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Implementing a Formative Feedback Framework in Kit-Build Concept Mapping: Evidence from Three Classroom Trials

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Abstract: Kit-Build Concept Map (KBCM) has been established as an effective tool for formative assessment, with previous research demonstrating its capability to provide automated assessment, visualize student understanding, and support instructional feedback. However, while formative assessment using KBCM has been achieved, a systematic method for implementing pedagogically grounded feedback based on its analytics has not been well established. This study proposes a formative feedback framework and reports its classroom implementation and evaluation. In this framework, teachers prepare proposition-to-text dictionaries and tiered feedback questions targeting misconceptions identified through missing links in student maps. The feedback is delivered in progressive stages, encouraging students to revisit source text, correct single-proposition errors, and integrate multiple propositions for deeper understanding. The framework was implemented in three classroom trials with undergraduate informatics students (n=16, n=10, n=10). Although the effect of feedback alone varied depending on content complexity, large overall learning gains were observed from the reading phase to the final feedback stage in all trials (effect sizes: 0.895, 0.878, 0.886, $p<0.05$). These results indicate that the implementation of the proposed framework can effectively enhance student understanding by systematically addressing misconceptions through targeted, supportive feedback.

Keywords: Kit-Build Concept Map, Formative Assessment, Formative Feedback, Analytics

1. Introduction

In recent years, the intersection of learning analytics with formative assessment has created promising opportunities to enhance teaching and learning experiences (Stanja et al., 2023).The integration of learning analytics into formative assessment practices enables educators to process larger volumes of data, identify patterns in student understanding, and generate more targeted and personalized feedback than would not be possible through traditional methods alone (Wise, 2019).

Among various pedagogical tools supporting formative assessment, concept mapping is effective in visualizing knowledge structure and assess conceptual understanding (Novak & Cañas, 2008). Building on traditional concept mapping approaches, Kit-Build concept mapping has emerged as a specialized methodology with the potential for supporting meaningful learning and formative assessment (Hirashima, 2024; Pailai et al., 2017; Pinandito et al., 2022). In the Kit-Build approach, students reconstruct a concept map using components (concepts and relationships) that have been deconstructed from an expert or teacher-created reference map. This re-composition process supports students' understanding development while simultaneously creating opportunities for automated assessment.

The Kit-Build concept map (KBCM) system offers several distinct advantages for formative assessment. KBCM provides cognitive benefits associated with traditional concept mapping, including knowledge organization, structural visualization, and the development of relational understanding (Tsai & Huang, 2002). Unlike conventional concept mapping that requires time-consuming manual evaluation, Kit-Build enables automated assessment through proposition-level exact matching between student-created maps and reference maps (Hirashima et al., 2015). The analyzer in the KBCM system provides visualizations of student understanding at both individual and group levels, allowing teachers to identify common misconceptions and knowledge gaps across an entire class (Pailai et al., 2017). These visualizations suggested an efficient assessment and provided a basis for targeted instructional interventions.

Formative feedback is suggested to improve learners thinking and behavior (Shute, 2008), where it should be non-evaluative, supportive, timely, and specific. Elaborative feedback using hints, cues, and prompts, e.g., identification of missing links as what the analyzer of KBCM system provides, is valuable for teacher to provide targeted feedback that addresses misconceptions of learners.

Despite the analytical capabilities of KBCM and the known principles of effective feedback, there remains a significant gap regarding how to systematically translate the results provided by KBCM systems into structured formative feedback practices that enhance student learning. While the KBCM approach generates valuable data about student understanding, the question of how teachers should interpret this information and develop appropriate feedback strategies within a cohesive framework remains largely unexplored. This study addresses this gap by proposing and evaluating a comprehensive framework for formative feedback within the KBCM approach. Through three classroom trials, we investigate how formative feedback based on Kit-Building concept mapping analytics affects student understanding, providing evidence-based recommendations for educational practice.

2. Methodology

2.1 Implementation Process of the Formative Feedback Framework

To implement the proposed formative feedback framework in classroom settings, we followed a structured process involving both teacher preparation and student activities as shown in Figure 1(a). The teacher's role included creating the reference concept map, developing proposition-to-text dictionaries, and preparing both single- and multiple-proposition feedback questions. Students engaged in a three-phase learning sequence: (1) initial reading, (2) kit-building activity using the KBCM system, and (3) receiving personalized formative feedback. This feedback cycle was repeated across three independent classroom trials, allowing us to investigate the framework's practical effectiveness in varying instructional contexts.

KBCM reveals student misconceptions through its proposition level exact matching methodology, which automatically compares student maps against the reference map. The system identifies three types of error links: missing links (propositions missing from student maps), excessive links (incorrect connections made by students), and leaving links (unused linking words) (Pailai et al., 2017). The difference map visually highlights these errors with tagged numbers showing how many students share each misconception as shown in Figure 1(b). Missing links information of the KBCM analyzer become the focus of the study to develop targeted single proposition feedback, allowing instructors to address precise knowledge gaps in student understanding.

In KBCM formative feedback framework, teachers create three essential components prior to the Kit-Building activity. Initially, they develop a dictionary connecting each proposition to a specific part in the learning material. Then, they prepare a dictionary of questions as the feedback to confirm students' understanding for every proposition. Lastly, they construct a dictionary of deeper feedback questions that assess comprehension across multiple propositions; thus, aligning the feedback with learning goals for each material.

Upon completion of the kit-building activity, teachers gain insight into student misunderstandings through missing links identified in the kit-build analyzer.

In this phase, teachers implement feedback in progressive stages. Initially, students were directed to re-read relevant textual material using the proposition-to-text dictionary. Following the review, teachers posed feedback questions that verify understanding of the identified missing links and propositions, effectively addressing misconceptions at the single-proposition level. After resolving all the individual proposition misconceptions, the teachers provided deeper feedback questions to address relationships issues of multiple propositions in the reference map.

2.2 Participant and Learning Material

The experiment consisted of three voluntary seminar classes on Web Programming course topic in Politeknik Negeri Malang. Second and third-year Informatics undergraduate students were participating through open registration with no attendance requirements. The participation varied across the three sessions, which consisted of 16, 10, and 10 students respectively. The topic was chosen because students already had the necessary fundamental knowledge required prior to learning. All the learning materials, reference map, and kit were collaboratively developed and reviewed with other instructors of the same course.

Notably, all three classroom trials were intentionally varied in terms of content complexity and student cohort. Experiment 1 and 2 were focused on the topic of "Foundational Model-View-Controller in PHP", Experiment 3 incorporated a more technically demanding topic of "Laravel Framework API routing with parameters". The variations allowed the study to examine the robustness and adaptability of the feedback framework across different instructional level.

2.3 Development of Single and Multiple Proposition Feedback

Single proposition feedback was designed to ensure students understand fundamental conceptual relationships after completing the material re-reading activities based on missing links identified by the Kit-Build analyzer. The feedback targeted individual propositions through focused questions, e.g., the proposition "Laravel routing: has routing file for : API backend" shall prompt questions similarly to "After re-reading the material, do you think Laravel has routes that support API for backend?". Similarly, for the proposition "Web application: route file located in: route/web.php", an appropriate feedback question would be "What function does the file in route/web.php serve?". These targeted inquiries help students connect concepts without direct evaluation, encouraging knowledge construction through guided reflection on specific technical relationships.

Multiple proposition feedback is given after all individual propositions are resolved. This step is important because students need to comprehend every single proposition before thinking about multiple propositions that require deeper cognitive level. The feedback align with the FP level in formative assessment feedback, where instructors provide guidance to deepen student understanding. Questions at this level strategically combine multiple propositions to help students progress toward comprehensive learning goals. For instance, an instructor might integrate three propositions: "Laravel routing : has routing for : web application," "web application : route file located in : route/web.php," and "Required parameter : must be written in format : {id}" to form a process-oriented feedback question: "What steps should a programmer take when creating a route for a web application that includes required parameters?". This approach encourages students to synthesize discrete concepts into a cohesive understanding of practical implementation.

2.4 Experiment Procedure

The experiment followed a three-phase learning cycle with assessments after each phase as described in Figure 2. First, students read materials for 30 minutes and completed an after reading assessment. Next, they spent 45 minutes of kit building activity, followed by after kit building assessment. The teacher then analyzed their kit structures using kit build analyzer to identify misconceptions and provided 30 minutes of personalized feedback, after receiving the feedback, students completed after feedback assessment. The three assessment scores (after reading, after kit building, and after feedback) were obtained to track how students' understanding changed throughout the process.

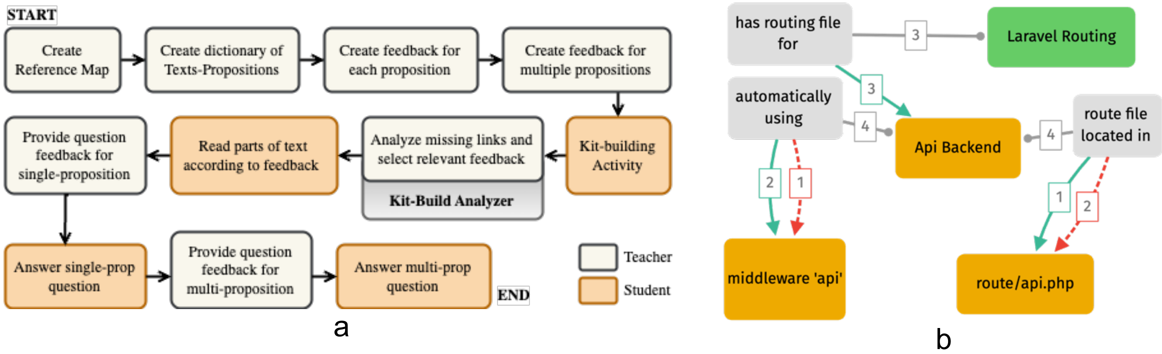

Figure 1. Formative Feedback Framework (a) and Kit-Build Analyzer Result (b)

Figure 2. Experiment Procedure

3. Result & Discussion

From each experiment, three scores from each phase: the reading score, kit building score, and feedback score were gathered. Each score represents student performance after completing its respective phase. The descriptive statistics of the scores are shown in Table *1*.

Table 1*. Scores Descriptive Statistics*

Experiment	Participant	Phase	Mean	Median	Min	Max	SD
Experiment 1	16	Reading	68.18	70.0	50	80	9.81
		Kit Building	90.00	100.0	70	100	11.83
		Feedback	90.90	100.0	80	100	10.44
Experiment 2	10	Reading	79.50	80.0	65	95	10.91
		Kit Building	85.00	87.5	65	100	12.90
		Feedback	90.00	90.0	75	100	9.12
Experiment 3	10	Reading	65.50	62.5	40	90	17.55
		Kit Building	76.00	77.5	45	95	15.59
		Feedback	87.00	87.5	70	100	9.77

Since data were not normally distributed, Wilcoxon test was used to compare scores between phases (reading vs. kit building, kit building vs. feedback, and reading vs. feedback). Both statistical significance (*p-values*) and effect sizes (*r*) were calculated to assess differences between phases, with results shown in Table *2*.

Table 2 presents comparisons between consecutive phases and overall improvement of students understanding. The comparison between Reading and Kit-Building compares students' performance following the initial reading and the kit-building activities. The comparison between Kit Building and Feedback suggested how students understanding changed after they received the feedback. The comparison between Reading and Feedback captures the total learning gain following the complete learning sequence.

The significant improvements from Reading to Kit-Building suggest that re-construction activities in Kit Building enhanced conceptual understanding beyond what Reading activity provided. Particularly in Experiment 1, an average 21.82-point improvement is suggested after the students carried the Kit-Building activity.

The Kit Building-Feedback comparison suggested varying patterns across experiments. In the Experiment 1, the minimal effect size (0.070) and non-significant *p-value* (1.000) suggested that kit-building alone might have sufficient to grasp the concepts. However, significant improvement (effect size 0.901, $p<0.01$) was suggested in Experiment 3. The result is indicating that feedback was crucial in a situation where more technical and practical materials were involved.

Table 2.*Effect Sizes and p-values Across Learning Phases*

Experiment	Reading-Kit Building		Kit Building-Feedback		Reading-Feedback	
	r	*p-value*	*r*	*p-value*	*r*	*p-value*
Experiment 1	**0.819**	0.0133*	0.0704	1	**0.895**	0.00345**
Experiment 2	**0.571**	0.0731	**0.555**	0.137	**0.878**	0.00843**
Experiment 3	**0.778**	0.0169*	**0.901**	0.00517*	**0.889**	0.00579**

Note: *p<0.05; **p<0.01. Bold: large effect sizes (>0.5).

The consistently large effect sizes observed between Reading and Feedback phases (0.878-0.895) demonstrated that the three-phase KBCM framework supports knowledge construction through multiple phases. Students are likely benefited from both re-construction activity in kit-building and reflect their metacognitive approach from the feedback; creating stronger mental models than something that could be attained from any single approach.

These variations across the trials offer preliminary insights into how the framework may function under different instructional conditions. In simpler learning settings (experiments 1 and 2), the feedback phase yielded modest incremental gains following the kit-building activity. In contrast, experiment 3, which involved more complex and integrative content, showed more pronounced improvements, suggesting that the framework may be particularly useful in contexts requiring deeper conceptual engagement. These findings provide initial evidence of the framework's adaptability and its potential applicability across varying educational scenarios.

4. Conclusion

According to the results and discussion, it can be concluded that the implementation of formative feedback framework for the Kit-Build Concept Map offers promising potential to enhance student understanding by systematically addressing misconceptions. While the scope of implementation was limited to merely three classroom trials, the findings provide initial yet meaningful evidence of the adaptability and educational value of the framework. Future studies could potentially develop and refine the framework and examine its broader applicability in diverse instructional contexts.

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