Applying Liljedahl's Thinking Classrooms in a Higher Education Digital Technology Course

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Abstract. This paper explores student learning experiences in the ICT course Digital Technology using one specific pedagogical approach, Peter Liljedahl's "Thinking classrom". We assigned 25 students to random groups to solve a network problem on whiteboards and conducted in-depth interviews with 10 participants. Thematic analysis revealed improved communication and academic focus, though knowledgeable students still took more active roles. While most students felt engaged, some noted drawbacks such as increased energy demands, awkwardness, and reduced autonomy, and expressed concerns about using this method for summative assessments.

Keywords: Thinking Classrooms · Active Learning · Group Dynamics · Focused Thinking · Higher ICT Education · Didactics

1 Introduction

In ICT education, lecturers often struggle with students' diverse backgrounds, varying knowledge levels, and motivations. Traditional strategies like lectures, labs, and strategically composed group work aim to engage students but can reinforce preconceived roles, with more knowledgeable students dominating. This issue is particularly pronounced in ICT due to the broad range of prior experience.

Ability grouping, where students are assigned to groups based on skill level, is intended to balance knowledge but can perpetuate existing hierarchies and limit participation [2]. Liljedahl's "Thinking Classroom" uses random groups and non-permanent vertical surfaces like whiteboards to disrupt these dynamics and promote equitable participation.

Although well-studied in K-12 math, Liljedahl's approach is less explored in higher education ICT settings. This study implements the "Thinking Classroom" model in a "Digital Technology" course to understand student experiences. Twenty-five students worked in random groups to solve a network problem on whiteboards, followed by interviews with 10 participants.

This paper addresses two main research questions. First, does Liljedahl's "Thinking Classroom" approach support student focus and knowledge acquisition in an ICT course in higher education? Second, what are the underlying mechanisms that support the learning process?

2 Related literature

Our paper is related to multiple literatures. The first explores how classroom structure affects student engagement, highlighting activities that do not directly lead to learning. The second examines equitable teaching practices, such as detracking and complex instruction, to promote respect, responsibility, and high achievement.The third focuses on strategies like role assignments and structured group processes to support equitable participation.

The first literature focus on how a student's thinking and learning are influenced by how the lecturer structures classroom time. In a typical math lecture, the teacher is the focal point, explaining theory and rules, providing examples, and assigning tasks while students passively listen. Liljedahl [20] is using the concept of "Studenting" to describe students' behaviors during class. He finds that only a few students actively engage, while most are distracted, zoning out, or pretending to understand.

Liljedahl's "Thinking Classrooms" [20, 18, 19] fosters active thinking and learning by having students work in randomly assigned groups of three at whiteboards. The visible randomness of group formation helps reduce social barriers and encourages collaboration. Each group gets one marker to promote shared responsibility, and the use of erasable boards reduces fear of mistakes. This approach increases knowledge sharing among students, decreases reliance on the teacher, and boosts engagement, enthusiasm, and collaborative problem-solving.

While Thinking Classrooms has been primarily studied in K-12, this paper applies it to higher education, where group dynamics pose unique challenges. Working with unfamiliar peers can lead to poor performance, negative learning, and emotional experiences [17, 5]. Miscommunications may arise due to differing language use. Literature suggests that preparing students with meta-cognitive and reflective skills can improve collaboration [5, 16]. This involves making students aware of potential conflicts, their own and others' behaviors, and understanding gaps [16, 7]. A sense of belonging is crucial, as alienated students are less effective in groups. Belland et al. [6] recommend focusing on cooperation over competition and fostering social responsibility.

The second literature focuses on complex instruction by Cohen and Lotan [11, 10], which promotes equitable participation by addressing social and academic status differences through groupworthy tasks, recognizing diverse abilities, and assigning roles for active participation. Such tasks fosters collaboration, reduces achievement gaps, and enhances math engagement. Similarly, Boaler [2] and Boaler and Staples [3] demonstrate that teaching mixed-ability students using heterogeneous grouping and complex instruction fosters respect, responsibility, and high achievement, leading to improved academic performance and inclusivity.

The third literature emphasizes structured group processes to promote equitable participation. Cheng et al. [9] found that group heterogeneity had little effect on self- and collective efficacy, but effective group dynamics, positive interdependence, accountability, and equal participation were essential for successful collaboration. Similarly, Esmonde [14] showed that group quizzes often

led to inequitable participation, while presentations encouraged more balanced engagement. Chang and Brickman [8] noted that strategies like role assignments and peer evaluations promoted participation but did not fully address social loafing and uneven contributions, with higher-scoring students benefiting more from group work. This highlights the need for carefully structured activities to foster truly equitable learning environments.

We contribute to these three literatures by using visibly random groups in a multidimensional classroom with an open-ended problem, without assigning roles, competences, or responsibilities. The key difference is the use of random group composition and not assigning roles, following Liljedahl [19] to disrupt established roles and promote more equal participation in group work.

3 Method

3.1 How vertical whiteboards was implemented in class

Vertical whiteboards (VW) are erasable boards that require students to stand while using them. The course Digital Technology has 47 students who are in the fourth semester of their bachelor's degree. The course is one of four elective courses available to non-technology students. For example, some of the student have a background in HR, digital marketing or economics. There are slightly more men than women, with ages ranging from 20 to 30 year.

The students have worked in randomly assigned groups of three on VW three times. First, for decimal-binary conversion in this course. Second, for web design in a different course, Creative Web Project. The third time was in this course in a session on network infrastructure, which was the main focus of the interviews. The respondents were influenced by all sessions, but were told to focus on the third session.

The lecture consists of two 45-minute lecture sessions followed by two 45-minute lab sessions. The group assignment occurred in the last 25 minutes of the lecture session, including a five-minute summary. The lecture covered the data link layer of the OSI model, including switches. About 25 students attended. The group assignment was announced after the first 45-minutes. Two students left during the break and did not return. The teacher formed visibly random groups of three, with one group of two, in total eight groups. They worked on 60x80 cm whiteboard films taped to the walls with a marker and erasing paper.

The assignment, presented on a slide, described network data components, suggested symbols for drawing, and included a structured bullet list. The assignment was given in Norwegian to the students and translated into English for this paper, seen in the figure 1. The students worked on the task for 20 minutes before the teacher summarized key points using examples from two groups. During the session, the teacher observed, asked questions, and encouraged them to look at other groups' work. The teacher also used a red marker to highlight useful and important parts of their answers.

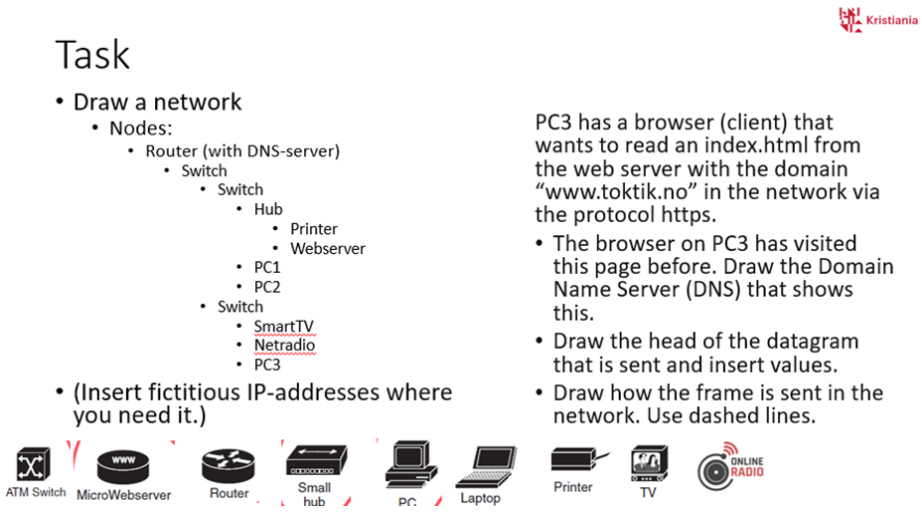

Fig. 1. The presented task

3.2 Data collection and Thematic analysis

We conducted in-depth interviews with 8 students and sent questions to 2 students who couldn't attend in person. Using a semi-structured guide with 14 questions (12 open-ended and 2 ranking), we presented the same questions to all 10 students. The questions explored topics including the students experiences with randomly assigned groups, their level and style of participation, group dynamics, comparisons between individual work, traditional group work, and working in Liljedahl's setup, as well as communication flows between groups. Interviews lasted 35-50 minutes, conducted by two of the three researchers: one asked questions while the other took detailed notes and asked clarifying or follow-up questions. The teacher did not participate in data collection.

We used thematic analysis as outlined by Braun and Clark [4]. This six-step process starts with familiarizing ourselves with the data and making notes, followed by iterative creation and refinement of codes. Once refined, the codes are grouped into themes. Finally, we write the report presenting and analyzing the findings. Two of the three researchers conducted the thematic analysis, often working together but with separate documents. They read and reread the respondents' answers, taking notes, and discussing reflections in meetings. The third researcher joined discussions at the end of each main step. Once the codes and themes were established, all three collaborated to write the findings and discussion chapters.

4 Findings

This section presents students' perceptions of group work, following the structure of Liljedahl's Thinking Classrooms [18]. Subsections 4.1 to 4.6 explain the conceptual foundations of the approach, while subsections 4.7 to 4.10 outline practical aspects of implementing Thinking Classrooms in higher education.

4.1 How students perceive they learn

In vertical whiteboards (VW) sessions, students can listen, speak, and draw. Listening to peers explain concepts or engage in dialogue offers a learning experience, though some suggest discussing actively yield better results. Initially, listening might be necessary due to unfamiliarity but prepares students for participation. One student noted, *"I base a lot of my learning on other people. Knowing who to ask is important."* Asking questions and explaining confirms knowledge or reveals gaps, requiring active thinking.

Drawing on whiteboards aids learning and retention. Students find it activates them and increases focus, offering benefits not usually experienced in regular lectures. Drawing aids understanding technical topics, gaining overviews, and improving recall while fostering creativity in problem-solving.

Students noted advantages and disadvantages when comparing regular group work with VW. Opinions on the learning effectiveness of individual work, regular groups, and VW were split, with only one student preferring individual work. None found VW least effective, while some ranked regular groups or individual work as least effective. Regular groups can be bothersome due to varied questions, whereas VW focus everyone on the same task. Fixed groups can develop bad habits, focusing more on task completion or socializing rather than collaboration.

Most students focus more during VW sessions due to social pressure and limited time, though unfamiliar peers can lead to less serious engagement. Increased focus improves learning, but successful sessions require effective group work and prior knowledge.

Students appreciate the diversity of personalities, working styles, and knowledge in VW sessions, fostering creative idea sharing and new perspectives. This diversity introduces different approaches to solving tasks and encourages breaking old routines. One student remarked, *"...instead of being with the same groups as usual, you get new inputs from students who may take the course very seriously."*

4.2 Different roles, power dynamics and participation

Students report varied experiences with different group sizes. Groups of three or more can lead to freeriding and breaks, while groups of two may result in mutual dependence but lack diverse input. Groups of three can facilitate easier agreement and more effective collaboration. When students know each other, more small talk occurs.

In interviews, several roles emerged: (i) The instigator, who takes the initiative to talk or draw, often stepping up when others are reserved or introverted. Leadership styles varied, with some leading by drawing, talking, or both, and others waiting to understand group dynamics before contributing. (ii) The draftsman, the primary drawer, sometimes emerged spontaneously. Often, the draftsman was not the topic expert but contributed through drawing. Some groups designated a draftsman, while others avoided it due to bad handwriting.

One student identified three specific roles: (i) the drawer, (ii) the questioner, and (iii) the controller. Some students chose not to participate actively. There is a clear link between knowledge and participation; knowledgeable students often lead and speak the most, enhancing group dynamics. Equal knowledge levels lead to equal participation, fostering balanced contributions. The drawer usually has ideas and answers, while less knowledgeable members provide input or suggestions.

The respondents express how they compare each other to others regarding knowledge level, and through seeing how others are faring, they see experience this as a way of understanding how well they are faring themselves. Students let those with more knowledge speak first. Speaking increases with understanding; both answering and initially waiting to answer are seen as valuable contributions. The knowledgeable student typically takes the lead, while less knowledgeable ones tend to pull back.

Social aspects also influence participation. One student provided stability by being comfortable with others, while another spoke only when appropriate. Some students felt they couldn't express themselves freely. Taking control was sometimes seen as necessary to ensure progress and efficiency, noting that vertical boards offer less control over the end result.

4.3 Communication dynamics in groups

We asked our respondents how much they spoke compared to the others in the group. Six out of ten stated they got to speak equally as the others, while three reported to have spoken the most, and the last reported having felt they spoke least. Students reported differently regarding different group sizes. In a group of two, communication can be limited and become tense. Groups of three allow for easier communication and agreement, while groups of four can become disruptive and messy. Larger groups lead to more communication but can also result in chaos, and in groups of six or more, it can be hard to leave an individual mark. Groups of three allow more even contribution time, while groups of two may focus on quickly finishing with minimal input. Groups of three or more tend to generate more creative ideas.

In fixed groups with predefined roles, collaboration starts more efficiently. In newly formed, random groups, students need time to get to know each other and assume roles, making the group feel more spontaneous yet busy. Someone usually needs to take control to start solving tasks. Students mentioned that when unsure how to proceed, conversations would stop, and they would keep

looking at the board, feeling "on hold." Self-chosen groups made it easier for some to speak.

The teacher should avoid regulating group discussions, as discussing with a teacher has a higher threshold than with peers. Students trust a teacher's input more than a peer's, and if no one knows the answer, seeking help from the teacher is suggested. The board is used for explaining through drawing, pointing, and verbal explanations. Some students prefer seeing group members' faces while communicating. Getting accustomed to the task took time, but observing other groups helped them proceed.

4.4 Communication and learning between groups

One student suggests that teachers facilitate intergroup communication by having groups visit and provide feedback to others, as standing lowers the barrier for interaction. One group helped identify errors in another's solution, while some found mistakes in their own work through comparison. Students valued seeing varied approaches and different thinking styles in other groups' drawings. Some wished for more time to revise their work after these interactions. Some students preferred learning within their own group or from a peer, while others found it helpful to see how other groups solved the task, comparing drawings and understanding different thought processes. When stuck, they looked to other groups for ideas and received constructive feedback. Seeing and explaining solutions to others helped reinforce their learning and improved retention. One student is open to dialogue with other groups and values quality assurance from their answers. Some groups trust other students' work, but others are skeptical and prefer not to rely entirely on peer solutions. They want the teacher to provide an expert conclusion to ensure answer quality. Students felt slightly awkward but positively challenged sharing their work. Learning from other groups and joint reviews enhanced the class environment.

4.5 The social aspects of vertical whiteboards

Meeting new peers can be challenging, but VW facilitate social connections and engagement. Despite initial discomfort, students generally find working with different individuals rewarding, and a good alternative learning method when it comes to technical topics where a regular lecture may be hard to maintain focus. Standing at the boards promotes face-to-face interaction better than sitting side-by-side. Activities within and between groups enhance the class environment, attributed to clear expectations and structure from the teacher.

Comfort levels with VW vary, from shyness to ease of interaction, typically improving as students get to know each other. Some students noted their peers' initial discomfort but observed improvement over time. Different perceptions of familiarity exist. Some students feel being in the same class suffices, while others need more interaction for comfort. Working with familiar people feels safer, but VW encourage stepping out of comfort zones and can lead to socially preferred interactions with random peers.

Initially, students may hesitate to speak out of fear of appearing wrong; adaptation and the demonstration of abilities are crucial. Confidence affects willingness to speak up and take risks. Opinions on group size vary: groups of three encourage inclusive collaboration, though some worry about exclusion if others know each other. Groups of two ensure inclusion but can be risky if the pair doesn't get along. Disagreement and disinterest can negatively impact group dynamics.

4.6 The students' general opinions and preferences

With three students, communication can be slow. Groups of four or five generate more communication. For exams, two students may suffice, but for creative tasks, three to six are ideal, with three being a minimum. Two generate too few contributions, while four can make the board messy with too many contributions. Students prefer to form their own groups but acknowledge the benefits of randomly assigned groups, which they find more challenging and potentially beneficial. Working with different individuals feels socially satisfying and positively challenging, often putting students outside their comfort zones. One student liked the task, another appreciated the visual aspect and method, and yet another saw few disadvantages given the students' shared study program.

All interviewed students preferred standing over sitting for cooperative tasks. One initially thought sitting was better but changed preference after the experience. One believed sitting was best for structured academic work, while another had no strong preference. Preferences for group work vary significantly. Some students prefer working alone, solving tasks independently, and being individually assessed. Others are okay with occasional group work and some favor it generally. Some prefer randomly composed groups, especially on VW. Many believe in preparing individually before group work to ensure readiness. The value of variety is highlighted, with some noting that randomly composed groups are fairer and quicker. Additionally, some enjoy drawing on whiteboards, both alone and in groups.

4.7 Students' views on which tasks work best on VW

Students' opinions on the task vary. Some found it easy, others demanding. Many better understood the topic through the task, appreciating the variety and stating the *"assignment worked well."* One student desires more sessions with additional tasks. However, logistical challenges like insufficient time, inefficient use of time, limited teacher-student interaction, and the need for plenary guidance were cited as reasons the task was inappropriate.

When asked for examples of tasks less suitable for random groups using vertical boards, students mentioned: (i) assignments requiring long written answers; (ii) very open-ended questions; (iii) factual questions or arithmetic of binary numbers; (iv) tasks combining elements from several lectures; and (v) very advanced topics.

In response to the previous question, students also identified tasks where vertical boards would be beneficial, including: (i) drawing and visualizations; (ii) calculations; (iii) practical working methods; and (iv) complex tasks involving reflections or multiple topics. One student saw no task type unsuitable for vertical boards.

Students emphasize that their preferred work mode (e.g., individual or group, standing or sitting) depends on the task. Time-use is critical, with preferences influenced by task duration and required focus. Several students noted the session was too brief, standing activities should be time-limited, the method was time-consuming, and in-depth tasks take significant time. They also mentioned insufficient teacher interaction time, leading them to seek help from other groups.

4.8 Standing vs. sitting in group work

We asked students if they preferred to stand or sit during group projects, followed by why standing or, if sitting, why not standing. Most students preferred to stand during collaborative projects. They noted several advantages: standing makes the solution process more creative with more ideas and new perspectives. It improves focus and motivation, and some found transparency inspiring. There is a higher level of engagement and activity, summarized by one student as "room for action, movement, and freedom." Standing also gives more freedom of movement.

Students also highlight logistical benefits of standing. They can see each other's faces and get an overview of the solution. It allows switching between looking at the board and each other. Additionally, communication and dialog within and across groups are easier when standing. As a bonus, students mention that standing improves circulation and body movement, offering variation from regular lectures. It feels less formal and, for some, provides more autonomy over personal space compared to sitting closely together. There are some obvious drawbacks to sitting in a group. First, the task centers around the person writing. Second, students can become restless and lose focus. Finally, sitting is perceived as more formal and too intimate.

4.9 Working alone or in a group?

Students generally agree that learning and retention are better in regular or VW groups compared to working alone, but they also acknowledge drawbacks and situations where working alone is preferable. Some respondents prefer working alone for the control and freedom it provides. One student mentioned they learn best by reading alone, as VW don't allow simultaneous thinking and writing. Working alone reduces distractions, eliminates concerns about freeriders, and eases the fear of making mistakes. As one student noted, *"[Alone] I get to write while I think. It's easier to write, make mistakes, and focus on my thoughts."* Working with unfamiliar peers can result in a "bad" group dynamic, with less skilled or motivated members, or a poor fit. Some students also feel responsible for supporting others, making VW groups more energy draining. While many

believe learning is best in these groups, they prefer not to use them for mandatory assignments or exam prep - for this kind of work they trust their teacher more than their peers. Conversely, some students find group work energizing and motivating, while working alone on their PC can lead to poor focus and unproductive habits.

4.10 Optimal learning activities after completing the task

We asked students which learning activities they preferred to enhance the "VW-task" outcome. They suggested various activities, differing in focus. Some students preferred a teacher-led summary, such as a class half-circle where the teacher explains "the solution," ensuring quality-assurance. Others suggested activities like students explaining solutions across groups with the teacher present or interactive sessions facilitated by the teacher. At the other extreme, students favored discussions within and across groups. Many students expressed a preference for an individual activity, typically involving creating a personal summary or explanation of the solution. Some also wanted an independent practice, quiz, or assessment afterward to ensure they understood the concepts. This activity could include a practical exercise. Many students want a picture of the solution. Some wish to photograph their group's work and others'. They also seek assessment of their drawings, tying into the teacher-focused activity, where students desire verification of their understanding. Finally, some students appreciate the teacher presenting the solution at the end to avoid influencing their own work. Some also feel "full" after the session and would like to take a break.

5 Discussion

Subsection 5.1 and 5.2 discuss conceptual aspects and subsection 5.3 and 5.4 discuss practical aspects of Thinking Classrooms.

5.1 Establishing roles

In strategically composed groups, knowledgeable students often become highly influential [10]. They create an academic status order through repeated interactions, affecting roles and participation. In our non-strategically assigned groups, roles like leader and draftsman emerged naturally. The leader initiates discussions, while the draftsman draws and asks questions; sometimes, draftsmen also propose solutions. In some groups, one student was both leader and draftsman, guiding the project, while in others, the draftsman visualized ideas and facilitated discussion.

Our findings align with Esmonde [14], who identifies expert and novice roles in group work, where *"an expert is a student recognized as such by peers"* ([14], p. 257). Knowledgeable students in our data often assumed the "leader role" and were most active in group work, likely emerging through tacit consensus, with

students stating, "you talk about what you have control over," allowing knowledgeable peers to lead. These roles were accepted based on perceived merit. Similarly, Esmonde [14] found that expert students were *"frequently deferred to and granted the authority to decide whether their own and others' work was correct"* ([14], p. 257). Chang et al. [8] found students often self-assign roles, leading to inconsistent participation. Similarly, Cheng et al. [9] observed high achievers either dominate or withdraw due to perceived low-quality group processes.

Organic role assignment may aid task completion but can result in unequal learning outcomes. Cohen and Lotan [10] note this common issue, where some students dominate while others withdraw. While some knowledgeable students facilitated tasks, others felt unable to fully express themselves. We used visibly random group assignments to disrupt established roles and encourage equal participation. However, knowledgeable students still led and were the most active. Our findings suggest random groups and open-ended problems promote equity but are insufficient for balanced participation in higher education. Chang et al. [8] also noted assigned roles are often disregarded.

Some students prefer to let others speak first, then contribute with enhanced understanding, aligning with Boaler's concept of a multidimensional classroom [2]. However, some felt the need to take control for progress and efficiency. Social factors influence participation; comfort with peers provides stability, while some students feel unable to express themselves fully. Boaler and Staples [3] found that students value "authority" and "agency," enhancing their relationship with the material. When knowledgeable students dominate, less knowledgeable students benefit less. Some increase participation as they understand more, yet others feel they lack opportunities to express themselves. Proposing solutions and receiving feedback could benefit these students more, as uneven contributions and social loafing persist.

5.2 Communication dynamics inside and between groups

Working in groups promotes both verbal and non-verbal communication, critical for effective thinking and learning. Group size impacts communication flow significantly. Groups of two may have too little or tense communication, while groups of four or more may struggle to include everyone. Three participants are often the optimal size for balanced communication.

Standing helps students stay engaged with the task and maintain a shared focus on the whiteboard, enhancing the communication flow and creativity. Seeing each other's faces is easier, making communication smoother.

Student familiarity also affects communication flow. Familiar groups may drift into social conversation, while random groups stay task-focused. Visible whiteboard work improves between-group communication by allowing groups to spot errors and reinforce understanding through similar or differing solutions.

Questions engage peers and facilitate learning. Students often find it easier to ask questions to peers, even if they trust the teacher's explanations more. The VW fosters group communication through drawings and pointing, serving as a common focal point for collaborative problem-solving.

5.3 The students' general opinions and preferences

All students interviewed preferred standing over sitting in random groups of three for task-solving, possibly influenced by the task itself. One student noted sitting might be better for structured academic work. There was no clear preference for random or fixed groups. Students recognize the benefits of random groups, such as increased challenge and learning potential but also noted social pressure and time constraints leading some to prefer fixed groups. Students perceive learning through various activities and mediation. They find listening to peers, engaging in dialogues, asking questions, and explaining concepts beneficial [15]. Additionally, making drawings and using visual scaffolding helps in acquiring knowledge [1].

Some students consider the nature of the task when choosing activities. Complex tasks may require group work on VW, while independent work might be better for academic writing or checking their understanding. Kirschner [17] found suitable team tasks need to be complex enough to justify teamwork for enhanced learning and performance. To consolidate knowledge from using VW, students suggest different approaches. Some prefer a teacher-led summary, others advocate peer discussions, and some favor quizzes or tasks to ensure mastery of the material.

5.4 Working alone or in a group, and the social aspects

Collaborative learning requires coordination of emotional and motivational resources [21]. Some respondents report that working on VW demands more energy than working alone or with familiar peers due to various reasons: shyness, fear of saying something wrong, or the need to "feel the room." Shyness and fear of embarrassment deter many from participating in small groups, and the shyer they are, the less confident they feel [22, 12]. Students often need to establish relationships with peers before feeling comfortable asking for help, and many respondents need to know their group members before engaging efficiently.

An essential part of Liljedahl's thinking classroom is students leveraging each other's knowledge to solve tasks [19]. This requires groups of three to be engaged and committed. Some students reported that unengaged members disrupted group dynamics. However, others felt a responsibility toward their group, showing greater social and academic engagement. Scaffolding for motivation and commitment, emphasizing task value, and fostering a sense of belonging could be beneficial, as Belland [6] suggests. Overall, our students perceived the group climate as good, reporting no significant conflicts.

Students often aim to improve social skills, gain approval, and achieve status among peers or teachers [13]. Dowson [13] also discusses "social concern," or understanding schoolwork to help others. Our findings indicate respondents see group work as a positive challenge, helping them enhance social skills and reduce anxieties, making them feel more competent [22, 12]. Students also express the need to present themselves well to gain approval and status. Conversely, they

fear saying something wrong or appearing unintelligent, which creates tension between contributing valuable input and risking loss of status [22].

Some respondents worry about being left out of group discussions if the other two members know each other well. Achieving a shared goal requires considering all group members' ideas [6], making these concerns a significant issue and potential challenge.

For some students VW has a drawback - you can't write down what you are learning as you go. Being able to jot down thoughts helps alleviate working memory. However, the VW system encourages instant information sharing and knowledge creation and a summary will have to be created after the session is finished. Kirschner et al. [17] found that task complexity and cognitive load distribution among group members determine efficiency. It might be beneficial to incorporate breaks for individual note-taking and thinking in Thinking Classrooms or expect greater preparation for these sessions in advance.

6 Conclusion

We have applied Liljedahl's Thinking Classrooms methodology in the course Digital Technology. Students generally report positive learning and social experiences, though some find active participation challenging. Our findings suggest random groups and open-ended problems promote active participation, but we still see the more knowledgeable students dominate the group work.

We find that Liljedahl's "Thinking Classroom" approach supports student focus and learning in an ICT course. Students report that peer interaction, active participation, and creative problem-solving, particularly through whiteboard collaboration, enhance their learning. The diversity of perspectives in whiteboard sessions adds value, though working with unfamiliar peers is a challenge.

Our contribution to the field of practice is that we suggest adding preparatory steps, like awareness and meta-cognition about group work, and social ice breakers before sessions. We also recommend incorporating breaks for individual note-taking and thinking during the session and also expect greater preparations for these sessions in advance.

Our findings are based on the self-reported experiences of 10 students, particularly regarding their learning preferences, social situations, and communication. Despite the generally positive feedback, we cannot determine if these positive experiences translate to better learning outcomes.

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