

Embedding SEL-Informed Emotional-Support Language in Online Inquiry-Based Biology Lessons: A Pilot Feasibility Study

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Received July 6, 2026

Accepted September 24, 2026

Electronic access October 31, 2026

Background/Objective: This pilot evaluated whether SEL-informed emotional-support language could be embedded in an online biology inquiry lesson and whether participation, survey, and written-response procedures were feasible.

Methods: Students completed two non-equivalent Edpuzzle lessons: Lesson A explored urbanization and its impact on nonhuman populations, and Lesson B explored cancer risk and animal models, which included six planned episodes of SEL-informed emotional-support language. Retrospective feasibility criteria summarized participation and data collection. The author and an independent second coder classified 182 de-identified written responses with a four-category rubric and resolved disagreements by consensus.

Results: Eleven students were active in Lesson B; seven completed it (63.6%), and six completed its survey (54.5% of active students). Four of seven students active in both lessons produced matched surveys (57.1%). Before adjudication, coders agreed on 127/182 responses (69.8%); unweighted Cohen's κ was 0.499 (bootstrap 95% CI 0.397–0.598). After adjudication, 70/77 Lesson B responses (90.9%) were Developed or Brief. No lesson-stopping technological issues were reported, and all six planned episodes were delivered.

Conclusion: Parent or guardian permission, student assent, Lesson B activation, technical delivery, SEL-informed emotional-support language delivery, and written-response usability met the post hoc criteria. Lesson completion, survey return, and cross-lesson matching did not. Recruitment coverage, direct acceptability, and receipt of the SEL-informed emotional-support language were not assessed. Because there were differences in the two lessons and only four surveys matched, this study does not provide evidence that the SEL-informed emotional-support language improved emotions, engagement, persistence, or scientific inquiry reasoning.

Keywords: inquiry-based learning; emotional scaffolding; metastrategic knowledge; biology education; scientific inquiry reasoning.

Introduction

Science instruction in which students build explanations for phenomena places them in a difficult position. In biology classrooms, this includes creating models, utilizing evidence, and revising models. However, it is difficult, as students must work with partial ideas before they know whether those ideas are correct. These practices are central to science learning; however, research has cautioned against equating inquiry with minimally guided discovery. Kirschner, Sweller, and Clark argued that unguided or minimally guided instruction is generally less effective and less efficient than strongly guided instruction, especially for learners who do not yet have sufficient prior knowledge to provide their own internal guidance¹.

Hmelo-Silver, Duncan, and Chinn added that problem-based and inquiry learning use extensive scaffolding to reduce cognitive load and support learning in complex domains,

and thus should not be equated with unguided instruction². A meta-analysis of 72 studies found positive overall effects of guidance on inquiry activities and learning outcomes³. Recent secondary science research supports this conditional view: students engaged in guided inquiry might enjoy the activity but still need help with hypothesis formation, observation recording, and evaluating hypotheses against evidence⁴; equipment scaffolding was associated with greater student interest and effort in secondary science inquiry⁵; and structured inquiry has positive, but frequent open inquiry has negative, associations with scientific and mathematical literacy⁶. Guided inquiry is thus defined by support that also preserves students' opportunity to reason with uncertainty. Observational research in technology-scaffolded collaborative inquiry also found that teachers provided both instructional guidance and socio-emotional support, although such support was uneven across groups⁷.

Inquiry support may be distributed across peers and digi-

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tal tools. Peer assessment has been found to support the revision of collaborative products and scientific conclusions⁸, and technology-supported collaborative inquiry has been associated with improved scientific literacy skills⁹. In optics, metacognitive prompts embedded in guided inquiry improved integrated science-process skills relative to guided inquiry alone¹⁰, yet video modeling improved Grade 9 inquiry performance, whereas adding metacognitive prompts produced no additional benefit¹¹. These findings illustrate the variety of sources through which inquiry can be supported. They also suggest that adding scaffolding does not consistently improve student outcomes across contexts.

For purposes of this study, explicit inquiry refers to instructional designs in which scientific practices are identified and explained, and students are asked to reflect on their strategic use of those practices. White and Frederiksen demonstrated that science inquiry, modeling, and metacognitive reflection can facilitate learning gains for students when they evaluate the quality of their own thinking¹². More specifically, Ben-David and Zohar demonstrated that metastrategic knowledge facilitates students' understanding of what a strategy is, why it is useful, and when it is applicable¹³.

A computer-based revision model helped students with fragmented ideas produce more integrated science explanations¹⁴; scripted peer-feedback prompts produced more focused and actionable feedback and improved inquiry outputs¹⁵; and an authentic-inquiry case study illustrated inquiry as flexible, creative, provisional, collaborative, and tool-mediated¹⁶. Collectively, these findings indicate that providing explicit guidance on reflecting and revising student work will facilitate awareness of otherwise implicit inquiry processes.

These approaches align with what Vygotsky described as the Zone of Proximal Development (ZPD): the distance between what a student can accomplish on their own and what they can accomplish with adult guidance or collaborative assistance from more skilled peers¹⁷. They also align with later design frameworks that expanded on this body of work, as scaffolding in software aimed at supporting inquiry can target specific difficulties in scientific practice^{18,19}. Consequently, online inquiry environments have incorporated misconception prompts and predict-observe-explain-evaluate or self-regulatory scaffolds^{20,21}, instructional guidance²², dialogic scaffolding²³, and think-alouds²⁴, with effects varying across outcomes and instructional conditions. In the current pilot, Edpuzzle served as the digital mechanism for delivering such prompts and collecting student responses. The Edpuzzle pauses required written answers from students. Thus, the students' scientific inquiry reasoning became a visible classroom artifact.

Inquiry scaffolding addresses more than just the cognitive demands of scientific reasoning. The uncertainty involved

in revising models also produces emotional demands on students. Pekrun's control-value theory of achievement emotions posits that academic emotions are shaped by students' perceptions of control and task value²⁵. Lower perceived control over valued tasks can lead to negative emotions, which can then undermine performance. Normalizing uncertainty and permitting revision were implemented in this research to support perceived control by giving students a clear course of action when they felt uncertain. Additionally, by framing their initial ideas as provisional, the design hoped to minimize the effects of evaluative threats and encourage students' participation in the inquiry. These were proposed mechanisms only, as receipt of the SEL-informed emotional-support language, perceived threat, and persistence were not directly measured.

Research on social and emotional learning (SEL) provides additional context to the current study. Teachers in technology-scaffolded collaborative inquiry provided more guidance to groups they perceived as motivated and willing to collaborate, while socio-emotional support was minimal despite the challenging learning environment⁷. This pattern provides a rationale for examining SEL-informed emotional-support language within inquiry environments. Durlak et al. conducted a meta-analysis of 213 universal school-based social-emotional learning programs and found that, compared with controls, participating students showed significant improvements in social-emotional skills, attitudes, behavior, and academic performance²⁶. RULER illustrates a systemic, theory-based approach that integrates social-emotional learning across a school's curriculum, policies, and family and community contexts²⁷. The present study did not implement a full SEL curriculum; instead, these frameworks informed the use of SEL-informed emotional-support language in the lesson. Rosiek defined emotional scaffolding as teachers' use of pedagogical representations intended to influence students' emotional responses to subject matter²⁸. Belland, Kim, and Hannafin proposed a similar framework for designing scaffolds that address both motivational and cognitive outcomes²⁹. Collectively, the above references served as a foundation for the language used in the lesson, helping minimize the effects of evaluative threats, normalize the practice of revising, and maintain focus on the inquiry task. Emotional scaffolding, therefore, offered a more specific rationale for brief supportive language in the inquiry lesson than did the broader SEL program alone.

More recent empirical research provides additional context for examining emotion alongside instructional support. Studies have associated achievement-emotion profiles with perceived instructional quality and mathematics achievement^{30,31}; control-value appraisals with domain- and lesson-level emotions³²; momentary emotions with later learning outcomes³³; teacher support with self-efficacy through achievement goals and academic emotions³⁴; and grades with

achievement emotions in reciprocal within-person relations³⁵. Taken together, these studies indicate associations among students' emotional experiences, instructional support, and academic outcomes, although these relationships may be reciprocal and context dependent. Recent work developed a brief ten-emotion instrument for secondary students³⁶ and reported mixed reciprocal relations between need-supportive teaching and student and teacher emotions³⁷. A cross-sectional study associated teacher support with student engagement through self-efficacy and resilience, with positive academic emotions moderating part of the modeled relationship³⁸. These studies support examining emotional experience alongside instructional support while also explaining why small descriptive measures should not be viewed as direct measures of intervention effects.

Limited research has examined the feasibility of embedding brief SEL-informed emotional-support language in an online secondary biology inquiry lesson while simultaneously collecting participation, survey, and written-response data. OpenSciEd was the curricular source for all lesson adaptations. OpenSciEd is an open-source organization focused on developing materials that promote phenomena-based science learning³⁹. The Next Generation Science Standards emphasize science and engineering practices, disciplinary core ideas, and cross-cutting concepts⁴⁰. New York's P-12 Science Learning Standards are aligned with this standards framework⁴¹. Therefore, OpenSciEd is a practical method for adapting inquiry-based biology lessons into online instructional materials that are standardized.

Because the two lessons differed in content, emotional sensitivity, reading and graph demands, prompt structure, and biological complexity, the pilot was framed descriptively and did not treat Lesson A as a control or baseline for Lesson B. Only four students completed both lesson surveys with exact cross-lesson matches.

The pilot addressed three feasibility questions for SEL-informed emotional-support language in online inquiry-based biology:

- 1) Can SEL-informed emotional-support language be incorporated into an online inquiry-based biology lesson while maintaining visibility of the inquiry process?
- 2) Can Edpuzzle records, post-lesson surveys, and written artifacts provide usable data on participation, affective indicators, and scientific inquiry reasoning?
- 3) What evidence of scientific inquiry reasoning was visible in written responses generated during the lesson with SEL-informed emotional-support language?

Methods

Design

This study uses a descriptive feasibility-pilot design. Lesson A explored the influence of urbanization on nonhuman populations, whereas Lesson B examined how cancer risk is assessed through the use of animal models. Lesson B also included SEL-informed emotional-support language in the script. The lessons differed in topic, emotional sensitivity, reading load, graph interpretation, number and type of prompts, and biological complexity.

Each student generated a unique pseudonymous code for linking the two lessons. The participant-generated pseudonymous codes resulted in only partial matches. Lesson A could not be treated as a baseline or pre-intervention condition for estimating the effect of Lesson B.

Lesson-specific values are presented only to describe implementation and data availability. The lessons cannot be compared, and observed differences cannot be attributed to SEL-informed emotional-support language because the lessons were non-equivalent and the matched sample was very small.

As the SEL-informed emotional-support language was delivered in Lesson B, this was the primary implementation of interest. The retrospective criteria for activation, completion, survey return, SEL-informed emotional-support-language delivery, and written-response usability were applied when evaluating Lesson B. Lesson A was documented descriptively but was not considered as a control or baseline condition when evaluating the two lessons.

Participants

Participants were a convenience group of students enrolled in IB Biology HL and IB Biology SL, approximately 15–17 years old, from multiple class sections. The invitation was not sent to every student who may have been eligible based on broad grade level. Consequently, the proportion of the full eligible school population recruited cannot be calculated. Fifteen students were invited to this pilot; all 15 received parent or guardian permission and provided affirmative student assent. Participation in both lessons and the research was voluntary. Students had not previously used OpenSciEd Biology materials.

After eliminating one invalid entry from both lessons that did not belong to a student, there were fifteen valid entries remaining within the cleaned Edpuzzle export files. Nine students were active in Lesson A, and 11 were active in Lesson B. Seven were active in both lessons; five fully completed both lessons; five reached at least 90% progress in both; and six submitted written responses in both. Seven students completed the Lesson A survey, six completed the Lesson B survey, and four completed both surveys. Separate re-

ports are provided for these differing denominators because participation, completion rates, survey response rates, and response contributions were not equivalent categories. An ‘active’ record indicated that Edpuzzle recorded a student opening and interacting with the lesson. ‘Full completion’ means that Edpuzzle designated the assigned lesson as complete. ‘At least 90% progress’ was defined as a platform progress value of 90% or greater. These categories were used only to describe the availability of data; they were therefore not interpreted as measures of student engagement. Thirteen students contributed at least one of the 182 written responses. Two valid pseudonymous participants contributed zero responses. Paired participation and survey completion numbers are recorded in Table 1.

Table 1 Paired participation and survey completion

Paired participation category	n
Appeared in cleaned Edpuzzle exports	15
Active in Lesson A	9
Active in Lesson B	11
Active in both lessons	7
Fully completed Lesson A	8
Fully completed Lesson B	7
Fully completed both lessons	5
Reached at least 90% progress in both lessons	5
Submitted written responses in both lessons	6
Completed Lesson A survey	7
Completed Lesson B survey	6
Completed both surveys	4

Materials

Lesson A involved introducing students to the effects that urbanization has on nonhuman species. During the first part of Lesson A, the students observed and documented data as well as formulated questions. After viewing a case study on urban versus nonurban juncos, the students modified their model. This format allowed students to see the inquiry cycle at work, yet no explicit guidance on regulating affect was presented in this lesson.

Lesson B focused on using animal studies to investigate the risks of developing cancer. Students analyzed graphs related to cancer. They also examined trends related to cancer prevalence based upon age and height. Additionally, the students studied why researchers use animal studies when attempting to understand cancer. Finally, after studying the frequency of cancer among animals, the students constructed a model that explained which groups develop cancer and why. Since Lesson B dealt with an emotion-sensitive topic, the voice-over

script for Lesson B contained specific phrases that were intended to provide emotional support to help minimize possible discomfort experienced by students while exploring information about cancer.

The original content for each of these decks was reduced and modified to allow them to be used in an online environment. The Urbanization Deck was adapted into a total of 19 slides from its original total of 29 slides. The Cancer Deck was similarly reduced to a total of 20 slides from its original total of 27 slides. Both decks used the same general inquiry-based structure, but the Cancer Deck provided SEL-informed emotional-support language to help manage emotions while students explored information about cancer.

Lesson B included six planned episodes of SEL-informed emotional-support language designed to occur across five slides. There were two episodes of SEL-informed emotional-support language on Slide 5 and one episode each on slides 1, 8, 9, and 10. Episodes occurred during the introduction to the topic, construction of claims, development of initial models, assessment of initial models, and final assessment. Topics included acknowledgment of the emotional burden of cancer; recognition that difficulties and uncertainties will be encountered; framing initial claims as hypothetical; providing language for making tentative claims; redirecting uncertainty toward the pursuit of evidence; and acknowledgment of persistence. All six scripted episodes were verified retrospectively to be read aloud in the lesson videos. Table 2 documents the exact episodes of SEL-informed emotional-support language and their placement, defined by the slide on which each was spoken in the prerecorded video.

Procedure

Students were invited before lesson access. Parent or guardian permission and affirmative student assent were collected through Google Forms. Participation was voluntary. It did not affect grades and did not restrict access to required instruction. Students generated pseudonymous codes themselves for cross-lesson matching. Access to both lessons was followed by their post-lesson surveys, which included a timing item asking whether at least 24 hours had passed since the prior video lesson. The researcher distributed prerecorded Edpuzzle materials and forms. Participants’ teachers did not conduct any part of this study.

After lesson delivery, Edpuzzle records were exported and cleaned. For all participant-generated coding, normalization procedures were applied to both capitalization and spacing so that only exact matches were compared. Written responses were extracted, and the author assigned one holistic category to each retained response. A randomized packet from which explicit lesson labels, original question numbers, participant codes or identities, and author ratings had been removed was

Table 2 Exact episodes of SEL-informed emotional-support language in Lesson B and retrospective delivery check

Episode and location	Exact spoken SEL-informed emotional-support language	Primary move, intended function, and theoretical basis
Slide 1, after the lesson introduction	Talking about cancer can feel heavy because many of us know someone who's been affected. It's okay if this brings up feelings. If at any time you experience feelings of being overwhelmed, or if you need to pause, it's perfectly fine to stop momentarily, take a deep breath, and refocus. Emotional responses such as these can occur when conducting actual science on real-world issues as real scientists.	Labeling an affect; normalizing a difficult experience; providing an action-oriented way to regulate an emotion. Informed by emotional scaffolding, control-value theory, and SEL emotion-recognition/self-management principles.
Slide 5, before Claim-Evidence-Question directions	Sometimes it's hard to turn patterns in data into clear claims and questions. That's completely normal — even for scientists. We're going to use Claim-Evidence-Question structure as a tool to help. Your first try does not have to be perfect.	Identifying an area of difficulty; providing structure; allowing for revisions.
Slide 5, after Claim-Evidence-Question directions	If you feel unsure or worried about 'getting it wrong,' try this strategy: Start your sentences with 'It seems like...' or 'One possible claim is...' That reminds your brain that this is only a first draft of your thinking.	Provisional language; control support. Provides a concrete response strategy intended to reduce perfection threat while preserving evidence-based claim construction.
Slide 8, before initial-model work	Your model right now is a first draft. Scientists expect to revise their models as they learn more. Your goal is just to get your current ideas down on paper so you can improve them later.	Revision permission; uncertainty normalization. Frames an incomplete model as expected and revisable, supporting perceived control during initial model construction.
Slide 9, during model monitoring	If you're not sure what to circle, start with the part of your model you feel least confident about. That sense of uncertainty is actually a clue of where you need to seek out additional evidence. This is a monitoring strategy: checking where your model is weak. Scientists do this to decide what to investigate next.	Uncertainty reframing; monitoring; evidence-seeking support. Reframes uncertainty from failure into diagnostic information and gives an actionable next step: identify where additional evidence is needed.
Slide 10, final reflection	If today felt challenging, that actually means you were using some of the same strategies real researchers use, such as interpreting messy data, building and revising models, and sticking with the problem even when it wasn't simple. Those strategies take practice.	Challenge normalization; persistence affirmation.

then provided to the second independent coder. Exact agreement and κ statistics were calculated before consensus adjudication of the 55 disagreements.

Measures

Edpuzzle was employed to ensure uniformity of access to each lesson and to record lesson participation, progress, and response activity. These records documented time spent on lessons, progress toward completion, and responses to specific questions posed in each lesson.

Students responded to an immediate post-lesson survey measuring effort, achievement emotions, task clarity, and perceived emotional support. The effort items were based on the

Effort/Importance component of the Intrinsic Motivation Inventory (IMI), which had previously been assessed for psychometric properties⁴². The survey-based indicators measuring achievement emotions used the AEQ-S wording for irritation, confidence, boredom, shame, and enjoyment and were adapted from the AEQ-S⁴³. As adapted single indicators were used instead of entire validated scales, they were viewed as exploratory descriptive indicators rather than emotion scale scores.

Two 1-to-7 task clarity ratings were used. One task-clarity rating was based on the Learning Climate Questionnaire (LCQ)⁴⁴, and one task-clarity rating was developed specifically for inquiry clarity. Two additional LCQ items were averaged as a descriptive measure of perceived emotional sup-

port⁴⁴. The pilot composite did not assess receipt of the SEL-informed emotional-support language, nor did it reproduce the original LCQ construct. Supplementary Table S1 contains the exact wording and scoring, including reverse scoring the low-energy item as 8 minus the original response.

Due to the small size of the pilot sample, discrete emotions were not analyzed separately. Irritation, boredom, and shame were averaged as a descriptive negative affect composite; confidence and enjoyment were averaged as a descriptive positive affect composite. The composites descriptively summarize individual survey responses and do not represent classroom-level processes. Therefore, future research should validate the modified items and analyze discrete emotions individually. Also, the low-energy item could reflect student fatigue or activation.

Formal coding of written artifacts

Each of the 182 retained responses was coded into one mutually exclusive category. The author-developed rubric assessed both biology content evidence (e.g., conceptual representation, mechanism, model quality, etc.) and inquiry process-related evidence (e.g., whether the participant used modeling, revision, prediction, and data use as strategic scientific practices). Developed responses connected data or evidence to a claim or explanation, described a meaningful biological mechanism, or explained why and how an inquiry strategy was used. Off-task responses did not contain any substantive response to the prompt. Brief responses contained a relevant and interpretable claim, pattern, factor, strategy, prediction, or revision but little explanation, evidence, mechanism, or scientific purpose. Minimal responses contained relevant content but were too fragmented or vague for meaningful interpretation. The author, acting as the first coder, classified all 182 responses. Then the second coder received a packet with the response order randomized, with the prompt text but not lesson labels, original question numbers, participant codes, participant identities, or author-side categories. Complete masking of lesson origin was impossible as topic words such as urbanization and cancer had to be included to interpret responses. Supplementary Appendices S1–S8 provide the full codebook, borderline rules, prompt-specific worked examples, coding documentation, agreement matrices, and counts by prompt and randomized participant identifier. Table 3 summarizes the full artifact coding rubric. Table 4 provides a summary of the final adjudicated response coding using response-level denominators.

Data Analysis

As the focus of this analysis was feasibility, no lesson-specific effect estimates were generated for participation, completion

of tasks, survey results, or written response quality. Summary statistics for each method were only calculated in order to determine if there were usable data generated.

Lesson duration did not serve as a direct measure of student engagement or lesson difficulty due to potential variance in reading speed, interruptions, or inactive browser time.

Descriptive summary statistics (means and standard deviations) were provided for the full sample composite scores. There were seven survey responses for Lesson A and six for Lesson B. As only four surveys matched across lessons, no inferential statistical analyses were performed. Agreement and unweighted Cohen's κ were determined prior to adjudication. Linear- and quadratic-weighted κ values were listed as supplemental statistics as the four response categories can be viewed as ordered. Confidence intervals were derived from 20,000 non-parametric bootstrap samples. The two coders collectively reviewed all disagreements using the previously established definitions to agree upon a consensus rating that fell into one of the four categories and retained both original ratings. Therefore, only the adjudicated categories for each item were included when reporting descriptive frequencies. Pooled response proportions were not utilized as either a student-level metric or as a measure of lesson effectiveness.

The feasibility criteria were developed retrospectively after data collection; they were neither prespecified nor intended as validated efficacy cutoffs. Instead, they served as operational benchmarks for identifying procedures that appeared workable and procedures requiring modification. A 70% benchmark was used for activation, completion, survey return, cross-lesson matching, and acceptability as a practical majority-uptake signal. A benchmark of 80% was established for permission, student assent, and interpretable written responses. These are the domains that needed a higher benchmark for ethicality and usable data. Technical delivery of the lesson required no reported lesson-stopping issues. The benchmark for the delivery of SEL-informed emotional-support language was at least 90% of the planned episodes narrated. However, meeting a benchmark is merely an indicator of feasibility within this study only.

Table 5 below summarizes the retrospective feasibility criteria and observed values.

Ethics

The principal, vice-principal, and school psychologist reviewed the proposed study, including the ethics and procedural considerations, before the research was conducted. A science-teacher advisor provided oversight. This school review was separate from institutional ethics review.

There was no institutional IRB approval or exemption prior to the start of this study. Parent or guardian permission and affirmative student assent were obtained via Google Forms

Table 3 Artifact coding rubric

Artifact level	Definition	Biology content evidence	Inquiry process evidence
Developed	Connects evidence to an explanation or explains revision	Mechanism, evidence, or conceptual accuracy is visible	Explains the purpose of modeling, revision, or evidence use
Brief	Names an idea or strategy with limited explanation	Some relevant content is present	Strategy is named, with limited purpose explanation
Minimal	Too vague for deep interpretation	Fragmentary or unsupported content	Little process reasoning is visible
Off-task	Response is not relevant to the prompt	No usable biology evidence	No usable inquiry process evidence

Table 4 Summary of Final Adjudicated Response Coding Using Response-Level Denominators

Artifact level	Lesson A final count	Lesson A response-level %	Lesson B final count	Lesson B response-level %
Developed	54	51.4%	25	32.5%
Brief	45	42.9%	45	58.4%
Minimal	4	3.8%	2	2.6%
Off-task	2	1.9%	5	6.5%
Total written responses coded	105	100%	77	100%

prior to participation. Participation in this study was completely voluntary; it would have no effect on a participant's grade(s), nor would it limit any participant from receiving the instruction. The researcher was not the students' classroom teacher, and the researcher and students only interacted via pre-recorded Edpuzzle materials. The participants generated their own pseudonymous codes for cross-lesson matching. The codes incorporated indirect information from a protected code-generation recipe and thus were not described as fully anonymous. No names or other direct identifiers were collected. The researcher handled the original codes only for normalization and exact matching. There was no name-to-code lookup key. Randomized response and participant IDs replaced them in coding and reporting files. The independent coder received no participant codes or identities, and randomized reporting IDs could not be used as a lookup for names. Because all participants were minors and Lesson B addressed cancer, the researchers included a statement in the script acknowledging that some students might experience discomfort. Researchers did not make any determinations regarding the psychological or emotional state of the individual participants based upon observations obtained in the study. Larger-scale studies in the future should obtain prospective institutional ethics review and formalize the study procedures.

Results

Feasibility outcomes

As presented in Table 5, parent or guardian permission and affirmative student assent were collected for all fifteen invited students, and eleven of them were active in Lesson

B. No lesson-stopping technical failures were reported. All six planned episodes of SEL-informed emotional-support language were delivered in the final Lesson B narration based on a retrospective investigator check.

Lesson B completion (7/11, 63.6%), Lesson B survey return (6/11, 54.5%), and survey matching among active students in both lessons (4/7, 57.1%) fell below the retrospective 70% targets.

The final adjudicated distribution classified 70/77 Lesson B responses (90.9%) as Developed or Brief, meeting the retrospective 80% written-response-usability target.

Coverage of the broader eligible school population, direct student acceptability, and student receipt of the SEL-informed emotional-support language were not assessed.

Behavioral participation records

Nine students were active in Lesson A; eight completed the lesson and eight reached at least 90% progress. Eleven students were active in Lesson B; seven completed the lesson and eight reached at least 90% progress. Mean recorded time among records containing answered questions was 7.11 minutes for Lesson A and 12.30 minutes for Lesson B. Recorded time is descriptive only and may reflect students' reading speed, interruptions, inactive browser time, topic, prompt structure, and the lessons' burden rather than engagement or difficulty. Table 6 summarizes the specific lesson participation and progress rates.

These platform records indicated that Edpuzzle collected usable data on students' participation and progress through each lesson. However, these data do not demonstrate an engagement effect. Shortcomings in student participation in-

Table 5 Retrospective feasibility criteria and observed values

Domain	Retrospective target	Observed value	Interpretation
Coverage of the whole eligible population	At least 70% of an enumerated eligible pool invited	Not calculable; the full grade-level eligible pool was not enumerated	Not assessed
Parent or guardian permission	At least 80% of invited students	15/15 (100%)	Met
Affirmative student assent	At least 80% of invited students	15/15 (100%)	Met
Lesson B activation	At least 70% of assented students begin the lesson	11/15 (73.3%)	Met
Lesson B completion	At least 70% of active students fully complete the lesson	7/11 (63.6%)	Not met
Lesson B survey completion	At least 70% of active students submit the survey	6/11 (54.5%)	Not met
Cross-lesson survey matching	At least 70% of students active in both lessons produce matched surveys	4/7 (57.1%)	Not met
Written-response usability	At least 80% of Lesson B responses are developed or brief	70/77 (90.9%), based on final adjudicated coding	Met
Technical delivery	Zero lesson-stopping technical failures	0 reported failures	Met
Script-delivery fidelity	At least 90% of planned episodes of SEL-informed emotional-support language delivered in the final narration	6/6 planned episodes delivered (100%)	Met retrospectively
Direct student acceptability	At least 70% positive responses on a direct acceptability item	No direct acceptability item was administered	Not assessed

Table 6 Lesson participation and progress

Measure	Lesson A	Lesson B
Active students	9	11
Full completions	8	7
Completion rate among active students	88.9%	63.6%
Students reaching at least 90% progress	8	8
Mean total lesson time among students with answered questions	7.11 min	12.30 min

cluded the Lesson B completion rate, survey return rates, and cross-lesson matching. In future implementations, the burden associated with Lesson B could be reduced, and both technological issues and nontechnological reasons for terminating the lesson early could be documented. The survey could also be directly incorporated into the lesson sequence.

Survey descriptives

Table 7 presents the full-sample and matched-subset survey descriptives.

Lesson A written responses described urbanization and

nonhuman populations. Developed responses described food supply, shelter, human interaction, and habitats. Prompts in later modeled revisions also addressed adaptive behaviors, decreased fear of humans, changes in food supplies, and changes in survival pressures.

Lesson B responses addressed reasoning about biological mechanisms related to cancer risk. In developed responses, students related cancer to the cumulative effect of mutations that increase with age. They also attributed the incidence of cancer to environmental exposures, genetics, the presence of protective genes (such as p53), and protection mechanisms in large animals. Later prompts, after new evidence was presented, included more conditional explanations.

Strategy-reflection responses provided descriptive evidence of metastrategic explanations. Some responses named prediction and modeling as tools for deciding what to examine, and some explained revision and evidence use as ways to improve an explanation. These characteristics were visible in the artifacts but were not separately coded variables.

Brief and Minimal responses contained less explanation. Some named a strategy without explaining its scientific purpose, and some provided little interpretable biology or inquiry-process evidence. Off-task responses contained no usable response to the prompt. The range demonstrated that on-line prompts could be used to generate both analyzable and

Table 7 Survey descriptives**Panel A. Full-sample descriptives (Lesson A n = 7; Lesson B n = 6)**

Composite	Lesson A M	Lesson A SD	Lesson B M	Lesson B SD
Effort	4.71	1.33	5.06	0.57
Negative affect	1.76	1.01	2.00	0.92
Positive affect	3.79	1.15	3.67	0.75
Task clarity	5.71	1.58	5.67	0.98
Emotional support	5.29	2.27	5.17	2.32

Panel B. Matched subset (n = 4)

Composite	Matched Lesson A M	Matched Lesson B M
Effort	4.67	5.33
Negative affect	2.00	1.92
Positive affect	3.50	3.75
Task clarity	4.88	5.50
Emotional support	4.75	4.50

Note. Panel A reports full-sample descriptive values for Lesson A (n = 7) and Lesson B (n = 6). Panel B reports the exact matched subset (n = 4). The matched values are highly unstable, descriptive only, and are not inferential tests or effect estimates. Effort, task clarity, and emotional support used 1-to-7 scales; positive and negative affect used 1-to-5 scales.

low-information artifacts for the feasibility evaluation.

The pooled category distributions are descriptive. Responses were nested within participants; prompt structure varied significantly; and each lesson included a varying number and types of prompts. Lesson A contained 12 open-ended prompts and 105 student responses, whereas Lesson B had 9 open-ended prompts and 77 student responses. Distribution at the prompt-level is shown in Supplementary Table S7.

Before adjudication, the coders agreed on 127 of 182 classifications (69.8%; Wilson 95% CI = [62.8%, 76.0%]). Unweighted Cohen's κ , the primary chance-corrected estimate, was 0.499 (bootstrap 95% CI = [0.397, 0.598]). Of 55 disagreements, 54 were adjacent-category disagreements: 28 Developed/Brief, 24 Brief/Minimal, and two Minimal/Off-task; the remaining disagreement was Brief/Off-task. The adjudication retained all aspects of the frozen codebook. Final counts were 54 Developed, 45 Brief, four Minimal, and two Off-task responses for Lesson A, and 25 Developed, 45 Brief, two Minimal, and five Off-task responses for Lesson B. These response-level distributions do not compare lesson efficacy. Table 8 provides some examples of written artifacts.

Discussion

Implementation feasibility

As stated earlier, the primary intent of this study was to examine the feasibility of delivering a biology lesson containing SEL-informed emotional-support language via an online platform while generating usable data outcomes and written inquiry artifacts. Overall, the results from this pilot support a very preliminary feasibility claim. The lesson could be

delivered via Edpuzzle. Analyzable written responses were generated. The completion, survey-return, and cross-lesson-matching rates did not meet the retrospective feasibility standards.

Rather than having a separate social-emotional component, Lesson B incorporated SEL-informed emotional-support language into the inquiry process.

Acknowledging the topic of cancer, the script addressed the possibility of discomfort and distress. It also gave permission for students to revise early on, and it defined uncertainty as a trigger to find additional evidence. This design illustrates the intended integration.

Data-collection feasibility

The platform produced 182 analyzable written responses. 105 were from Lesson A and 77 from Lesson B. Survey data were collected; however, neither the number of surveys returned nor the number of cross-lesson matches met the retrospective standards. Direct acceptability and student receipt or recognition of the SEL-informed emotional-support language were not assessed.

Descriptive patterns in the Lesson B artifacts include cancer risk related to age, cumulative genetic damage, environmental exposure, inherited traits, protective genes, DNA repair mechanisms, making predictions using evidence, and revisions to existing models. These are not evidence of improvement in student outcomes.

The formal coding assigned one holistic response-quality category to each response. This approach showed that the online prompts generated responses ranging from Developed to Off-task, as it preserved the distinction between disciplinary

Table 8 Example written artifacts

Lesson	Prompt context	Artifact type	De-identified, lightly edited excerpt	Interpretation
A	Model revision after the junco case	Model revision	Urban juncos are bolder and less afraid of humans, and urban birds can access food and space in cities.	Links evidence from the junco case to behavioral adaptation.
A	Final strategy reflection	Strategy reflection	Scientists use revising to check their work and thinking.	Names revision with limited explanation of scientific purpose.
B	Cancer mechanism model	Mechanism	Mutations build up in DNA, causing cells to grow uncontrollably when repair systems fail.	Connects age, mutation, repair, and uncontrolled cell growth.
B	Model revision after animal cancer evidence	Model revision	Large, long-lived animals were expected to have higher cancer rates, but evidence from whales and elephants suggests protective mechanisms such as p53.	Demonstrates conditional reasoning after new evidence changed the initial size- and age-based expectation.
B	Graph noticing prompt	Minimal response	[color-only response]	Provides little interpretable evidence of biology or scientific inquiry reasoning.

Note. Supplementary Table S6 provides de-identified worked examples with wording intact except for whitespace normalization. To evaluate interrater agreement, the original response texts were used.

explanation and explanation of scientific practice.

The coding procedure also displayed moderate reproducibility prior to adjudication, as exact agreement was 69.8% with unweighted Cohen's $\kappa = 0.499$. As 54 out of the 55 disagreements involved adjacent categories, the supplemental weighted estimates were higher: linear-weighted $\kappa = 0.592$ and quadratic-weighted $\kappa = 0.714$. This indicated that the coding framework was preliminarily capable of producing reproducible classifications. Nevertheless, refinements to the distinctions between adjacent response quality levels will be needed prior to large-scale application.

Inability to assess effectiveness

Effectiveness cannot be assessed due to inequivalence in lesson content; only four respondents' surveys matched; survey indicators were modified and descriptive; receipt of the SEL-informed emotional-support language was not measured; and no pre/post biology content or inquiry strategy assessment was administered. Therefore, there is no indication whether the use of language in Lesson B affected emotions, persistence, participation, knowledge of biology, or scientific inquiry reasoning.

Broader research has shown that caution is warranted when concluding that additional scaffolding improves student outcomes based solely on its availability. Related studies document needs for guidance in chemistry inquiry, teacher-guided collaborative science, and online self-regulated inquiry^{4,7,21}.

Other research has shown that the effect depends on both the type of support and the specific metric being assessed. An example is the PISA 2015 data, which showed that frequent use of open-inquiry activities was associated with lowered literacy. Another study indicated that adding more metacognitive prompts to video modeling did not yield greater performance improvement than using video modeling alone¹¹. Essentially, these findings emphasize the importance of defining each type of scaffold with regard to its function, timing, and burden.

Limitations

The pilot study has several limitations that affect its interpretation.

First, the sample was very small. Only four students completed both the post-lesson reflection surveys. These survey results should be considered descriptive and unstable indicators.

Second, the two lessons provided in this study were not equal instructional conditions. Lesson A dealt with the impact of urbanization on nonhuman populations, and Lesson B dealt with cancer risk to animals. Because the topics involved in Lesson A and Lesson B differ in terms of emotional weight, reading difficulty, demands placed on students to interpret graphs, and biology reasoning complexity, differences observed between the lessons cannot be attributed to the inclusion/exclusion of SEL-informed emotional-support language.

Third, the survey questions used in this study were adapted

from existing questionnaires and assessments for use as classroom-friendly tools. Many of the survey items were adapted from validated psychometric scales; however, none of the composites used in this study were used in their entirety. Instead, all were reduced for immediate post-lesson reflection. Due to the small sample in this study, the author was unable to conduct analyses of specific discrete emotions (e.g., confidence, enjoyment, irritation, boredom, shame). Consequently, the effort, affect, task clarity, and emotional support scores obtained in this study should be viewed solely as descriptive classroom data and should not be regarded as validated measures of student motivation or emotion.

Fourth, the holistic categorization of written artifacts was another constraint. Although all 182 written responses were independently categorized by a second coder during revision of the paper, the unweighted agreement was moderate rather than strong ($\kappa = 0.499$). Most disagreements between coders were located at Brief/Developed and Minimal/Brief boundaries. The quadratic-weighted κ (0.714) was higher because many disagreements concerned adjacent categories. Because the unweighted κ is the primary reliability estimate, it should be used. This illustrates a need to refine the codebook for any further large-scale pilot replication.

Finally, the study did not include a pre-post content assessment or a pre-post measure of inquiry strategy use. Consequently, this study's data do not indicate if students increased their biology knowledge, improved their scientific inquiry reasoning, or developed greater metacognitive strategies as a direct result of participating in either lesson.

Future Research Directions

Studies that assess whether participation, affective experiences, or writing products are associated with the inclusion of SEL-informed emotional-support language in lessons will require a learning condition in which students have access to two versions of the same lesson: one with SEL-informed language and one without. This is to isolate lesson topics, reading loads, emotional sensitivity to the subject matter, interpretation of graphs, and complexity of biological reasoning.

Future studies should also reduce the amount of missing data. Post-lesson reflection surveys should either be built into each lesson or completed immediately after each lesson to minimize missing paired data. Furthermore, larger samples would enable researchers to explore specific types of achievement emotions separately instead of grouping them as broad categories for positive/negative affect composite scores^{32,36}. Larger samples would also facilitate a more stable comparison across effort, task clarity, perceived emotional support, and various aspects of scientific inquiry reasoning.

Future studies should compare the same lesson with and without SEL-informed emotional-support language, while us-

ing the same content, prompts, reading burden, emotional sensitivity, graph-interpretation demands, biological complexity, and assessment procedures.

They should also assess students' use of inquiry strategies and their biology knowledge before and after lesson instruction, document the fidelity of script delivery, and measure whether or not participants noticed the SEL-informed emotional-support language. These additions would allow a more cautious assessment of SEL-informed emotional-support language.

The distinctions defined between evidence regarding biology content and inquiry processes in this study should also be preserved.

Conclusion

SEL-informed emotional-support language was embedded in Lesson B as planned. The pilot generated analyzable participation and written-response data. Parent or guardian permission, student assent, activation of Lesson B, technical delivery, delivery of SEL-informed emotional-support language, and written-response usability satisfied the post hoc criteria. The lesson's completion, survey return rate, and cross-lesson matching did not. Recruitment coverage, direct acceptability, and receipt of the SEL-informed emotional-support language were not assessed. Because the lessons were non-equivalent and only four surveys were matched, this study provides no evidence that the SEL-informed emotional-support language improved emotions, engagement, persistence, biology knowledge, or scientific inquiry reasoning.

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Supplementary information

The online version contains supplementary material available at <https://nhsjs.com/?p=59308>