Similar Learning Performance with Different Regulation Process in Collaborative Problem Solving Learning Activities

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Introduction

- To face complicated problems in the digital era, collaboratively solving problems (CPS) is one important part of the workspace. Meanwhile, CPS promotes the development of learners' metacognition, collaboration, and cognitive skills (Fiore et al., 2018).
- However, the mere presence of technology does not necessarily lead to successful collaboration because the effectiveness of CSCL is a complex set of interactions with other variables (Jeong et al., 2019).
- To investigate how individuals interdependently regulate activities in collaborative learning to achieve shared learning goals, a concept named Socially Shared Regulation (SSR) has emerged (Sharma et al., 2024).

Research questions

Existing research conducted in formal face-to-face learning contexts has focused on the emergence of SSR progressed over time (Vuorenmaa et al., 2023) . Results show that group-level regulation emerges more frequently in joint interactions.

However, no information about the relationship between group performances and multifaceted aspects of SSR in the collaborative progress, and none of them has been conducted in authentic face-to-face engineering CPS practice courses.

- What SSR group profiles can be detected based on groups' adoption ratio of deep-level SSR behaviours and task completion scores during authentic engineering classroom activities?
- How are the SSR group profiles related to groups' SSR processes during CPS assisted by CSCL scripts?

Methods

Research procedure

- Participants: 36 undergraduates from a public Chinese university participated, forming 18 dyads groups.
- Tasks: supported by CSCL scripts, students worked together to take turns being the IP sender and receiver using Internet Control Message Protocol (ICMP) package. Group members were required to use their own computers to take turns being the IP sender and receiver.
- Challenges in the tasks: To complete the tasks, students faced several challenges in both computer operation and group management. These challenges included visualization software configuration issues, operating system differences, network environment constraints, and uncertainty in experimental data. Resource sharing and the balance of individual learning and group work also impacted the task completion.

Methods

The CSCL script was produced based on the general self-regulation learning model, discussion patterns code schemes in collaborative engineering courses (Lyu et al., 2023), and the instructor's 20 years of teaching experience.

Planning phase	**1.** Tasks explaining and analysing: Clarify the definition and requirements of the tasks.
	2. Function analysing: To solve the given task, what functions need to be identified?
	3. Design considering: To form solutions, what components need to be considered?
	4. Prior examples: Any experience in watching others' operations to solve similar tasks?
	5. Prior operating experience: Any self-experienced operations to solve similar tasks?
	6. Given resources: Resources available and accessible for the task.
Performance and reflection phase	1. Solution generation: Operation plans.
	2. Operation progress: Whether all operation actions have been completed?
	3. Operation results: Whether the task has been completed following the operation plan?
	4. Phenomenon occurred: What signals or warnings appeared when solving the subtasks successfully or not?
	5. Discussion and reflection: What reasons led to or promoted the operation plan successfully or not?

Methods

Data analysis

SSR code scheme: The coding instrument from (De Backer et al., 2016) was employed as the initial version of the code schemes. During transcription, additional SSR phases were identified. The final SSR code scheme included Orientation, Planning, Support strategies, Monitoring, as well as Evaluation and reflection dimensions of SSR, which consisted of related strategies and further activities.

Code	Levels	Activities	Descriptions
Planning in advance	Low	Formulating problem solving plan (planning in advance)	A general starting solution for the group task only appears at the beginning.
	Deep	Selecting problem solving plan (planning in advance)	Few general alternative starting solutions for the group task only appear at the beginning.
Interim Planning	***Low***	***Formulating problem solving plan repeated (interim planning)***	The previous operation is performed again without changing the operating variables. The purpose is to check whether there are accidental phenomena in the previous operation.
	Deep	***Formulating problem solving plan new (interim planning)***	To test whether the desired operation result will be obtained after changing an operation variable.
	Deep	***Peers' formulating problem solving plan new (interim planning)***	New operation solution produced by peers from other groups after asking for help.
	Deep	***Teacher's formulating problem solving plan new***	New operation solution produced by teacher after asking for help.
	Deep	Selecting problem solving plan	Few alternative operation solutions produced during the task.
	Deep	***Questioning the problem solving plan***	Express confusion to group members' operation solutions.

Methods

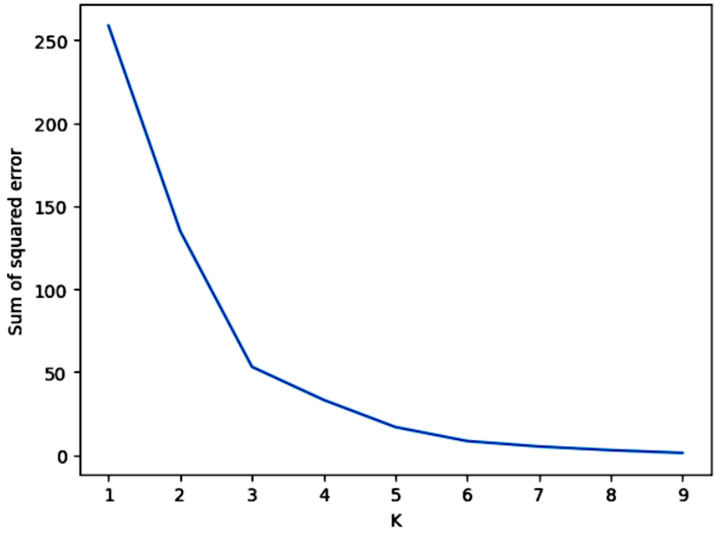
- **Task completion evaluation:** As a performance result of groups, task completion was measured in several aspects, including whether learners use their own computers (some students' computers had problems, and they borrowed computers from other groups) (one point for one group member's computer), software installation readiness (one point for each computer), the completion of subtasks (one point for one subtask, five subtasks in total), and the different detailed helps asked from other groups.

- **K-means clustering**: After data pre-processing and analysis, k-means cluster analysis was performed to cluster the group SSR behaviours. K-means is an unsupervised machine-learning algorithm that assigns data points to clusters centers (centroids) based on similarity, which has been widely adopted (De Backer et al., 2022)

- SSR sequential visualization: For comparing the temporal flow of SSR behaviours across different clusters, Disco (https:// www.fuxicon.com/disco/) was used, a process mining software with the fuzzy algorithm, which is a common algorithm to explore the regulation process (Zabolotna et al., 2023; Vuorenmaa et al., 2023).

Results

Each dyad's recording data consisted of at least 50 minutes of discussion. The speech recordings data comprised 5,761 SSR behaviours. These categories included 317 (5.5%) behaviours for Orientation, 755 (13.1%) for Planning, 271(4.7%) for Support strategies, 3899 (67.7%) for Monitoring, and 519 (9%) for Evaluation and reflection.



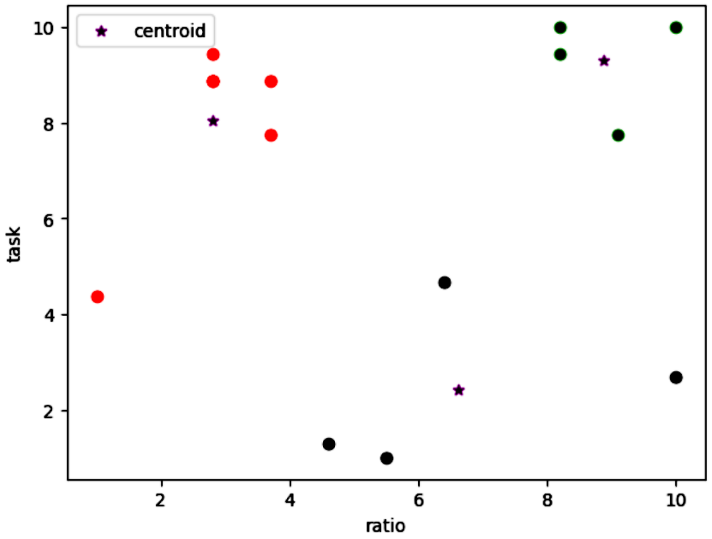
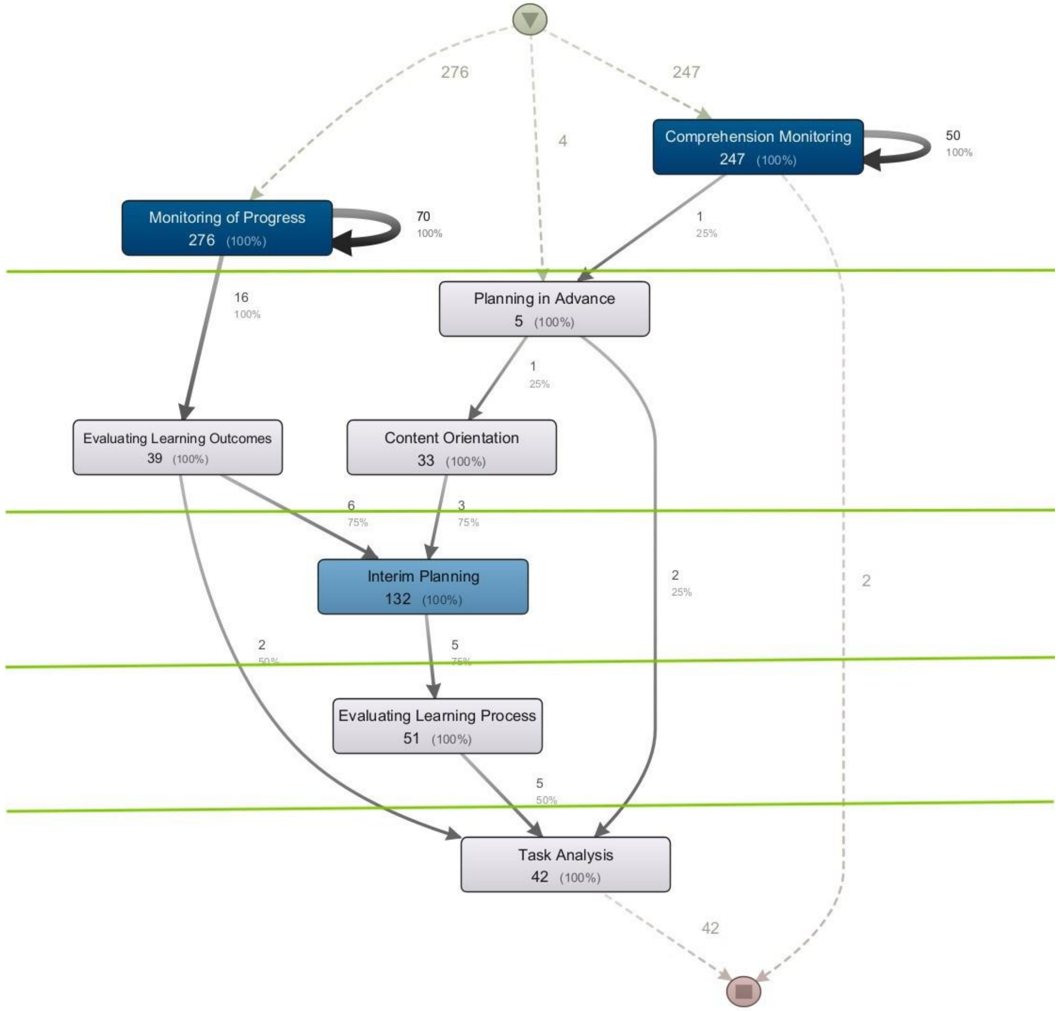


Figure 1. K-means clustering results (left: optimal clusters of “k” with the elbow method; right: visualization of the k-means clustering results (k=3)).

Results

The SSR process for "HdeepHtask" cluster is illustrated in Figure 2.
Groups in this cluster began with "Monitoring of Progress" and "Comprehension Monitory". Then, students in this cluster tended to deeply analyze the task, including "Planning in Advance" -> "Content Orientation", "Evaluating Learning Outcomes" -> "Task Analysis" or "Planning in Advance" -> "Task Analysis".
After this, there was a main path, "Interim Planning" -> "Evaluating Learning Process" -> "Task Analysis". No Support strategies were found in this SSR profile.
Based on the features of the regulation process, this cluster can be labelled as "Intragroup-elaborating-oriented regulation process group".



Results

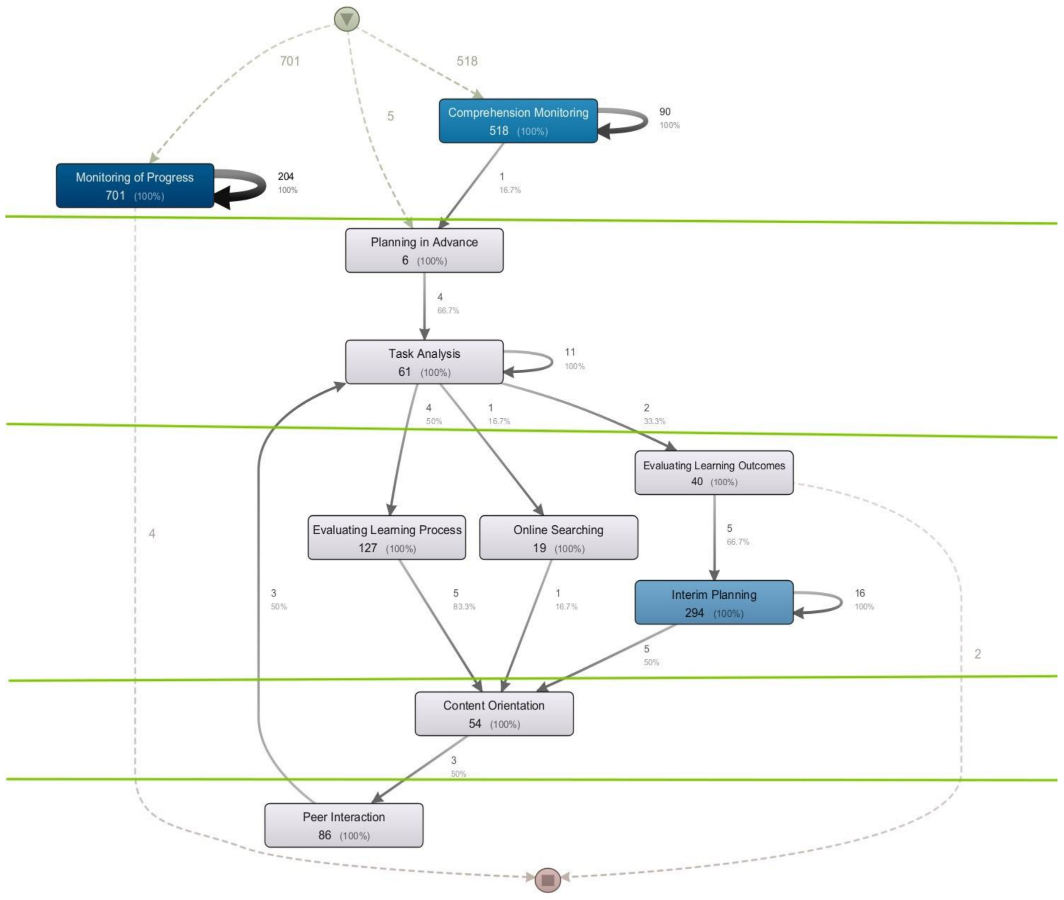
The SSR process for “LdeepHtask” cluster is illustrated in Figure 3.

Like the “HdeepHtask” cluster, this cluster started with “Monitoring of Progress” and “Comprehension Monitory”.

Unlike the “HdeepHtask” cluster, this cluster followed “Planning in Advance” -> “Task Analysis” and then demonstrated different paths, namely, “Evaluating Learning outcomes”, “Online Searching”, or “Evaluating Learning Outcomes” -> “Interim Planning”.

After this, these three paths converged on the path “Content Orientation” -> “Peer Interaction”. As a path loop, “Peer Interaction” stepped into “Task Analysis”, which appeared before. “Peer Interaction” and “Online Searching” as Support strategies were both found.

Considering common behaviours were categorised across all five dimensions, this cluster can be labelled as “All-round-oriented regulation process group”.



Discussions and conclusions

- **Different starting behaviours**: Different from the sequential patterns in (Zabolotna et al., 2023), where planning->task understanding was the beginning, our group regulation behaviours mostly started from Monitoring phase (Monitoring of Progress or Comprehension Monitoring).

- The difference might lie in the task types

The CPS in (Zabolotna et al., 2023) involved creating posts about a physics topic, which need more discussion (38% behaviours in share/compare and 26% behaviours in negotiate/co-construct, as shown in their descriptive statistics for knowledge construction phases). Our tasks required students to identify the real situation in their own computer settings according to task requirements and then operate the ICMP packet sending and receiving step by step. Therefore, as a testing function, monitoring phase at the beginning helped students compare and match the task requirements and their computers’ real settings and then forming operation plans.

Discussions and conclusions

- Prompting and scaffoldings from instructors is necessary, especially in face-to-face CPS operating courses.

- CPS stimulates the inquiry process and covers related domain knowledge and operation procedure through the careful selection of authentic problems (Van Den Beemt et al., 2020). CSCL scripts potentially scaffold SSR behaviour in CPS by setting milestones to help with their current working plan, externalising scaffolding to reflect on the execution process, and evaluating group artefacts through shared efforts.

- multiple support strategies should be encouraged to help groups critically reflect on their execution process and propose iterated solutions. More importantly, guiding groups to realize the multiple functions of SSR would help them adjust execution rhythm within limited time (Iiskala et al., 2015).

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