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# Reflective assessment in knowledge building classrooms: fostering positive epistemic emotions and quality discourse on educational research

C. Gutiérrez-Braojos<sup>1\*</sup> , G. Zhu<sup>2</sup>, C. Rodríguez-Domínguez<sup>3</sup> and P. Rodríguez-Chirino<sup>1</sup>

\*Correspondence:  
calixtob@ugr.es

<sup>1</sup> Department of Research Methods, Assessment, and Evaluation in Education, University of Granada, Granada, Spain

<sup>2</sup> National Institute of Education (NIE), Nanyang Technological University, Singapore, Singapore

<sup>3</sup> Department of Computer Languages and Systems, University of Granada, Granada, Spain

## Abstract

Knowledge Building (KB) is an educational approach that aims to foster communities of students to identify, solve and refine their knowledge of a subject. This study explores the relationships between university students' epistemic emotions and their achievement in Knowledge Building discourse and, examines whether engaging in reflective assessment can enhance these emotions and achievements. This quasi-experimental study aims to analyze the effects of reflective assessment in an educational research course with 113 students new to KB. Students' epistemic emotions were collected using self-reported surveys, while data about the quality of contributions were collected using Knowledge Forum (KF) platform. Our results show the relationship between epistemic emotions and quality of discourse. In addition, results indicate that reflective assessment contributes to positive emotions and the quality of discourse on the educational online platform KF. This study suggests that reflective assessment enhances the quality of KB discourse and shared knowledge, even when students are unfamiliar with KB pedagogy.

**Keywords:** Cooperative/collaborative learning, Knowledge building, Online learning, Evaluation methodologies, Reflective assessment, Epistemic emotions, Quality of discourse, Educational research skills

## 1 Introduction

Computer-Supported Collaborative Learning (CSCL) in education involves the integration of technology to support students working together to build knowledge and solve complex problems (Stahl et al., 2014). Numerous applied research studies have shown that most students can learn to collaborate, enhance their ideas, and acquire new knowledge when supported by a suitable technological environment (e.g., Guiral & Pifarré, 2023). However, resistance from some novice students toward constructivist approaches has been observed in socio-constructivism educational environment (Gutiérrez-Braojos et al., 2024). These resistances are particularly noticeable when students are accustomed to individual and passive learning conditions (Blignaut, 2014). Such students may

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experience maladaptive emotions and reactions when they need to take more agency for their learning (Dembo & Seli, 2004).

Knowledge Building (KB) is an educational socioconstructivist model that pioneers Computer-Supported Collaborative Learning (Stahl et al., 2014). Implementing KB in the classroom frequently utilizes technologies such as Knowledge Forum (KF), which allow learners to propose and build upon each other's knowledge and connect different contributions in shared virtual spaces (Scardamalia, 2004). Recent studies suggest that reflective assessment, where students monitor their progress and direct their inquiries, could sustain KB discourse and enhance conducive emotions supported by analytics technologies (e.g., Zhu et al., 2019). However, these studies lacked comparison groups, making it difficult to attribute all benefits solely to reflective assessment, and the small sample sizes might have undermined the validity of the findings. This study aims to address these limitations.

### 1.1 Knowledge building and progressive discourse

Knowledge Building is an educational approach to foster knowledge-creation culture in schools. It empowers students to collaborate to satisfy shared knowledge needs with the support of technology (Scardamalia & Bereiter, 2021). Teachers are to design an educational environment which provides scaffolds (tools, questions, strategies, or supports) and opportunities for students to share, discuss and inquiry ideas, build new skills and create new knowledge (Ma & Scardamalia, 2023). Teachers must gradually delegate responsibility to the students who have to take the initiative to improve their understanding and create new knowledge (Zhang et al., 2009). Students make new meanings and understanding of shared knowledge problems through build-on questions, ideas or insights, constructive use of evidence and authoritative sources, and synthesis (e.g., Tan et al., 2021).

In this sense, discourse plays a key role in Knowledge Building (Resendes et al., 2015). Discourse refers to the specific use of language to represent and build knowledge about a particular topic in a sociohistorical context (Foucault, 1972). Language is the artifact that humans use to understand, transmit, argue, persuade, exercise control, and cooperate with other humans or with artifacts (Mercer, 2019). Students typically participate in KB discourse by posting notes in online forums (e.g., Knowledge Forum), carry out different discourse moves (e.g. asking questions, proposing ideas or explanations) with the intention of improving the shared knowledge within the community (Scardamalia, 2002). The quality of discourse has been evaluated using different category schemes (Zhu & Lin, 2023); Zhang et al., 2009). These schemes usually include analyzing the scientificness and complexity of KB discourse. The "scientific sophistication" dimension assesses the extent to which a student has transitioned from relying on intuition to embracing a more rigorous scientific framework, developing a deeper understanding. The complexity dimension describes the extent to which students have made an effort to elaborate a complete explanation that responds to the questions at stake in the community (Zhu et al., 2022).

Although Knowledge Building is a promising approach to foster the conceptual change and advancement of knowledge in the community (Zhang et al., 2020), some studies indicated that its implementation does not always result in the active engagement of all community members or community's knowledge advancement (Cacciamani et al., 2021;

Gutiérrez-Braojos et al., 2018; Zhu et al., 2021). In fact, there are some challenges and difficulties related to fostering high-quality discourse among students (Zhu et al., 2021); van Heijst, et al., 2019), especially for unfamiliar learners in KB who are grappling with complex conceptual problems or attempting to understand complicated subject matter (Gutiérrez-Braojos et al., 2018). In other words, implementing KB involves a profound transformation of how knowledge should be worked with in the classroom. Hence, students often need time to appropriate the KB dynamics (Zhang et al., 2009).

Despite its well-documented potential, Knowledge Building research has identified challenges associated with its implementation in real educational contexts. Prior studies show that such implementations do not automatically lead to high-quality collective discourse or equitable participation, particularly when students are unfamiliar with inquiry-based and collaborative pedagogies (Cacciamani et al., 2021; van Heijst et al., 2019; Gutiérrez-Braojos, et al., 2022). Moreover, institutional constraints, culturally shaped expectations about teaching and learning, and the uneven appropriation of technological tools mediating Knowledge Building environments may influence how KB principles are enacted in educational practice (Blignaut, 2014; Coll et al., 2023; Stahl et al., 2014). From this perspective, Knowledge Building implementations benefit from incorporating moments of reflection and adjustment that allow students to assess their own learning processes and participation, particularly when the pedagogical approach represents a significant departure from their prior educational experiences, as evidenced by recent studies conducted in Knowledge Building contexts (Yang et al., 2024).

### 1.2 Epistemic emotions and the quality of discourse moves

Students experience emotions when building knowledge. Epistemic emotions refer to subjective affective states triggered when students become aware of or address a need for knowledge, such as identifying misconceptions, searching, reviewing, and selecting relevant information, constructing arguments based on different evidence, coordinating viewpoints, or even reconsidering epistemic beliefs, among other needs or challenges (Chevrier et al., 2019). Control-value theory (Pekrun et al., 2016) describes the antecedents and effects of epistemic emotions in educational processes and outcomes. Students experience epistemic emotions when they are in or out of control of learning activities and achievement outcomes that are subjectively important to them. Positive epistemic emotions (e.g., curiosity, enjoyment, and surprise) tend to demonstrate a positive and significant relationship with engagement, self-regulated learning, and achievement, whereas negative epistemic emotions (e.g., frustration, anxiety, and boredom) do not exhibit a negative and significant relationship with these constructs (Muis et al., 2018). Empirical results are not conclusive regarding the impacts of confusion on learning (Vilhunen et al., 2022).

In asynchronous Knowledge Building environments, epistemic emotions are particularly relevant due to the sustained cognitive effort involved in collaborative inquiry. These conditions may give rise to more complex emotional demands during knowledge construction and shape the ways in which students regulate, sustain, and adjust their participation in collective knowledge-building processes. Despite the growing interest in epistemic emotions, research examining their role in such contexts remains limited,

particularly with regard to their relationship with students' participation in collective knowledge-building activities (Teo et al., 2022).

The control-value theory is commonly adopted in Knowledge Building studies to understand the impact of epistemic emotions on progressive discourse or to design reflective assessment/metacognition sessions to foster conducive epistemic emotions (Lee et al., 2024, 2025, Yang et al., 2022, 2024). Individuals' emotions could affect the quality and discursive movements carried out by students in online forums (Zhu et al., 2019; Hou et al., 2025). Previous studies suggest the influence of reflective assessment (or meta-discourse in Zhu et al., 2022; Zhu, & Lin, 2023) on students' emotions. However, these studies did not have a control/comparison group, making it impossible to totally attribute the changes to reflective assessment. Previous studies also had relatively small sample sizes. This study aims to address these issues.

### 1.3 Reflective assessment impacting on knowledge building process

Assessment plays a central role in the educational experience. Assessments are tools with the potential to transform a situation entirely, leading to a significant shift in the processes and outcomes of knowledge acquisition (Reeve & Sharkawy, 2014). To achieve this, assessment should put reflection in the center of educational learning (Dewey, 1933). According to Dewey, reflection enables individuals to become aware of and deliberate about their actions, rather than relying solely on trial and error to navigate confusing or problematic situations (Kori et al., 2014). Reflection facilitates students be aware of their strengths and weaknesses better when learning (Radovic et al., 2023). This approach not only enhances comprehension but also fosters the development of metacognitive skills essential for long-term learning and personal growth (Merkebu et al., 2023). In other words, reflective assessment encourages students to understand "How are we doing?" and to reflect on "How can we do it better?" (Herman et al., 1992). Reflection on one's own actions and thinking facilitates a transformative perspective that focuses on improvement (Procee, 2006).

According to the principle of Knowledge Building, assessment should be concurrent and transformative to foster the advancement of knowledge (Scardamalia, 2002). The KB pedagogy emphasizes the importance of conducting reflective assessments concurrent with the community's inquiry process. This approach, aligned with the KB principle of collective responsibility, involves students taking charge of monitoring both personal and communal progress, developing an awareness of knowledge gaps, redirecting the community's iterative efforts to meet their learning needs, and enhancing their ongoing inquiry. (Zhu et al., 2022); Kim, 2024). To facilitate this process, the implementation of KB is often accompanied by portfolios (van Aalst & Chan, 2007) and/or analytical technologies that provide information on how knowledge develops in discussions among community members, typically in online environments (Yang et al., 2024). Among these technologies is software X (Gutiérrez-Braojos et al., 2023), which allows students to access analytical results and visualizations based on their participation in the KF platform. This provides students with evidence of their individual and community knowledge work (Hong & Scardamalia, 2014), facilitating reflection on how to improve collective knowledge building.

Various studies have found that the implementation of reflective assessment sessions can generate significant benefits during Knowledge Building implementations (e.g. Cacciamani et al., 2021; Lei & Chan, 2018, Yang et al., 2024). These sessions can empower students by improving their awareness and control over the KB process. By providing students with information about their progress and current situation in relation to their goals, they can reflect on their learning beliefs and gain insight into areas for improvement and identify ways to positively change their academic behaviour (e.g., Jiang et al., 2023). Even students with low achievement levels can contribute to progressive discourse (Zhu et al., 2022), making these sessions inclusive and beneficial for all members (Gutiérrez-Braojos et al., 2020). These sessions help students to get control to overcome the challenges associated with advancing knowledge, and thereby fostering positive epistemic emotions (Yang et al., 2022). Accordingly, it encourages them to take ownership of their educational journey.

#### 1.4 The current study

Although previous studies suggest the positive impacts of Knowledge Building on students' skills to collaborate and improve ideas while acquiring new knowledge, findings indicate that some students have difficulties in advancing community knowledge. During the initial weeks of the intervention, students often experience confusion due to limited subject knowledge or unfamiliarity with KB pedagogy. This initial confusion is a common response as students adapt to new learning methodologies and content areas (Author). This study comparatively analyses two KB implementations, with and without reflective assessment sessions, to understand the effects of reflective assessment on students' epistemic emotions and the quality of their community discourse. These answers may reveal the value of reflective sessions in advancing KB. Concretely, this study aims to answer two research questions:

- Q1. What are the relationships between university students' epistemic emotions and achievement in Knowledge Building discourse?
- Q2. Does carrying out reflective assessment help improve university students' epistemic emotions and achievement in Knowledge Building discourse?

## 2 Methods and materials

### 2.1 Participants and course design

This study took place at a university in (X), involving 113 undergraduate students from two different classes focused on action-research over 16 weeks. The classes were delivered in a blended mode, combining both online and in-person components (Coll et al., 2023). The Knowledge Building pedagogy was employed in the course, supported by Knowledge Forum (Scardamalia, 2004), to support students' blended learning. KF is an online space designed based on the twelve KB principles for students to post, read, and build on their community ideas (see Fig. 1 as an example). Students worked face-to-face twice a week and used the KF to share and develop their ideas for the rest of the week. They did not have prior knowledge of KB pedagogy and technology, nor did they have knowledge in the subject matter of the course. Adopting a quasi-experimental design, the classes were assigned into two groups and

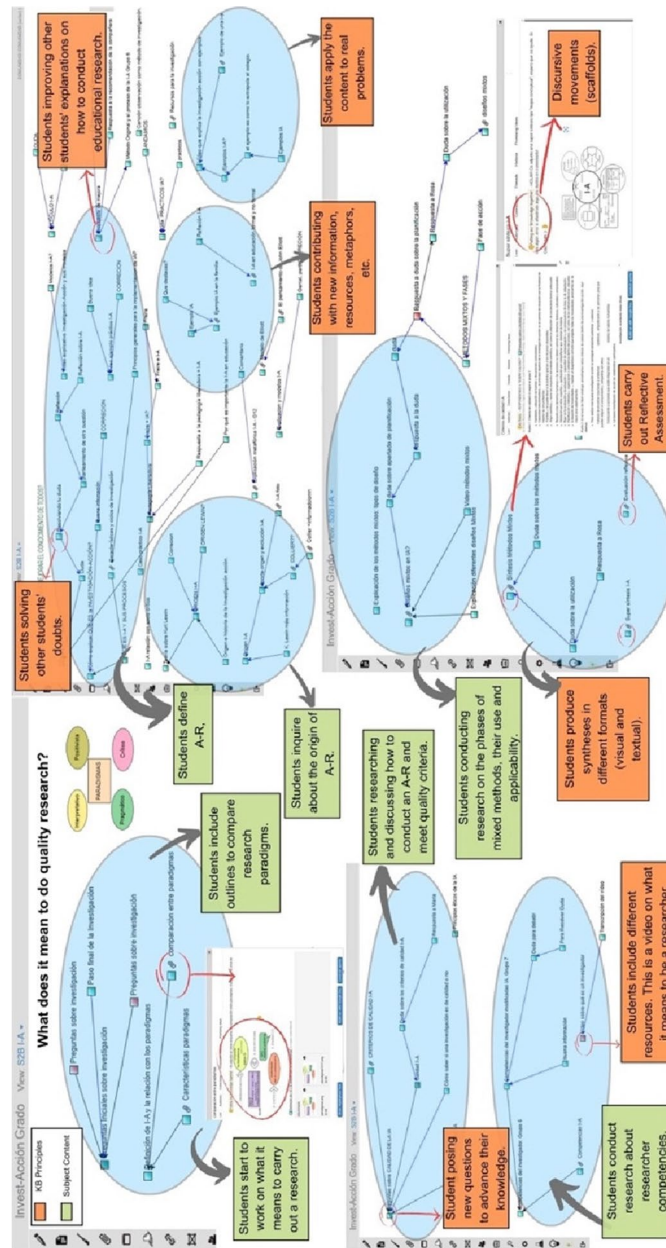


Fig. 1 Discourse movements in knowledge forum

compared to each other, class "A" or control group ( $n = 61$ , 91.8% female); and class "B" or experimental group ( $n = 52$ , 86.53% female). Both classes were taught by the same instructor, followed the same syllabus and learning objectives, and used identical instructional materials, learning activities, and assessment criteria throughout the course. Students in both groups had the same access to technological resources, including the Knowledge Forum platform, and participated in an equivalent number of face-to-face and online sessions under the same institutional conditions. Therefore, the two groups were comparable in terms of structural, pedagogical, and technological conditions, supporting the ecological validity of the quasi-experimental design.

A sequence of modules was implemented to foster KB principles. Both groups completed modules 1, 2, 3, and 5, while module 4, focused on reflective assessment, was exclusive to the experimental group.

- Module 1: Getting familiar with KB principles and KF. Students participated in training sessions to get familiar with the KB pedagogy, principles, and KF during the first two weeks.
- Module 2: Identifying big questions. The students first worked in small groups of five to six to identify significant questions that present professional challenges related to action-research. They formulated these key questions by analyzing the official syllabus of the subject and considering the professor's feedback on an initial assessment of the course content.
- Module 3: The students followed the cycles of inquiry and discussion to solve big questions established in Module 2, enhancing ideas and fostering a deeper collective understanding. The cycle is composed of 3 iterative phases:
  - i. Concretions and distribution of questions to solve: The whole class (students and instructor) reflects collaboratively to break down a big question into a map of sub-questions. Then, the small groups democratically distribute the sub-questions among themselves.
  - ii. Inquiry and dialogue on KF: Student groups developed collaborative notes on the platform to address sub-questions. Then, students made individual contributions to refine ideas, using epistemic markers, 24–48 h before class, allowing peers to build on them and incorporate feedback before face-to-face sessions.
  - iii. Pooling: Similar to a mini-conference (with one or several interventions), students presented the work carried out by their group (or several groups) in trying to solve one or several sub-questions to their peers. The presentations were made by students voluntarily, randomly and on a rotating basis. During the presentation, the rest of the students were invited to note down the ideas that they considered most relevant to satisfy their knowledge needs and their own contributions that could help improve individual or collective knowledge in a personal journal. After students' presentations, the instructor or one student provided clarifications or scaffolds to either correct misconceptions or deepen

the inquiry (e.g., providing contradictory evidence, other points of view, or revisiting big questions that were initially raised and could be appropriate to further the inquiry).

- Module 4: Reflective assessment. The students individually conducted sessions of concurrent reflective assessment to improve their contributions to the collaborative process and shared knowledge. During a class session, the instructor explained and provided access to a nominal report he had prepared, which included the use of visual analytics. The purpose of the reflective assessment session was to help students become aware of their progress regarding two key principles of the KB organized in two sections:
  - i. Fostering continuous and responsible collaborative participation with progressive discourse: This section emphasizes the importance of moving from an egocentric participation, where contributions are focused on one's own ideas ("my theory"), to a more collaborative approach. In this transition, students start using different scaffolds, such as "a better theory," "a question," or "your idea has limitations," which promote more responsive and collective engagement. This shift encourages students to take part in a community-oriented discourse where they are accountable for collective knowledge improvement. It aligns with the KB principle of "collective cognitive responsibility," emphasizing that students jointly contribute to and are responsible for the growth of the community's understanding. To this end, the report provided analytical visualizations generated from the prototype of software X (see Authors).
  - ii. Fostering awareness about knowledge in progress: This section encourages students to recognize that knowledge is dynamic and continuously evolving. Students learn that ideas are always improvable, and that Knowledge Building is an iterative process. This reflects the KB principle of "improvable ideas," which underscores that all ideas are subject to refinement and development through collaborative inquiry and sustained dialogue. By promoting this awareness, the community is motivated to continuously enhance and refine their questions and ideas, fostering a culture of ongoing improvement and deeper understanding (Table 1).

In each reflective session, the instructor explained both sections of the report. Subsequently, the students had to carry out a portfolio facilitated by a template with two sections: closed questions (on a Likert-scale) to facilitate reflection on the principles of Knowledge Building, and open-ended questions for self-assessment regarding the achievement for each section:

- Module 5: Final Synthesis and Evaluation. During the final two weeks, the students carry out a final self-assessment and built an artifact that included a synthesis of their experience in the subject, highlighting the epistemic emotions experienced and the knowledge constructed for helping others to understand the subject matter. The students made graffiti, board games, and short video.

**Table 1** Purpose of reflective assessment sections and visual analytics

Report sections	Visual analytics to facilitate reflective assessment
Foster collaborative and responsible participation	<ol style="list-style-type: none"> <li>1. Average percentage of unread notes per individual</li> <li>2. Percentage of individuals who wrote at least 3 notes</li> <li>3. Average student participation frequency per week</li> <li>4. Participation frequency per anonymized member, including Gini coefficient to show distribution of participation among students</li> <li>5. Network participation at three previous points in the time, organized regarding centrality, including density indicator</li> <li>6. Percentage of discourse scaffolds used during the discourse</li> </ol>
Foster awareness about knowledge in progress	<ol style="list-style-type: none"> <li>7. Percentage of notes with an acceptable quality according to an external evaluator</li> <li>8. Concepts cloud at three previous points in the time organized to show key concepts during the discussion</li> <li>9. Percentage of promising ideas selected and classified by students</li> <li>10. A sample of notes that included the most promising ones, as evaluated by the community</li> </ol>

## 2.2 Data collection and analytics procedures

A no-invasive short version of Epistemically-Related Emotion Scale developed and validated by Pekrun et al. (2017) was applied to collect data on students' self-perceived epistemic emotions. This scale is frequently used in the recent empirical literature on epistemic emotions (e.g., Muis et al., 2018; Zhu et al., 2021). Participants were asked to rate along a 5-point Likert scale in three moments: weeks 6, 11, and 16. They inform on how strongly they felt each of the emotions (i.e., surprise, enjoyment, curiosity; confusion, frustration, anxiety, boredom) when working collaboratively to fulfil their knowledge needs.

On the other hand, 1,174 notes written by students during the course were collected from the KF and organized according the three moments abovementioned. Each note was treated as a unit of analysis and arranged chronologically. Each note was coded according to a coding scheme developed based on previous research about Knowledge Building discourse (Zhu et al., 2021). This scheme is composed of four dimensions (questioning, theorizing, sophistication, and authoritative sources), and each dimension has sub-classifications based on levels of achievement, whereas "1" is the lowest level (see Table 2). First, the researchers jointly coded 30 selected notes from the total set of notes in trial mode to develop shared understanding of the coding scheme. Then, two analysts who are experts in the category system independently coded the remaining notes, achieving a 93.79% inter-rater agreement. The discrepancies in the ratings were discussed and debated with the assistance of a third, experienced analyst, as needed, until a reasonable decision was reached. For each dimension, we calculated the mean score across all notes contributed by each student. The composite Quality of Contributions (QC) score was then obtained by averaging these four means. (i.e., the sum of the four dimensions divided by four).

To answer the first research question, we prepared a wide-format data file which contained each student's Knowledge Forum notes scores coded using the coding

**Table 2** Knowledge building discourse coding scheme

Questioning refers to the depth of the questions to develop the process of inquiry about a need or knowledge topic	
Level 1	Questions that are asked with the intention of clarifying or avoiding possible misunderstandings. They result in a correction of the wording rather than delving into the ideas
Level 2	It refers to questions that inquire about a fact, date, or specific information
Level 3	It refers to questions that identify inconsistencies, or seek new perspectives, or knowledge needs. They can open the debate
Theorizing refers to students' efforts to produce understandings or explanations about the topics worked on in their community	
Level 1	It refers to notes that literally repeat or paraphrase/ restate the ideas or information from previous notes. This level also includes notes that are disconnected from the knowledge needs of the subject
Level 2	It refers to notes that expand or bolster ideas or explanations written in previous notes (providing examples, experiences, evidence, resources, additional justifications, analogous phenomena or contexts) about a shared knowledge needed in the community
Level 3	These notes introduce a new idea or explanation about the shared knowledge needed in the community
Level 4	It refers to the notes that review the issues addressed in the community up to this point. It involves extracting and relating coherently the content that has been worked on or discussed, even, providing possible enhancements
Scientific sophistication assesses the extent to which students move from an intuitive understanding to a scientific understanding	
Level 1	It refers to notes that contain misconceptions or incomprehensible conceptions, mere opinions, or are disconnected from the field of knowledge being addressed in the community. They do not include any valuable content for the community
Level 2	It refers to notes with partially scientific explanations about the topic that is the subject of discourse. These notes could include correct parts, incorrect parts, and therefore they are hybrid
Level 3	It refers to notes that include a correct and consistent explanation based on scientific knowledge in the relevant field in which one is working
Authoritative sources: evaluates the extent to which students support their claims with authoritative sources in the field	
Level 1	It refers to notes that are not supported by anything or are based solely on personal experiences, resembling or being opinions, rather than scientific text (backed up by authoritative sources or evidence). In other words, the content does not contribute or rely on any authoritative source. It may include unknown references, or references that cannot be verified
Level 2	It refers to partially sustained notes with authoritative references or citations, organizational experiences. However, the reference(s) are not sufficient to support all the content
Level 3	It refers to notes whose ideas or explanations are supported with authoritative references or citations, experiences of organizations. (the citations/references can be verified)

scheme and their self-reported epistemic emotions. Next, AMOS was used to test a structural equation model that relates epistemic emotions to the quality of Knowledge Forum contributions. To address the second research question, the data file was transformed into a large format, and non-parametric tests were applied to analyze the improvement of experimental and control groups over time (Kruskall-Wallis) and to compare both groups cross-sectionally (Mann–Whitney-Wilcoxon), while also considering the associated effect size (Vargha-Delaney and *r*, respectively). These comparisons allow us to infer and discuss the role of reflective assessment. The analyses and graphs for addressing this question were conducted using RStudio (Patil, 2021).

### 3 Results

#### 3.1 What is the relationship between university students’ epistemic emotions and achievement in knowledge building discourse?

The correlational analysis show that the relationship between negative epistemic emotion and the quality of contributions is negative ( $r = -0.637, p < 0.001$ ). Conversely, positive epistemic emotions are positively related to the quality of contributions ( $r = 0.674, p < 0.001$ ). Finally, the relationship between negative epistemic emotions and positive epistemic emotions is negative ( $r = -0.748, p < 0.001$ ).

Based on these results, we conducted a structural equation model to test the relationship between positive epistemic emotions, negative epistemic emotions, and achievement in contributing to knowledge construction using Amos software (Byrne, 2010). The results yielded acceptable fit values ( $\chi^2 = 28.064; df = 18; p = .061; RMSEA = .41; SRMR = .014; CFI = .996$ ) (Schermelleh-Engel et al., 2003). In addition, the reliability values were acceptable ( $\omega_{PE} = .93; \omega_{NE} = .92$ ). The results indicate that epistemic emotions, regardless of their valence, show a significant relationship with the quality of contributions in Knowledge Forum (Fig. 2). Positive emotions showed a positive effect ( $\beta = .49; p < .0001$ ) on the quality of contributions, while negative epistemic emotions showed a negative effect ( $\beta = -.26; p > .0001$ ) on the quality of contributions. Both variables correlated negatively ( $\beta = -.80; p > .0001$ ).

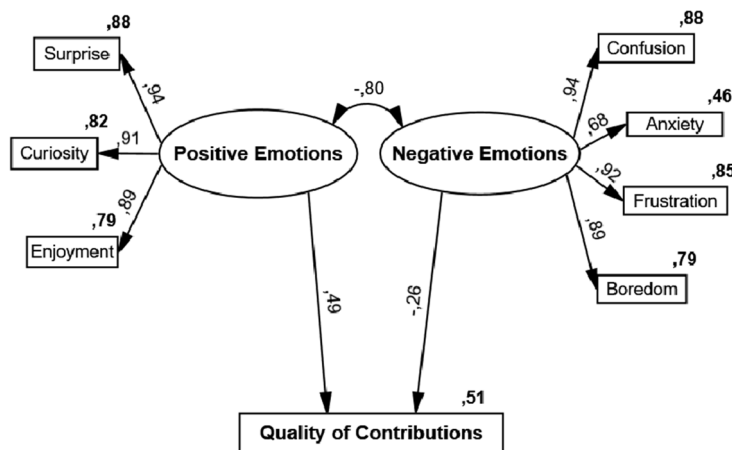


Fig. 2 SEM of epistemic emotions and quality of discourse contributions

**Table 3** Questions to facilitate reflective assessment per section in the portfolio

Sections	Questions per section
Section 1 Foster collaborative and responsible participation	- Do you think the members of your community are collaborating with each other? - Are all members equally responsible? - Is there room for improvement? If so, in which areas?
Section 2 Foster awareness about knowledge in progress	- There are notes with different quality. Why do other notes have lower quality? What do you think is necessary to create notes that contribute effectively to the community? - What changes do you observe in the key concepts over time? How do these changes reflect the evolution of collective understanding? Are there different perspectives, and how could they be resolved? Do we need more evidence? - Which of the identified promising ideas do you consider most valuable to explore further? Why?

**Table 4** Descriptive statistics of the experimental and control groups' scores across time points

Moments	Epistemic emotions	Control group (n = 61)		Experimental group (n = 52)	
		Mean (SD)	Mdn (Range)	Mean (SD)	Mdn (Range)
Moment-1	NEE	3.36 (.86)	3.25 (3.75)	3.50 (.82)	3.50 (4.00)
	PEE	2.51(.84)	2.67 (4.00)	2.35 (.75)	2.33 (2.67)
	QC	2.17 (.40)	2.17 (1.46)	2.22 (.26)	2.24 (1.05)
Moment-2	NEE	3.10 (.88)	2.75 (3.75)	2.36 (.62)	2.25 (2.75)
	PEE	2.67 (.94)	3.00 (4.00)	3.53 (.74)	3.67 (4.00)
	QC	2.28 (.40)	2.35 (2.00)	2.50 (.26)	2.54 (1.17)
Moment-3	NEE	2.51 (.91)	2.50 (4.00)	2.03 (.41)	2.00 (2.50)
	PEE	3.59 (.94)	4.00 (4.00)	4.00 (1.10)	4.33 (4.00)
	QC	2.46 (.34)	2.47 (1.50)	2.56 (.46)	2.67 (1.75)

NEE negative epistemic emotions, PEE positive epistemic emotions, QC quality of contributions

Mdn = Median

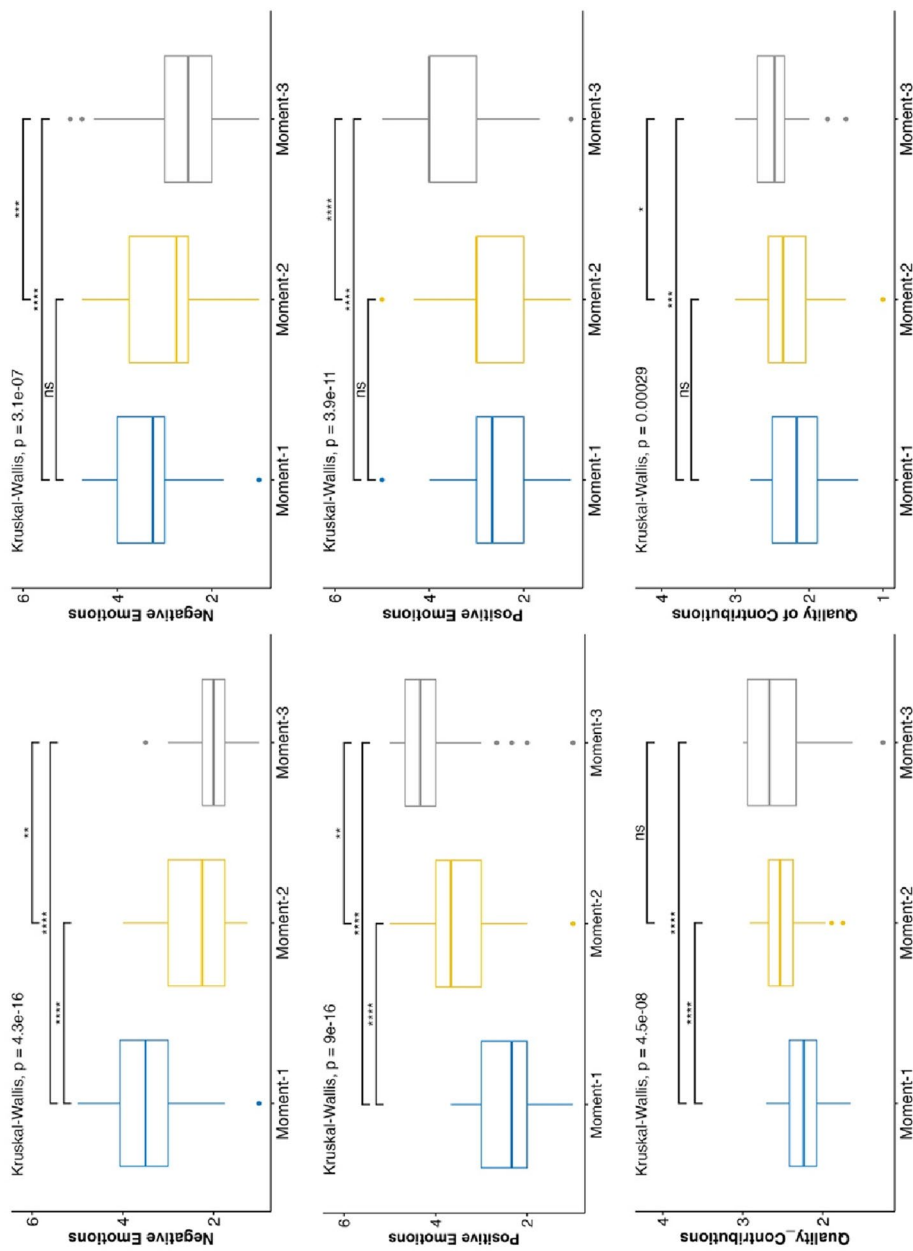
Range = maximum - minimum

### 3.2 Does carrying out reflective assessment help improve university students' epistemic emotions and achievement in knowledge building discourse?

Once the relationships between epistemic emotions and the quality of contributions were analyzed, descriptive and non-parametric comparative analyses were conducted to understand the effects of reflective assessment on epistemic emotions and the quality of contributions.

As shown in Table 3, the descriptive results indicate an improvement in the mean values of quality of contributions and epistemic emotions from time point 1 to 2 and 3 for both the experimental and control groups. Additionally, there is an improvement when comparing time point 3 with time point 2 in both groups. It is worth noting that the experimental group shows higher mean scores in all dependent variables compared to the control group as the course progresses (Table 4).

A Kruskal–Wallis test (Kruskal, 1952) revealed that both the experimental and control groups demonstrated a significant increase in positive emotions and decrease in negative epistemic emotions over time (Fig. 3). Specifically, in the experimental group, the effect size was large for all three variables, namely, quality of contributions ( $\eta^2_{QC} = .207$ ), positive epistemic emotions ( $\eta^2_{PEE} = .439$ ) and negative epistemic emotions ( $\eta^2_{NEE} = .449$ ). On the other hand, in the control group, the effect size was



**Fig. 3** Kruskal–Wallis comparisons between moments/time points \*groups (i.e., experimental and control groups)

moderate for the variable quality of contributions ( $\eta^2_{QC}=.07$ ), and large for the variables, positive epistemic emotions ( $\eta^2_{PEE}=.255$ ) and negative epistemic emotions ( $\eta^2_{NEE}=.155$ ).

Post-hoc Dunn tests using Benjamini–Hochberg FDR method for multiple hypothesis testing at a 5% cut-off were used to compare every pair of moments. The experimental group exhibited significant differences in every pairwise comparison, demonstrating a continuous improvement, whereas the control group only showed significant differences starting from time moment 3 (Fig. 3).

In Table 5, (VDA, Vargha & Delaney, 2000) indicates a large effect size in favor of the Experimental Group (EG) in most of the pairwise comparisons, except for the differences between time point 2 (M2) and time point 3 (M3) in negative epistemic emotions and quality of contributions, both of which show a moderate effect size. In contrast, the Control Group (CG) shows mainly moderate or small effects across time points, with VDA indicating a large effect size only in some of the comparisons between time point 1 (M1) and time point 3 (M3). These results suggest that, although both groups improved over time, the EG exhibited stronger and more consistent improvements, particularly in positive epistemic emotions and quality of contributions. For clarity, values above 0.71 reflect a large effect in favor of the first time point in the comparison (e.g., time point 1 [M1] in M1 vs. M3), whereas values below 0.29 reflect a large effect in favor of the second (e.g., time point 3 [M3] in M1 vs. M3).

Furthermore, a comparative analysis has been conducted between the experimental and control groups with respect to the variables of epistemic emotions and achievement in knowledge construction (Table 6). The results of analysis at time point 1 indicate that the experimental and control groups did not show significant differences in the study variables. The effect size magnitude is small in all comparisons of variables between the two groups at time point 1. This suggests that both selected groups demonstrate equivalence. The comparison between groups at time points 2 and 3 indicates that both groups showed significant differences in all study variables. However, the effect size or differences between the groups decreased at time point 3 compared to time point 2.

**Table 5** Statistics analysis: pairwise comparison between the three time points

Moments	Variables	VDA-EG	Direction & magnitude-EG	VDA-CG	Direction & magnitude-CG
M1 Vs. M2	Negative epistemic emotions	.863	(large, in favor M1)	.601	(small)
M1 Vs. M3		.932	(large, in favor M1)	.770	(large, in favor M1)
M2 Vs. M3		.645	(moderate, in favor M2)	.698	(moderate, in favor M2)
M1 Vs. M2	Positive epistemic emotions	.128	(large, in favor M2)	.42	(small)
M1 Vs. M3		.113	(large, in favor M3)	.176	(large, in favor M3)
M2 Vs. M3		.257	(large, in favor M3)	.213	(large, in favor M3)
M1 Vs. M2	Quality of contributions	.21	(large, in favor M2)	.43	(small)
M1 Vs. M3		.22	(large, in favor M3)	.29	(moderate, in favor M3)
M2 Vs. M3		.38	(moderate, in favor M3)	.36	(moderate, in favor M3)

Vargha–Delaney A (VDA) values above 0.71 indicate a large effect in favor of the first time point of the comparison, while values below 0.29 indicate a large effect in favor of the second. Values between 0.64–0.71 (or 0.29–0.36) indicate moderate effects, and values between 0.56–0.64 (or 0.36–0.44) indicate small effects. Reported magnitudes in the table explicitly state both the size and the direction of the effect

**Table 6** Statistical analysis: intergroup comparisons at each time point

Moment	Variable	Statistic	<i>p</i> -value	Size-effect	Magnitude
Moment 1 (CG Vs EG)	NEE	1422	0.341	0.0899	(small)
	PEE	1726	0.416	0.0768	(small)
	QC	1492	0.592	0.0507	(small)
Moment 2 (CG Vs EG)	NEE	2365	***	0.425	(moderate)
	PEE	706	***	0.486	(moderate)
	QC	1021	0.00115	0.306	(moderate)
Moment 3 (CG Vs EG)	NEE	2234	***	0.355	(moderate)
	PEE	970	***	0.341	(moderate)
	QC	1200	0.0261	0.210	(small)

NEE negative epistemic emotions, PEE positive epistemic emotions, QC quality of contributions

\*\*\*  $p < 0.001$

In summary, results indicate that both the experimental and control groups were equivalent in the beginning, and both groups showed progress in positive epistemic emotions and quality of contributions. The experimental group, who engaged in reflective assessments, achieved significantly higher scores earlier than the control group, although these differences between the groups decreased towards the end of the course.

#### 4 Discussion and conclusions

The "Knowledge Building" pedagogy is an approach recognized for its contributions to the field of Computer-Supported Collaborative Learning (CSCL). Previous studies have shown that epistemic emotions are related to the quality of contributions to improving shared knowledge (Zhu et al., 2019); Zhu & Lin, 2023). Similarly, studies have demonstrated the benefits of engaging in reflective assessments when implementing KB pedagogy in the classroom. In this study, we focused on examining the effects of reflective assessment on epistemic emotions and the quality of contributions in the Knowledge Forum.

Firstly, the relationships between different types of epistemic emotions and the quality of knowledge contributions were tested. The results showed that positive and negative epistemic emotions were negatively related. Quality of contributions had a positive relationship with positive epistemic emotions but a negative relationship with negative epistemic emotions. Additionally, this study suggested that positive epistemic emotions had a stronger effect on the quality of contributions in the online platform than negative epistemic emotions. The findings are consistent with previous studies, which suggest generally, positive emotions are positively correlated with learning, while the correlations between negative epistemic emotions and learning are negative (e.g., Pekrun et al., 2016). This study shows that those who contributed more to knowledge improvement tended to experience greater positive emotions. Similarly, in the Knowledge Building context, Zhu et al., (2019) found that those who generated more low-quality contributions were likely to experience greater negative epistemic emotions. Zhu & Lin, (2023) studied the correlations between different epistemic emotions and discourse moves based on students' oral discussions in classrooms. The coefficients they found were much smaller than those in the current study, which may be because they considered each discrete epistemic emotion separately and collected data in the natural classroom setting.

Secondly, we compared the emotions and the quality of the contributions in the Knowledge Forum over time of the experimental and comparison groups with or without employing reflective assessment. These groups followed different work sequences to comply with the principles of Knowledge Building. Our results indicate that reflective assessment contributes to positive emotions and the quality of discourse in KF, which is consistent with the findings of Yang et al., (2022). Although by the end of the course the groups tend to equate in terms of epistemic emotions and quality of knowledge contributions, this convergence appears to reflect a gradual adaptation to Knowledge Building practices over time. The control group took slightly longer to improve their epistemic emotions and contribution quality, but they also improved significantly. This could suggest that reflective assessment has a catalyzing function, accelerating the learning curve and helping students contribute to progressive discourse and experience positive epistemic emotions earlier than those without reflective sessions (Hmelo-Silver & Barrows, 2008). In other words, reflective assessment is particularly effective when students are new to Knowledge Building and during the early stages of implementing this pedagogy. It accelerates students' adaptation to this new way of working with knowledge by promoting earlier engagement in metacognitive and epistemic reflection. Over time, both groups seem to internalize these collaborative and self-regulatory routines, which naturally reduces the gap between them. In this sense, reflective assessment functions as a temporary but powerful catalyst that facilitates the transition toward autonomous and emotionally sustained knowledge creation. These results coincide with KB studies that claim that reflective assessment is a regulatory mechanism that helps the collective become aware of the process and improve their knowledge of the community (e.g. Zheng et al., 2021). By applying reflective assessment with novice students in Knowledge Building pedagogy and technology, we can actively encourage and facilitate the discussion, development, sharing, and implementation of increasingly effective strategies to enhance collective knowledge.

For education professionals, this article provides important insights for implementing Knowledge Building. These findings suggest that teachers implementing KB should conduct reflective sessions concurrently. These sessions prove to be an essential phase that positively influences the emotions experienced by students when collaborating in KB and helps expand the horizons of individual and collective knowledge. In fact, these results suggest that reflective assessment could help reverse or neutralize negative epistemic emotions. For example, consider the case of a student experiencing confusion and cognitive imbalance (Muis et al., 2018), the student can engage in reflective sessions to gather information about their situation and decide what changes to make to eliminate that confusion (e.g., seeking more authoritative sources of information, asking for help, or engaging in dialogue with an expert, collaborating with other peers). Therefore, instructors should implement reflective assessment sessions to facilitate students in assuming control of their learning, finding better ways to improve their understanding, foster positive emotions, and reduce procrastination (Monroy & González-Geraldo, 2022). In practical terms, instructors can use these reflective sessions to pause ongoing inquiry, jointly review examples of

students' contributions, and guide the group in identifying how discourse quality can be improved. For students, making this relationship visible helps them understand how improving their contributions to community knowledge can also shape their epistemic emotions, supporting more sustained engagement in collective knowledge building.

In conclusion, carrying out planned sessions of reflective assessments positively affects the emotional climate and quality of discourse developed among participants when students are not familiar with the principles of the Knowledge Building. This study has some limitations that make further research necessary. Firstly, although we consider the current study sample acceptable, it would be appropriate to carry out studies comparing different samples from different contexts to obtain more generalizable results. In particular, although this study was conducted with university students, the role of reflective assessment may be even more crucial in earlier educational stages. Research with adolescents shows that epistemic emotions can pose significant challenges during collaborative learning, since self-regulation skills are still developing (Teo et al., 2022). Moreover, adolescents tend to experience more emotional challenges such as confusion and frustration compared to adults, requiring additional scaffolding for emotional regulation (Törmänen et al., 2025). Therefore, future research should explore the scalability of reflective assessment in secondary and vocational education. Secondly, epistemic emotions were collected through a scale in which students were asked to express their feelings about working in the Knowledge Forum to improve community ideas. It would be interesting for students to be able to express their emotions at any time. New developments in the KF platform could incorporate a function integrated into the note for students to express their emotions whenever they want, either when writing or reading notes. This could provide richer information about emotional sequences over time or emotions experienced according to the content of the topic or the quality of contributions. Thirdly, no check on prior academic achievement was performed. Since all students were taking this course for the first time, we assumed comparable initial conditions. Nevertheless, we acknowledge prior academic performance as a relevant issue and have included it in the limitations section. Fourthly, epistemic emotions were measured using self-report instruments to capture students' overall perceptions during their participation in Knowledge Building activities. As with any self-report measure, this approach may be subject to general response biases. Collecting data at three points throughout the course allowed us to go beyond a single-point measurement. Future studies could complement this approach with additional data sources, such as trace-based or qualitative methods, to further strengthen the examination of epistemic emotions in collaborative knowledge-building contexts. Fifthly, in this study, two groups were compared, one of which had carried out reflective assessment sessions planned by the instructor. It would be interesting to study the effects of such evaluations in sessions organized according to students' knowledge needs. In this regard, we also note the need to continue working on the development of artifacts to help students and instructors decide when to carry out reflective assessment sessions. Finally, the sample was predominantly female, which should be considered when interpreting the findings, although the study was not designed to examine gender differences and no gender-related claims are made.

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**Authors' contributions**

Author 1: Conceptualized the article and led the research, actively participating in all tasks, contributed extensively to the technical aspects of reflective assessment, collaborated on the technical creation of visual analytics, performed analytical tasks, including study design, quantitative and qualitative data analysis, and drafting the manuscript, and participated in revising the manuscript. Author 2: Collaborated in conceptualizing the article, with a particular focus on epistemic emotions, contributed extensively to the manuscript writing, and reflected on the study's findings. Author 3: Contributed extensively to the technical aspects of reflective assessment, collaborated on the technical creation of visual analytics, performed analytical tasks, and participated in revising the manuscript. Author 4: Supported the study by Collaborating extensively to qualitative analysis and assisting in the manuscript revision.

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**Data availability**

The data will be available from the authors upon reasonable request.

**Declarations****Ethics approval and consent to participate**

This study was reviewed and approved by the Research Ethics Committee of the University of Granada, Spain. All participants provided informed consent before participating in the study, ensuring compliance with ethical research standards.

**Consent for publication**

All authors have read and approved the final version of this manuscript and consent to its submission for publication in *Journal of New Approaches in Educational Research*.

**Competing interests**

The authors declare that there are no competing interests associated with this manuscript. We confirm that this work is original and has not been published before, and of course, it is not currently being considered for publication elsewhere.

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