals. A sample presented on the developed e-LM is the Google form activity. After scanning the code for the video presentation, the learner conceptualizes how cheese is made by responding to the Google form prepared. Enough time will be given to learners to accomplish the task. A welcome preview of the reference will first appear on the learner's screen after scanning the QR code reference. Headed by Socio-scientific issues, the book's name, and publication details, the pdf file will be downloaded and viewed once "View PDF" is clicked (see Figure 7).

Figure 7
Smart mobile screen after scanning the QR code reference

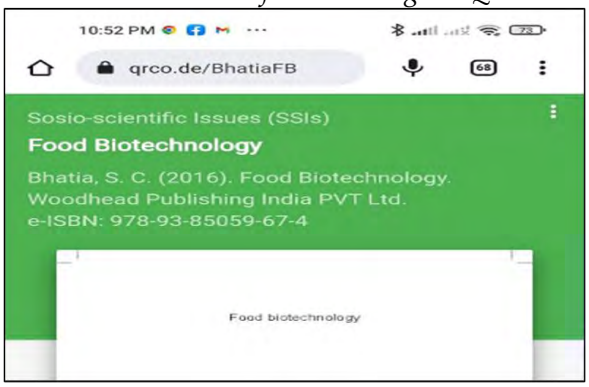


Figure 7 shows the illustration of the smart mobile after scanning the QR code reference. This gives convenience to learners in accessing the references for discovery learning activities. As cited by Bruner (1961), this teaching strategy was found to empower learners to develop their knowledge and allow them to take ownership of their learning experiences.

e-collaboration. e-collaboration happens while the learners work together. This aims to achieve a common learning goal supported by digital technologies to improve communication, data, and learning management. This strategy encourages the facilitator to blend it with other strategies in the proposed e-LM design framework. Google documents, Google Meet, reference QR codes, and emails are possible resources for e-collaboration. Class Activity House Rules will be presented first before the start of the activity. Evaluation criteria for skills and rubrics are also described in the house rules. Arizen and Suhartini (2020) supported that it fosters student mobility enabling one to study anywhere, anytime, at their convenience. This strategy was applied in in-person and online modalities which was validated by Blau et al. (2020) that incorporating e-collaboration in flexible learning can be advantageous.

Reflective Thinking Evaluation. After the test, the facilitator allows ample time for the learners to reflect on what they have learned. The activity is called "*Reflection Time: Are Biotechnology and I Connected?*"

To assess the learners' progress in the cognitive domain of learning, they will answer, "Today, I learned that…." This will result in improvement in their mental processing. They may share their thoughts, including the ideas, concepts, trends, and technologies taught in the session. Then, to evaluate their progress in the psychomotor domain of learning, they will respond, "Our topic today helped me to develop my skills in…." Their answers described their development regarding the manipulative skills they honed while performing the activity. Lastly, to apprehend the advances in the affective domain of learning, they will reply, "Our activity helped me realize that I can promote social concerns by … and environmental awareness by….". Their responses will show how the activity enhanced their attitudes and values regarding social concerns and environmental awareness. Before completing the introductory statements, the facilitator will provide helpful tips for scaffolding the learners' reflective thinking.

The designed teaching strategies and assessments encourage learners to use SSIs and try to explain their scientific phenomena. Through the use of scientific evidence, the presented science content became a part already of the learner. The skills of the learners were developed and their affective concepts were harnessed in their reflective thinking evaluation. This scenario was validated in the study of Yenni et al. (2017) where SSI contexts used in teaching materials were found to impact learners' ability to solve societal issues occurring in the environment.

3.2.4. Designing Appropriate Teaching Approaches for SSIs

A modernized approach to e- LM development is necessary to tackle future societal issues such as sustainability and climate change mitigation. The following methods are aligned with the current science teaching in the institution.

Use of Socio-contextualization. Socio-contextualization was incorporated in the e-LM through SSI corner packets. As these packets appear in the e-LM, this will initiate socio-contextualization. It will guide the facilitators to explore further social issues that may be applied to the topic presented. This SSI corner serves as a cue to the facilitator to socio-contextualize. Learners may also share their ideas freely to relate to the course content. Those local issues related to the content may also be shared. In doing so, the learner will realize the personal relevance of the topic. Socio-contextualization as applied to teaching material, was known to improve student learning outcomes as mentioned by Yenni et al. (2017) in their study. According to a study conducted by Karisan and Ziedler (2017) the socio-contextualization approach can effectively address current issues. It can be done by providing a deeper understanding of the social context surrounding them.

Flexible Learning Modality. This teaching approach permits flexibility of time, place, and audience, including, but not only focusing on, technology usage as cited in the CHED Memorandum Order (CHED, 2020). The e-LM observed the current cyclical scheme in the blended learning modality of the Institution. The flexibility of instruction brought by this approach created a twist in the development process. In addition, it complies with the demands of the new normal scenario. Smartphone technology, the inseparable gadgets to them, will be helpful in learning science. Teaching strategies supported by technology can be comfortably administered. On the other hand, the transition from one modality to another will not be a challenge for learners and facilitators. There is a repository of easy-to-access materials. Those portions of lessons that require face-to-face interaction can be performed whenever possible.

The use of socio-contextualization in a flexible learning approach was encouraged to situate societal issues by applying activities in e-learning such as videos, brain-netting, and e collaboration. This socio-contextualized flexible learning was found to assist learners in their attainment of scientific literacy improving their skills both in science and technology as confirmed by Dalaila et al. (2022) in their study.

3.3. Validation Process

The experts validated the e-LM after the development process. Table 5 shows the e-LM validation result on incorporating salient features in the e-LM.

Table 5
Experts' Validation of e-LM on the Incorporation of Salient Features

Salient Features	*Computed Mean average*		*Adjectival Rating*
1. Teaching Approaches		2.92	Highly incorporated
a. Flexible Learning	3.0		
b. Socio-contextualization	2.83		
2. Design structure		2.83	Highly incorporated
a. Introduction	3.0		
b. ILOs	2.75		
c. Content	2.75		
d. End of Test	2.83		
3. Priority SSIs		2.73	Highly incorporated
a. Lifelong learning issues	2.92		
b. Ethical issues	2.59		
c. Sustainability issues	2.86		
4. Teaching Strategies		2.93	Highly incorporated
a. Brain-netting	3.0		
b. Discovering Scientific Ideas	2.92		
c. Reflective Thinking Evaluation	2.83		
d. e-collaboration	3.0		
Overall Mean		2.85	Highly incorporated

Table 6 shows comments written by the evaluators in their filled-up validation form.

Table 6
Summary of the Evaluators' Comments on the developed e-LM using the Brain-DeCoR e-LM Framework

Validators (V)	*Comments*
V1	This e-LM certainly supports flexible learning. The SSIs are addressed with each topic covered. The activities provided are engaging, whether intended as individual work or group work. This ultimately allows collaboration among learners.
V2	The designed electronic Learning Material (e-LM) addresses socio-scientific issues in teaching Science with socio-context through flexible learning. The main purpose of the material was clearly stated and made justifiable. Generally, the material meets the needs of our 21st-century learners and their interest and engagement in learning about the Application of Biotechnology on Milk, Dairy, and Bread Products.
V3	The electronic learning material developed promotes the science teaching and learning process. It will definitely enhance the students' science achievement. This new educational contribution is necessary for the implementation of a blended/flexible learning modality

The comments and suggestions of the validators on the developed e-LM immensely helped the researcher improve and strengthen the claim on incorporating the salient features. Finally, it was presented again to validators for final evaluation after revisions. Experts issued a certificate of validation after the process.

3.4. The Curriculum Mapping

In the development phase, curriculum mapping guarantees alignment and consistency of what to teach. It also ensures details like what the facilitators facilitate, what learners learn, and how their learning is measured (Gulbis et al., 2021). The ILOs of the topic: Application of Biotechnology on Milk, Dairy, and Bread Products are linked to the elements of the OBE Framework covering Microbial and Food Biotechnology outcomes.

4. Conclusion and Recommendation

The SSI-based electronic learning material was developed and validated. It was conducted by situating the socio-scientific issues in the teaching of Science with socio-context through flexible learning. The development focused on the Application of Biotechnology in Milk, Dairy, and Bread Products under the course AST 101-Microbial and Food Biotechnology. To unlock the e-LM key features, the end-user (facilitator and learners) were acquainted with its salient features in the "Forewords." The development process of e-LM and its salient features were presented in detail. It comprises identified priority SSIs and the details of the design structure. The designing of the appropriate teaching and assessment strategies for SSIs and suitable teaching approaches for SSIs were also included.

The e-LM developed is flexible and accessible through smart mobile devices. The QR code scanning is designed to support the digital nature of learners. The e-LM conveniently responds to the varying modalities currently used in the academe. The socio-contextualization made the e-LM practical, applying to the learner's personal experiences. The teaching strategies are interactive in a modern way. These allow learners to connect their prior knowledge to the new incoming concept. Based on the validation conducted by five science facilitators, the salient features of the Brain-DeCoR e-LM Framework were found to be highly incorporated into the developed SSI-based e-LM.

The developed e-LM was recommended to be implemented on the intended participants. Furthermore, it is suggested to validate its effectiveness considering the e-collaborative activity

assessment and the result of student participant's reflection time assessment. The student performance in science achievement will denote the effectiveness of the developed e-LM.

Acknowledgements: The researcher would like to extend appreciation to the Commission of Higher Education and Batangas State University for the financial assistance; Dr. Rebecca C. Nueva España for the guidance; and the evaluators for their invaluable contribution.

Declaration of interest: No conflict of interest is declared by the author.

Data availability: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethical statement: The study covered the development of electronic learning material based on the existing SSI-based e-LM framework. No participants were involved in the development phase. Validators were presented anonymously. No ethical approval was required.

Funding: Financial assistance coming from Batangas State University and the Commission of Higher Education.

References

Al-Samarraie, H., & Hurmuzan, S., (2018). A review of brainstorming techniques in higher education, *Thinking Skills and Creativity,* 27, 78-91, https://doi.org/10.1016/j.tsc.2017.12.002.

Amos, R., & Levinson, R. (2019). Socio-scientific inquiry-based learning: An approach for engaging with the 2030 Sustainable Development Goals through school science. *International Journal of Development Education and Global Learning*, *11*(1) 29–49. https://doiorg/10.18546/IJDEGL.11.1.03

Arizen, A., & Suhartini, S. W. (2020). Mobile learning student worksheet based on socio-scientific-issues: Enhancing students' scientific literacy skills in biology. *Jurnal Pendidikan Biologi Indonesia*, *6*(1), 15–24. https://doi.org/10.22219/jpbi.v6i1.11196

Baytelman A., & Constantinou C. P., (2018). Investigating the relationship between content knowledge and the construction of ethical arguments on socio-scientific issues. *Proceedings of the ESERA 2017 Conference. Research, Practice and Collaboration in Science Education, Part 8: Scientific Literacy and Socio Scientific Issues*, 1031–1038. Dublin, Ireland: Dublin City University. http://gnosis.library.ucy.ac.cy/handle/7/62237

Belen, J. L., & Caballes, D. G. (2020). The beginning teachers 'challenges in an inquiry-based approach to teaching science: provision for a special science research elective Course. *CIIT International Journal of Software Engineering and Technology, 12*, 38-44.

Blau, I., Shamir-Inbal, T., & Avdiel, O. (2020). How does the pedagogical design of a technology-enhanced collaborative academic course promote digital literacies, self-regulation, and perceived learning of students? *The Internet and Higher Education*, 45, 100722. https://doi.org/10.1016/j.iheduc.2019.100722

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*(1), 32-42. https://doi.org/10.3102/0013189X018001032

Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review*, *31*, 21-32.

Bruner, J. S. (1971). *The relevance of education*. Norton.

CHED. (2020). *Memorandum Order No. 04.* Author. https://ched.gov.ph/

Dalaila, I., Widiyaningrum, P., & Saptono, S. (2022). Developing e-module based on socio-scientific issues to improve students scientific literacy. *Journal of Innovative Science Education, 11*(3), 292–301. https://doi.org/10.15294/jise.v10i1.54500

De Leon-Pineda, J. L., & Prudente, M. (2022). Using online journals to improve the teaching of reflection among preservice math teachers. *Reflective Practice*, *23*(3), 369-381. https://doi.org/10.1080/14623943.2022.2029737

English, L.M., & Carlsen, A. (2019). Lifelong learning and the sustainable development goals (SDGs): Probing the implications and the effects. *International Review of Education*, *65,* 205–211. https://doi.org/10.1007/s11159-019-09773-6

Erduran, S. (2020). Science education in the era of a pandemic. how can history, philosophy, and sociology of science contribute to education for understanding and solving the covid-19 crisis? *Science & Education*, *29,* 233–235. https://doi.org/10.1007/s11191-020-00122-w

Genisa, M.U., Subali, B., Djukri, Agussalim, A., & Habibi, H. (2020). Socio-scientific issues implementation as science learning material. *International Journal of Evaluation and Research in Education, 9*(2), 311-317. http://doi.org/10.11591/ijere.v9i2.20530

Gulbis, K., Krüger, T., Dittmar, M., & Peters, H. (2021). Approaches to mapping an undergraduate medical curriculum to a national competency-based catalog of learning outcomes. *Medical Teacher*, *43*(4), 439–447. https://doi.org/10.1080/0142159x.2020.1854704

Hernando, R., & Macías, J. A. (2022). Development of usable applications featuring QR codes for enhancing interaction and acceptance: a case study. *Behaviour & Information Technology*, *42*(4), 360–378. https://doi.org/10.1080/0144929X.2021.2022209

Karisan, D. & Zeidler, D.L. (2017). Contextualization of nature of science within the socioscientific issues framework: A review of research. *International Journal of Education in Mathematics, Science and Technology*, *5*(2), 139-152. https://doi.org/10.18404/ijemst.270186

Levinson, R. (2018). Introducing socio-scientific inquiry-based learning (SSIBL). *School Science Review, 100*(371), 31-35.

Maaravi, Y., Heller, B., Shoham, Y., Mohar, S. & Deutch, B. (2021). Ideation in the digital age: literature review and integrative model for electronic brainstorming. *Review of Managerial Science*, *15,* 1431–1464. https://doi.org/10.1007/s11846-020-00400-5

Magtibay , R. G. ., & Nueva España, R. C. (2024). Socio-scientific issues-based electronic learning material design framework development for flexible learning. *Journal of Practical Studies in Education*, *5*(2), 1-12. https://doi.org/10.46809/jpse.v5i2.81

Musau, F. M. & Francis M. M. (2018). *Geospatial dimensions of the linkages between ecosystem services and sustainable community development in Shimba Hills, Kwale County – Kenya* [Unpublished doctoral dissertation]. Kenyatta University, Kenya.

Pappas, C. (2014). *Instructional design models and theories: the discovery learning model. instructional design.* eLearning Industry. https://elearningindustry.com/

Picardal, M.T., & Sanchez, J.M.P., (2022). Effectiveness of contextualization in science instruction to enhance science literacy in the Philippines: a Meta-Analysis. *International Journal of Learning, Teaching and Educational Research*, *21*(1), 140-156. https://doi.org/10.26803/ijlter.21.1.9

Pietrocola, M., Rodrigues, E., Bercot, F., & Schnorr, S. (2021). Risk Society and Science Education: Lessons from the Covid-19 Pandemic. *Science Education, 30*(2), 209-233. https://doi.org/10.1007/s11191-020-00176-w

Presley, M.L., Sickel, A.J., Muslu, N., Johnson, D.M., Witzig, S.B., Izci, K., & Sadler, T.D. (2013). A Framework for socio-scientific issues based education. *Science Educator, 22*(1), 26-32. https://eric.ed.gov/?id=EJ1062183

Rogayan Jr., D. V., & Dantic, M. J. P. (2021). Backliners: roles of science educators in the Post-COVID milieu. *Aquademia, 5*(2), ep21010. https://doi.org/10.21601/aquademia/11053

Sadler, T.D., Foulk, J.A, & Friedrichsen, P.J. (2017). Evolution of a model for socio-scientific issue teaching and learning. *International Journal of Education in Mathematics, Science and Technology*, *5*(2), 75-87. https://doi.org/10.18404/ijemst.55999

Talen, J. (2016). Teaching with socio-scientific issues in physical science: teacher and student experiences. *International Journal of Evaluation and Research in Education, 5*(4), 271-283. https://doi.org/10.11591/ijere.v5i4.5954

van Den Hoven, J. (2019). Ethics and the UN sustainable development goals: the case for comprehensive engineering: commentary on "using student engagement to relocate ethics to the core of the engineering curriculum". *Science and Engineering Ethics*, *25*(6), 1789-1797. https://doi.org/10.1007/s11948-016- 9862-2

Yenni, R., Hernani, H., & Widodo, A. (2017, May). The implementation of integrated science teaching materials -based socio-scientific issues to improve students' scientific literacy for environmental pollution theme. *AIP Conference Proceedings*, *1848*(1), 060002. https://doi.org/10.1063/1.4983970