Informatics in Education, 2025, Vol. 0, No. 0, 0–0

DOI: https://doi.org/10.15388/infedu.2025.08

Theoretical Frameworks in Focus: Group Work Research in Project-Based CS Education

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Received: October 2024

Abstract.
This study builds on a recent systematic mapping of computing education literature by conducting an in-depth qualitative analysis of selected studies on group work in Project-Based Learning (PjBL), published between 2010 and 2021. We examined how prominent theoretical frameworks are used in this context. We found that frameworks were often applied either as teaching tools or to inform course design, and when used in these ways, authors frequently reported positive pedagogical outcomes. While frameworks like Tuckman's model were often referenced only superficially, Social Loafing was more commonly explored in depth. Inductive analysis was particularly effective in distinguishing between background mentions and more substantial integration of theory. We recommend a more intentional, theory-driven approach to research and pedagogy to strengthen conceptual clarity and practical impact. Shared community resources and clearer reporting practices could further support deeper theoretical engagement in the field.

Key words: Theory, Theoretical Framework, Project-Based Learning, Group Work, Content Analysis.

1. Introduction

As a research field, Computing Education Research (CER) has experienced significant evolution, moving from its initial phases marked by a prevalence of anecdotal contributions and exploratory "Marco-polo" papers to its current state as a more mature field that places a higher emphasis on methodological quality and a robust theoretical foundation (e.g., Tedre and Pajunen, 2022; Apiola *et al.*, 2022). This evolutionary path was also underscored in the recent study by Malmi *et al.* (2020), which points out the maturation of CER as it develops and refines its theoretical frameworks and models.

The discussion about the role of theory in CER has prompted various perspectives. Nelson and Ko (2018) caution against blindly insisting on theory, highlighting potential drawbacks such as diverting from the field's main goals as a design-based field, hindering the search for domain-specific theories, and creating publication bias. This caution might be particularly relevant to the present context of Project-Based Learning (PjBL), given

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the ample room for educational design within project settings. However, as highlighted by Tedre and Pajunen (2022), many researchers underscore CER's role as a research discipline dedicated to gaining a profound understanding of phenomena in computing education, beyond serving as a design field.

In computing education, projects have been a core component since the first documented curriculum in 1968 (Tomayko, 1998). PjBL provides a learning environment that simulates real-world scenarios and allows students to apply and demonstrate professional skills (Majanoja and Vasankari, 2018; Fincher *et al.*, 2001; Clear *et al.*, 2001). Within CER, the exploration of group work in PjBL represents a rich domain, encompassing areas such as communication, group formation, assessment, team dynamics, and team performance (Kokkoniemi and Isomöttönen, 2023b). A recurring theme in the literature is the concern that graduates often lack the group and collaboration skills expected by employers (e.g., Hernández-March *et al.*, 2009; Barr and Parkinson, 2019). These skills are also integral to modern software development—for example, the Agile Manifesto emphasizes individuals and interactions, communication, and collaboration (Beck *et al.*, 2001). The field's continued interest in Project-Based Learning is demonstrated by the recent publication of literature studies (Tenhunen *et al.*, 2023; Kokkoniemi and Isomöttönen, 2023b).

Given the complexity of group work in project settings, a strong and multidisciplinary theoretical foundation could offer structured frameworks that support both the design of effective educational experiences and the development of the profound understanding highlighted above. However, such depth is not yet clearly evident in the existing body of research. Kokkoniemi and Isomöttönen (2023b) note in their recent systematic mapping study that a significant portion of their data consisted of course descriptions with limited theoretical depth, which continue to dominate the literature. Previously, this pattern has been shown to extend beyond CER to PjBL more generally: a literature review by Helle *et al.* (2006) similarly found that much of the existing research at the time was descriptive in nature, with little in-depth theoretical or empirical investigation.

Kokkoniemi and Isomöttönen (2023b) identified theoretical frameworks adopted in group-work-focused studies within project-based learning in computing education from 2010 to 2021. While we use "computing" in its broad sense (e.g., ACM, 2012) throughout the paper—including in the discussion—the analysis in this study focuses specifically on the subset of computing education addressed in the mapping study. That is, educational contexts within Computer Science and Software Engineering that involve practical project activities such as building systems, writing code, and collaborating in teams, rather than more general or theoretical projects. Kokkoniemi and Isomöttönen observed that the use of theories was concentrated on a few theories and constructs, and given the high number of the papers mapped, even these were relatively little used. The present study builds upon this recent mapping study, examining *how* these frequently used theories were applied.

As an independent piece of research, the present study employs qualitative content analysis to explore the use of theory within a specific CER area. This piece of study is endorsed by the mapping authors, and to our knowledge, has not been conducted elsewhere.

We use the corpus identified by the mapping authors, restricting our analysis to theories that appeared five or more times during the mapping period. We reason that focusing on those with at least some (five) hits provides a meaningful basis for describing their usage and allows comparison between them. At the same time, this focus serves as an initial step toward advancing the discussion on the use of theory in this research area and identifying future needs for theoretical engagement. Our aim is to contribute to this conversation by examining how theory is engaged in CER, with a specific focus on group work studies—an area in which, as noted, theories are arguably beneficial and also available from other disciplines such as sociology and psychology. The research question we seek to answer is: *How have the prominent theories been used in the literature on group work in project-based learning in computing?*

Section 2 provides an overview of the background literature relevant to our study. In Section 3, we outline our methodological approach. Our findings are detailed in Section 4, while Section 5 delves into our discussion of these findings.

2. Background

In the landscape of CER literature, the term "theory" frequently lacks clear definitions, leading to conceptual ambiguity (Szabo *et al.*, 2019; Tedre and Pajunen, 2022; Malmi *et al.*, 2020). This lack of precision presents a challenge as it introduces varied interpretations and understandings of the concept within the literature.

In this study, we frequently use the term "theoretical framework," which acts as a tool for researchers to inform study designs, interpret data, and formulate conclusions. Varpio *et al.* (2020) provide a useful definition: "A theoretical framework is a logically developed and connected set of concepts and premises – developed from one or more theories – that a researcher creates to scaffold a study." Naturally, our use of the term encompasses named theories. Additionally, we use the more flexible term "construct" with concepts that may not be typically cited as theoretical frameworks, such as Social Loafing.

Furthermore, we *do not* differentiate between "group work" and "teamwork." While some studies distinguish between these terms, within our dataset, they are used interchangeably. To maintain consistency, we use "group work" to refer to both.

2.1. *Previous Works on Theory Use in CER*

The use of theory in CER has been extensively explored before, notably among others by the research group of Malmi et al. Below, we highlight some significant contributions to this area.

In 2014, Malmi *et al.* (2014) reviewed studies from 2005 to 2011 from several popular CER venues to identify the theories, models, and frameworks upon which CER builds on. Their findings suggested that CER extensively draws on work from other disciplines and there is a lack of dominant theoretical works universally applied within CER, noting that a considerable number of studies rely on their own theoretical constructs.

In 2016, Malmi *et al.* (2016) analyzed the research methodology of papers published in the European Journal of Engineering Education during the years 2009, 2010, and 2013.

They found a diversity in the use of theoretical concepts but pointed out that data analysis often relied on simplistic methods. Additionally, they identified deficiencies in how research questions, methodologies, and study limitations were reported.

In 2016, Lishinski *et al.* (2016) examined the application of theory and methodological rigor within four years of CS education research, focusing on the Computer Science Education journal and ICER conference proceedings. They observed a notable rise in the percentage of papers leveraging theories external to CS education, a contrast to findings from previous literature reviews. However, measures of methodological quality displayed no corresponding evolution.

In 2019, Malmi *et al.* (2019) discovered 65 new computing-specific theoretical constructs within three key publication venues. They then investigated the subsequent use of a significant portion of these constructs in research, revealing limited use: nearly all papers citing these constructs only mentioned the original sources, often without clarifying the reason for the citation.

In 2020 Malmi *et al.* (2020) identified new domain-specific theories and models related to emotions, attitudes, and self-efficacy in programming education, based on literature from 2010 to 2019. They further explored how these theories and models influenced subsequent research through an analysis of papers citing these theories. They concluded that there is methodological richness in quantitative research and the development of unique theoretical constructs and models tailored to programming learning signifies that CER is maturing.

In 2022 Malmi *et al.* (2022) expanded the investigation to domain-specific theories in computing education in general. They aimed to gain a comprehensive understanding of the nature and function of these theories in CER and their application across the field. The findings uncovered a significant body of work spanning various subfields of computing education, but the authors pointed out that the field continues to lack a definitive tradition of theory development.

In 2022, Tedre and Pajunen (2022) advocated for CER to adopt a model-based scientific approach, thus bypassing the conceptual burden of traditional theory. They recommended assessing the role of theory in CER through the lens of engineering, technology, and social science philosophies, rather than natural science. Furthermore, they emphasized the need for CER to develop its own research paradigm and define its theoretical relationships in terms specific to the field.

2.2. *Examined Theoretical Frameworks and Constructs*

This paper examines the use of several established theoretical frameworks and constructs which surfaced in the mapping study by Kokkoniemi and Isomöttönen (2023b). We selected these frameworks specifically because each appeared more than five times in that study, allowing for meaningful comparisons and analysis. In contrast, most frameworks in the mapping study appeared only once, which makes it difficult to draw any substantial conclusions about their application.

Bruce Tuckman's 1965 model, "Stages of Group Development," (Tuckman, 1965; Tuckman and Jensen, 1977) outlines the typical phases of group interaction: Forming (initial impressions, undefined roles), Storming (conflicts as ideas clash), Norming (establishing norms and roles), Performing (optimal group performance), and Adjourning (disbanding post-objectives). The *Five-Factor Model of Personality Traits* (Goldberg, 1990; Costa Jr. and McCrae, 2008; Digman, 1990), or the "Big Five," categorizes personality into five dimensions: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. *The Myers-Briggs Type Indicator (MBTI)* (Myers, 1962) is a questionnaire that assesses psychological preferences, classifying personalities into four dichotomies: Introversion/Extraversion, Sensing/Intuition, Thinking/Feeling, and Judging/Perceiving. *David Kolb's Experiential Learning Theory (ELT)* (Kolb, 1984) involves a four-stage learning cycle: Concrete Experience (gaining knowledge through experiences), Reflective Observation (reflecting on these experiences), Abstract Conceptualization (learning and theory formation), and Active Experimentation (applying theory in new contexts). Lastly, *Social Loafing* (Latane *et al.*, 1979), or "Free Riding", is a problematic phenomenon that occurs in group settings, where individual members of a group exert less effort towards achieving a common goal than they would if they were working alone.

3. Method

The data comprised a corpus selected from the 2023 systematic mapping study by Kokkoniemi and Isomöttönen (2023b)[2]. That study focused on group work in PjBL within computing education, covering studies from 2010 to 2021. Following established mapping guidelines, the studies were identified through searches in ten academic databases or search engines and are part of the final mapping dataset (Kokkoniemi and Isomöttönen, 2023a). Using a keywording process, Kokkoniemi and Isomöttönen (2023b) classified the papers across research questions related to publication trends, methods, theoretical frameworks, and group work areas, aiming to provide a structured overview of the field and highlight research gaps. The original study's selection criteria focused on educational contexts in Computer Science and Software Engineering involving software development and related activities—such as building systems, writing code, and team collaboration—rather than more general or theoretical projects. This scope encompassed a wide range of topics, some of which emphasized group work over technical content. Group work in such contexts aligns with the computing domain, where collaborative practices are central to modern software development. For instance, Agile Manifesto emphasizes individuals and interactions, communication, and collaboration (Beck *et al.*, 2001). The specific papers used in our analysis are listed in Table 1.

We employed a qualitative content analysis methodology structured into three phases, informed by the guidelines of Hsieh and Shannon (2005) and Elo *et al.* (2014). The original terminology from Hsieh and Shannon (2005) refers to our first two phases as "conventional" and "directed" content analysis. Meanwhile, Elo *et al.* (2014) use the terms "inductive" and "deductive" to describe similar concepts. For consistency and readability, we

[2]The theoretical frameworks and constructs in our analysis are derived from Table 5 in Kokkoniemi and Isomöttönen (2023b).

adopt the latter terminology throughout this paper. The three phases of our analysis were: (1) an inductive (i.e., conventional) approach (Hsieh and Shannon, 2005; Elo *et al.*, 2014) to develop a classification from paper content; (2) a deductive (i.e., directed) approach (Hsieh and Shannon, 2005; Elo *et al.*, 2014), where we applied an existing, inductively developed framework (Malmi *et al.*, 2020, p.39), reflecting on our initial inductive analysis; and (3) a summative step (Hsieh and Shannon, 2005) involving frequency calculations to generate heatmaps illustrating the depth of theory application.

The inductive analysis involved carefully reading each paper to identify theoretical applications. We created new classes or assigned papers to previously extracted classes based on these applications. This process necessarily involved a degree of subjectivity in interpreting how theories were applied. After analyzing all papers, we merged classes with similar meanings, allowing some overlap. Our focus was on understanding *how* theories were utilized rather than minimizing class numbers. Finally, we grouped related classes into thematic groups, letting them emerge organically from the classes.

The deductive analysis involved identifying the classes outlined by Malmi *et al.* (2020, p.39) in the examined papers. We chose this classification scheme because we believed that augmenting inductive analysis with a deductive approach would enhance the overall analysis. Notably, this scheme had already been applied in two CER studies (Malmi *et al.*, 2020, 2022), indicating its potential usefulness. However, we did not find use for all of the scheme's classes in our context.

The summative phase assessed the depth of theoretical application in the papers using heatmaps. Scores were assigned to each relevant class in both the inductive and Malmi et al.'s schemes. Classes I1 to I8, I12, and I14 (refer to Table 2) scored 1, while I13 was not scored due to overlap. Malmi et al.'s classes D1 to D3, considered mutually exclusive, scored 1, 2, and 3 respectively, and A1 to A7 scored 1. Overlapping or non-depth classes scored 0. These scores generated heatmaps (Figure 1) for both schemes, visualizing paper-wise score frequencies. The summative approach (Hsieh and Shannon, 2005) is also evident in the layout of inductive and deductive coding results in Table 2.

The first author initially conducted the inductive and deductive analyses, explaining emerging categories to the second author using exemplary paper segments for relevant class labeling. This was done to obtain intelligible and relevant labeling for the classes and resulted in changing several labels. To validate the process, the second author independently classified seven papers using both approaches. The findings and any differences in classification were then reviewed and discussed in an intensive research meeting. Classifications were tabulated systematically for comparison, and discrepancies were resolved through detailed paper inspections to form an agreement on how to apply the classes in these situations. To measure the consistency of our classifications, we calculated the percentage of agreement between the authors, which was found to be 98%. While percentage agreement alone is not necessarily a definitive measure of inter-rater reliability, this high level of agreement provides confidence in the consistency of our classifications.

Table 1
Papers Used in the Content Analysis: A Single Paper May Appear in Multiple Theoretical Constructs

<table>
<tr><th>ID</th><th colspan="6"></th><th>ID</th><th colspan="6"></th></tr>
<tr><td colspan="14">Tuckman's Model of Group Development</td></tr>
<tr><td>2</td><td colspan="6">Auvinen, Falkner, Hellas, Ihantola, Karavirta, and Seppälä. 2020. Relation of Individual Time Management Practices and Time Management of Teams. Doi: 10.1109/FIE44824.2020.9274203</td><td>6</td><td colspan="6">Dascalu, Dumitrache, Coman, Moldoveanu. 2015. Group Maker Tool for Software Engineering Projects. Doi: 10.1016/j.sbspro.2015.08.266</td></tr>
<tr><td>8</td><td colspan="6">Fontenot, Canales, and Quicksall. 2014. Taking care of the team in a first-year design experience course. Doi: 10.1109/FIE.2014.7044433</td><td>11</td><td colspan="6">Kearney, Damron, Sohoni. 2015. Observing Engineering Student Teams from the Organization Behavior Perspective Using Linguistic Analysis of Student Reflections and Focus Group Interviews. https://eric.ed.gov/?id=EJ1076137</td></tr>
<tr><td>13</td><td colspan="6">Kuhrmann and Münch. 2016. When teams go crazy: an environment to experience group dynamics in software project management courses. Doi: 10.1145/2889160.2889194</td><td>15</td><td colspan="6">Largent. 2016. Measuring and Understanding Team Development by Capturing Self-assessed Enthusiasm and Skill Levels. Doi: 10.1145/2791394</td></tr>
<tr><td>16</td><td colspan="6">Largent and Chris Lüer. 2010. "You mean we have to work together!?!": a study of the formation and interaction of programming teams in a college course setting. Doi: 10.1145/1839594.1839603</td><td>23</td><td colspan="6">Neumann, Kowitz, Schranner, Azarnykh. 2017. Interdisciplinary teamwork in HPC education: Challenges, concepts, and outcomes. Doi: 10.1016/j.jpdc.2016.12.025</td></tr>
<tr><td>24</td><td colspan="6">Pieterse, Leeu, van Eekelen. 2018. How personality diversity influences team performance in student software engineering teams. Doi: 10.1109/ICTAS.2018.8368749</td><td>26</td><td colspan="6">Pieterse, Thompson, and Marshall. 2011. Rocking the boat - An approach to facilitate formation of effective student teams. https://www.researchgate.net/publication/328917182</td></tr>
<tr><td>27</td><td colspan="6">Pieterse, Thompson, Marshall, Venter. 2012. Participation patterns in student teams. Doi: 10.1145/2157136.2157218</td><td>29</td><td colspan="6">Sahin. 2011. A team building model for software engineering courses term projects. Doi: 10.1016/j.compedu.2010.11.006</td></tr>
<tr><td>30</td><td colspan="6">Schneider, Liskin, Paulsen, and Kauffeld. 2015. Media, Mood, and Meetings: Related to Project Success?. Doi: 10.1145/2771440</td><td></td><td colspan="6"></td></tr>
<tr><td>Year</td><td>2010</td><td>2011</td><td>2012</td><td>2013</td><td>2014</td><td>2015</td><td>2016</td><td>2017</td><td>2018</td><td>2019</td><td>2020</td><td>2021</td><td>Total</td></tr>
<tr><td>Papers</td><td>1</td><td>2</td><td>1</td><td>0</td><td>1</td><td>3</td><td>2</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>13</td></tr>
<tr><td colspan="14">Five-Factor Model of Personality Traits (Big Five)</td></tr>
<tr><td>3</td><td colspan="6">Bell, Hall, Hannay, Pfahl, and Acuna. 2010. Software engineering group work: personality, patterns and performance. Doi: 10.1145/1796900.1796921</td><td>5</td><td colspan="6">Chowdhury, Walter, and Gamble. 2018. Toward Increasing Collaboration Awareness in Software Engineering Teams. Doi: 10.1109/FIE.2018.8659198</td></tr>
<tr><td>7</td><td colspan="6">Doman, Besmer, Olsen. 2015. Teaching Tip: Managing Software Engineering Student Teams Using Pellerin's 4-D System. https://eric.ed.gov/?id=EJ1113948</td><td>21</td><td colspan="6">Monaghan, Bizumic, Reynolds, Smithson, Johns-Boast, van Rooy. 2014. Performance of student software development teams: the influence of personality and identifying as team members. Doi: 10.1080/03043797.2014.914156</td></tr>
<tr><td>22</td><td colspan="6">Mujkanovic, Bollin. 2019. Personality-Based Group Formation. Doi: 10.1007/978-3-030-23513-0_21</td><td></td><td colspan="6"></td></tr>
<tr><td>Year</td><td>2010</td><td>2011</td><td>2012</td><td>2013</td><td>2014</td><td>2015</td><td>2016</td><td>2017</td><td>2018</td><td>2019</td><td>2020</td><td>2021</td><td>Total</td></tr>
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<tr><td colspan="14">Myers-Briggs Type Indicator (MBTI)</td></tr>
<tr><td>1</td><td colspan="6">Alboaie, Vaida, and Pojar. 2012. Alternative methodologies for automated grouping in education and research. Doi: 10.1145/2381716.2381813</td><td>20</td><td colspan="6">Martínez, Licea, Rodríguez-Díaz, Castro. 2010. Experiences in software engineering courses using psychometrics with RAMSET. Doi: 10.1145/1822090.1822159</td></tr>
<tr><td>24</td><td colspan="6">Pieterse, Leeu, van Eekelen. 2018. How personality diversity influences team performance in student software engineering teams. Doi: 10.1109/ICTAS.2018.8368749</td><td>28</td><td colspan="6">Budi Laksono Putro, Yusep Rosmansyah, Suhardi Suhardi. 2019. Development of online learning groups based on MBTI learning style and fuzzy algorithm. Doi: 10.12928/telkomnika.v18i1.14922</td></tr>
<tr><td>31</td><td colspan="6">Silvestre, Ochoa, and Marques. 2015. Understanding the design of software development teams for academic scenarios. Doi: 10.1109/SCCC.2015.7416570</td><td></td><td colspan="6"></td></tr>
<tr><td>Year</td><td>2010</td><td>2011</td><td>2012</td><td>2013</td><td>2014</td><td>2015</td><td>2016</td><td>2017</td><td>2018</td><td>2019</td><td>2020</td><td>2021</td><td>Total</td></tr>
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<tr><td colspan="14">Kolb's Experiential Learning Theory</td></tr>
<tr><td>4</td><td colspan="6">Chen, Qiu, Yuan, Zhang, and Lu. 2011. Assessing Teamwork Performance in Software Engineering Education: A Case in a Software Engineering Undergraduate Course. Doi: 10.1109/APSEC.2011.50</td><td>8</td><td colspan="6">Fontenot, Canales, and Quicksall. 2014. Taking care of the team in a first-year design experience course. Doi: 10.1109/FIE.2014.7044433</td></tr>
<tr><td>12</td><td colspan="6">Kharitonova, Luo, and Park. 2019. Redesigning a Software Development Course as a Preparation for a Capstone: An Experience Report. Doi: 10.1145/3287324.3287498</td><td>14</td><td colspan="6">Kyprianidou, Demetriadis, Tsiatsos, and Pombortsis. 2012. Group formation based on learning styles: can it improve students' teamwork?.Doi: 10.1007/s11423-011-9215-4</td></tr>
<tr><td>17</td><td colspan="6">Lau, Shim, and Gottipati. 2021. Design and Supervision Model of Group Projects for Active Learning. Doi: 10.1109/FIE49875.2021.9637162</td><td></td><td colspan="6"></td></tr>
<tr><td>Year</td><td>2010</td><td>2011</td><td>2012</td><td>2013</td><td>2014</td><td>2015</td><td>2016</td><td>2017</td><td>2018</td><td>2019</td><td>2020</td><td>2021</td><td>Total</td></tr>
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<tr><td colspan="14">Concept of Social Loafing</td></tr>
<tr><td>9</td><td colspan="6">Fronza and Wang. 2017. Towards an Approach to Prevent Social Loafing in Software Development Teams. Doi: 10.1109/ESEM.2017.37</td><td>10</td><td colspan="6">Fronza and Wang. 2021. Social loafing prevention in agile software development teams using team expectations agreements. Doi: 10.1049/sfw2.12019</td></tr>
<tr><td>18</td><td colspan="6">Lin. 2016. Effects of an online team project-based learning environment with group awareness and peer evaluation on socially shared regulation of learning and self-regulated learning. Doi: 10.1080/0144929X.2018.1451558</td><td>19</td><td colspan="6">Marshall, Pieterse, Thompson, and Venter. 2016. Exploration of Participation in Student Software Engineering Teams. Doi: 10.1145/2791396</td></tr>
<tr><td>25</td><td colspan="6">Pieterse and Thompson. 2010. Academic alignment to reduce the presence of 'social loafers' and 'diligent isolates' in student teams. Doi: 10.1080/13562517.2010.493346</td><td>26</td><td colspan="6">Pieterse, Thompson, and Marshall. 2011. Rocking the boat - An approach to facilitate formation of effective student teams. https://www.researchgate.net/publication/328917182</td></tr>
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<tr><td>Papers</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>2</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>7</td></tr>
</table>

4. Results

The frameworks we focused on are presented in Section 2.2. Infrequently used theoretical frameworks were excluded as their limited application provides minimal insight and complicates comparisons. Seventeen distinct classes emerged from the inductive content analysis, presented in Table 2 and organized into five thematic groups separated by horizontal lines. These groups reflect different aspects of framework usage: scoping the studies, depth of usage, operationalization, pedagogical perspective, and advancement of frameworks. For each thematic group, we begin by presenting the inductive content analysis, followed by complementary deductive analysis, allowing comparative reflection between the two classification schemes. Our intention was not to create a competing scheme for

Table 2
Classification of the Usage of Theoretical Frameworks in Primary Studies

	Usage Classification	Tuckman$^{(n=13)}$	Big Five$^{(n=5)}$	MBTI$^{(n=5)}$	Kolb$^{(n=5)}$	Social Loafing$^{(n=7)}$
Inductively Formed Classes:						
I1	Is the Main Research Interest					9, 10
I2	Used as a Main Theoretical Base	11, 13, 15, 16	3, 5, 22	1, 20, 28		9, 10
I3	Not a Prominent Theory in the Study	2, 30		31		
I4	Used Explicitly in Related Work	6, 8, 16, 23, 24, 26, 27, 29	3, 5, 7, 21, 22	1, 20, 24, 28, 31	14, 17	9, 10, 18, 19, 25, 26, 27
I5	Used Explicitly for Hypothesis	11, 15, 16, 30	21			18
I6	Used Explicitly in Conclusion	11, 15, 16	3, 21, 22	1, 28	17	9, 10, 25, 26, 27
I7	Used Explicitly in Discussion	2, 11, 15, 16, 23, 24	3, 5, 21	1, 20	17	9, 10, 19, 25, 26, 27
I8	Used Explicitly in Results	11, 16, 30	3, 5, 21	1, 20, 28	4, 12	9, 10, 19, 26, 27
I9	Used Implicitly in Conclusion	30		24		18
I10	Used Implicitly in Discussion	30		28	14	18
I11	Used Implicitly for hypothesis		3	24		
I12	Used in Data Collection	16	3, 21	1, 24		9, 10
I13	Used in a Coding Scheme	11		24		19, 27
I14	Used in the Analysis	11, 15, 16	3, 21	1, 20, 28		9, 10, 19, 25, 26, 27
I15	Used in a Course as a Teaching Vehicle	8, 13		24		10
I16	Affected Course Design	13, 24, 26, 27		20, 28	4, 17	9, 26
I17	Theory Integrated into a New Viewpoint	15	5, 21			
Malmi* et al. *(2020) Classification:						
D1	Cited in Related Work - No Explanation	13			4, 14	
D2	Cited in Related Work - A Brief Explanation	6, 8, 23, 24, 26, 27, 29	7	31	12	26
D3	Discussed in Related Work	11, 15, 16, 30	3, 5, 21, 22	1, 20, 24, 28	17	9, 10, 18, 19, 25, 27
A1	Used as a Framework to Scope the Study	11, 13, 15, 26, 27	3, 5, 21, 22	1, 20, 28		9, 10, 25, 26, 27
A2	Used to Develop a Data Collection Instrument	16		1, 24		9
A3	Used as a Framework for Data Analysis	11, 15	5, 21	28		9, 10, 25, 27
A4	Used to Predict Results	11, 15, 16, 30	3	24		18
A5	Used to Interpret/Compare/Explain Results	2, 11, 23, 24, 30	3, 5, 21	1, 20, 24, 28	8, 14	9, 10, 18, 19, 25, 26, 27
A6	Used to Design a New Pedagogical Method	8, 13, 16, 26, 27		1, 20, 28	17	9, 26
A7	Used as Instrument in the Study		3	28	4	
C1	Modified or Extended Existing Construct to be Used in a New Context	15	21	20		
C3	Developed a New Construct from Existing Construct and Argumentation				17	19

Malmi *et al.* (2020) but to enhance our understanding through a reflective comparison.

4.1. *Frameworks in Scoping the Studies*

We observe that analyzed theoretical frameworks often contribute to a study's scope. Our inductive content analysis identified three classes related to the scope: I1, I2, and I3. In two papers, the theoretical framework was not merely a basis for research but the main focus. Marked as I1, these papers primarily concerned preventing Social Loafing. Classes I2 and I3 differentiate studies where the framework is the main theoretical base (I2) versus a less prominent role (I3). Only three papers were marked I3, indicating these frameworks were generally relevant to the studies.

Malmi et al. present a precise classification for examining whether a theoretical construct impacts a study's scope. They designate class A1 specifically for this purpose. A1 encompasses a broader range of papers than our individual classes I1–I2, as shown in Table 2, suggesting the possibility of more factors affecting a study scope that were identified in our inductive analysis.

Furthermore, Kolb's Experiential Learning Theory does not appear to have affected the scope of any study within our analysis, whereas the other frameworks have had such an influence. In particular, constructs like Tuckman's Model of Group Development and

Social Loafing are arguably inherently group-oriented, which may explain why they are likely to affect a study's scope in this analysis.

4.2. *Depth of Usage of the Frameworks?*

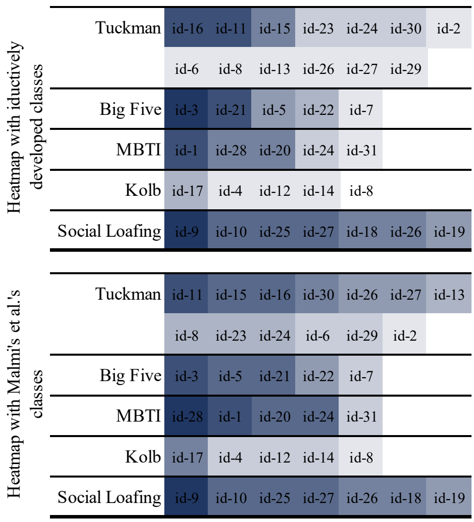
To inspect the depth of theory usage we inspected how explicit or implicit the use of theory is in the papers. With "explicit" use we refer to papers clearly applying the terminology and concepts of the theoretical framework. We found (refer to Table 2) that theories, when used, were typically employed explicitly. Class I4 covers any explicit mention of a framework in background sections or related work, irrespective of the section's title. In contrast to explicit, "implicit" use may not be immediately apparent and could require understanding the study's background literature to recognize its application. Implicit usage was limited to sections like hypotheses, discussions, and conclusions.

The respective classes for background literature in Malmi et al. classification are D1–D3, though we considered these classes to be mutually exclusive. Classes D1–D3 offer an understanding of the depth of framework utilization in sections focusing on related work, as they differentiate the extent to which frameworks are used. Furthermore, the results on D2 indicate that Tuckman's Model of Group Development is more typically given a brief overview in the related work sections of papers, in contrast to other theoretical frameworks within our analysis, which tend to receive more extensive discussion.

To further gauge the depth of theoretical usage, we summatively analyzed the classes assigned to each paper and assigned scores for the papers accordingly, as detailed in Section 3. In Figure 1, we present classification heatmaps, categorized by theoretical framework. With these rough visualizations, we attempt to demonstrate the depth of theory usage. We prepared separate heatmaps for the results of our inductive and deductive analysis. In these heatmaps, a darker shade indicates a higher score, suggesting more in-depth theory use. Both heatmaps show similar trends, with the most noticeable difference being that Tuckman's Model of Group Development receives a higher score in the second one. While the order of papers varies slightly, the top three scored papers for each theory are consistent across both heatmaps, except for Social Loafing, which still displays roughly comparable figures between the heatmaps.

The figures on Tuckman's Model of Group Development and the Big Five reveal a greater diversity in their depth of application compared to other frameworks, as evident in both heatmaps. Furthermore, we notice that Kolb's Experiential Learning Theory received low scores on both heatmaps, suggesting a limited application of theory in the studies reviewed. Conversely, Social Loafing showed a consistently deep application, likely because of its arguably close conceptual ties to group work in PjBL. This connection could account for its frequent usage beyond the related work sections. In certain instances, Social Loafing even serves as the main research interest (I1). In the second heatmap, MBTI also achieved a high score, indicating a more thorough application of theory. However, it is important to note that these results do not reflect the quality of the papers analyzed.

Fig. 1. An Illustration the Depth of Theoretical Framework Usage via Classification Frequency Analysis



4.3. *Frameworks and Operationalization*

By operationalization, we refer to the actions taken to specify the measurement or detection of a concept in practice. We observe that all the theoretical frameworks under analysis have been employed for operationalization, either in data collection or analysis.

Papers that utilize a framework specifically for data collection are marked with I12. Within our analysis, Tuckman's Model of Group Development is rarely utilized for this purpose, with one exception being paper 16, which crafted a questionnaire informed by the model. Instead, well-established questionnaires based on the Big Five and MBTI models have been employed in several studies for data collection. For instance, paper ID 21 used the International Personality Item Pool (IPIP-NEO) for measuring students' conscientiousness and agreeableness.

A few studies have adopted a framework as the basis for a coding scheme (I13), predominantly for data analysis rather than collection. Overall, frameworks seem to be more popular for data analysis than for data collection, as shown in Table 2.

In comparison to our inductively emerged classes, Malmi et al.'s classification distinguishes between the use of a theoretical construct for developing a data collection instrument (A2) and its direct application as an instrument (A7). Our analysis indicates that the use of the reviewed frameworks as direct instruments in research on group work in project-based education is generally limited, but there are examples of such usage, such as paper ID 24, which introduced a custom peer assessment questionnaire for MBTI personality dimensions.

4.4. *Pedagogical Perspective*

In several studies, theoretical frameworks have been directly used as teaching tools, where the framework is integrated into lectures, exercises, or team activities. Papers using theory in this instructional way are categorized under I15. Where applicable, reported pedagogical effects of using the framework in teaching are also commented.

Paper ID-24 involved students assessing their peers using MBTI personality dimensions and completing a reflective survey. This activity was designed to increase students' awareness of personality differences and enhance interpersonal skills. Although the authors found no evidence that personality diversity improved team synergy, they did observe a weak positive correlation between personality diversity and the quality of the team's final product. Similarly, paper ID-8 incorporated Tuckman's Model of Group Development into the first team retrospective, helping students recognize that the "storming" phase is a normal and productive part of team development. However, this paper did not report any direct measures of pedagogical impact from using the model.

Some studies in class I15 do evaluate pedagogical effects more explicitly. Paper ID-10, for instance, introduced the concept of Social Loafing to students and asked them to create team expectation agreements. While the intervention helped raise awareness, it was found insufficient on its own; the authors suggested that ongoing "meta rules" could help reinforce commitment and reduce social loafing. In paper ID-13, Tuckman's Model was introduced to students, and while the study did not directly measure the impact of the model itself, the authors reported positive learning outcomes overall, including students' ability to quickly develop collaboration strategies—even when group compositions changed.

In contrast to the instructional use (I15), papers in class I16 represent cases where a theoretical framework influenced the design of the course. Similar to I15, where applicable, reported pedagogical effects of using the framework in course design are also noted. In paper ID-26, for example, the course was structured to intentionally expose students to multiple "storming" phases, as described in Tuckman's Model, before forming final project teams. The authors noted that this approach gave students opportunities to identify their strengths and weaknesses and better prepared them for the final project.

The MBTI framework was similarly used in course design. In paper ID-20, MBTI results were used to assign students to project roles, and the resulting teams were described as successful, cooperative, and well-received by students. Likewise, paper ID-28 used MBTI to form project teams, reporting faster team formation, better group composition, and generally improved student performance.

The use of Kolb's Experiential Learning Theory also informed course-level decisions. Paper ID-17 applied the theory to structure the course around clearly defined stages, which helped align instructor and student understanding. Paper ID-4 used a Kolb-based learning style inventory for team formation, which promoted collaboration and balanced knowledge distribution within teams.

Across the studies reviewed, the reported pedagogical impacts of using theoretical frameworks were almost universally positive. Whether applied in instruction (I15) or course design (I16), frameworks were seen to enhance student learning or collaboration. However, these conclusions were often based on authors' reflections rather than quantitative evidence.

In Malmi et al.'s classification, the pedagogical perspective is approached from a different angle. Class A6 is designated for cases where theories were applied to develop *new* pedagogical methods. This class differs from both I15 and I16, possibly due to Malmi et al.'s specific focus on identifying new theories and models and to its original development for programming education (Malmi *et al.*, 2020), which as a research area is arguably quite different from ours. Hence, the distinct focus of their classification compared to ours is understandable. Notably, in our analysis, A6 is most frequently used in relation to Tuckman's Model of Group Development and the MBTI. However, we faced a challenge in interpreting the term *new*. We labeled something as *new* based on its presentation in the paper, rather than conducting a literature review to establish its novelty. This comparison implies that different contexts within computer science education may emphasize different elements of the pedagogy-related application of theory.

4.5. *Advancements of Theoretical Frameworks?*

Is there evidence of progress in the development of theoretical frameworks within our research scope? The inductive content analysis does not provide visible support for this, as only three papers were classified under I17, indicating the integration of theory into a new viewpoint and no additional classes emerged spontaneously to signify any advancements in framework development. This observation is paralleled in our deductive analysis using Malmi et al.'s classification, where classes C1 and C3–dedicated to adapting existing frameworks for new contexts or crafting new frameworks from pre-existing ones–were scarcely represented. Although Malmi et al.'s schema also encompasses class C2 indicating the development of a new theoretical construct from existing construct and evidence, it did not find use in our study. The development of new frameworks arguably represents a higher level of theoretical engagement, a probable reason for the limited presence of C1–C3 in our analysis in comparison to Malmi et al.'s, which specifically focused on identifying new theories and models in programming education, whereas we focused on the five most prominent ones in our research context.

5. Discussion

In this study, we analyzed the use of the five most prominent theoretical frameworks and constructs in group-work-specific project education literature, based on a recent systematic mapping study (Kokkoniemi and Isomöttönen, 2023b). Our findings offer several key observations.

A part of our summative analysis, we visualized the depth of theoretical framework application across papers using heatmaps. Although we regard these heatmaps as an initial attempt at illustrating the depth of application, we observed variability in how deeply the frameworks were applied. Our visualizations lead us to suggest that within this research domain, embracing a more theory-intensive approach to both research and its reporting could notably distinguish a study from the rest.

This conclusion is further supported by the observation that only five theoretical frameworks or constructs from the mapping study (Kokkoniemi and Isomöttönen, 2023b) appeared more than five times—the threshold we used to ensure a meaningful basis for describing usage patterns and enabling comparisons between frameworks. In contrast, they reported a total of 63 frameworks or constructs that were used fewer than five times, most appearing only once, which limited their inclusion in our analysis for comparative purposes. Additionally, 55.11% of the papers in their corpus lacked a clearly identifiable theoretical framework altogether. While this suggests that the broader landscape of theoretical use may be more diverse than our selected subset reflects, it also highlights a fragmented pattern of engagement where only a few frameworks are used with any consistency.

While our analysis covered a limited set of theoretical frameworks, the heatmaps revealed noticeable variation in how they were employed—some were deeply integrated into study design and analysis, while others appeared only in passing. This observation suggests that applying this type of visualization to a broader dataset could provide valuable insight into the ways theory is used across the field.

In Section 4.5, we showed that our analysis did not reveal any evidence of theoretical advancements based on the literature using these frameworks. As shown in Table 1, the frameworks appear consistently across the inspected period from 2010 to 2021, suggesting that their use is sustained rather than concentrated in specific years. This ongoing use, combined with the absence of evident theoretical development, points to a degree of stagnation in how these particular frameworks have been applied. An open question remains as to whether this pattern of stagnation extends more broadly across PjBL group work research, aligning with the observation by Malmi *et al.* (2022) that the CER continues to lack a definitive tradition of theory development.

An important distinction between our study and the original mapping study (Kokkoniemi and Isomöttönen, 2023a) is that the original work did not only focus on theoretical frameworks, whereas our analysis did. This difference in focus is reflected in the types of publications included: 65.3% of the papers in the original mapping were published in conferences or symposiums, compared to 58% in our corpus. In other words, our theory-focused selection resulted in a relatively higher proportion of journal articles. This aligns with the observation by Joy *et al.* (2009) that theoretical engagement is more common in journals, while conference publications, often limited by strict page constraints, tend to place less emphasis on theory. Given this context, an important question for the research community is whether conferences would generally benefit from placing more emphasis on theoretical contributions and/or increasing page limits to allow for more comprehensive theoretical engagement.

An illustrative example of how a theoretical framework can shape both the background and the analysis of a study is provided by Kearney *et al.* (2015), who examined group development in computer science engineering courses using Tuckman's Model of Group Development. The study begins with an extensive literature review on organizational behavior, with particular attention to Tuckman's model. The authors then applied the Tuckman's model during data analysis through a deductive coding scheme based on Tuckman's group development stages, though without adhering strictly to the original time sequence of the stages. Tuckman's influence continued into the findings section, which was structured according to the model's stages: Forming, Storming, Norming, and Performing—used directly as section headings. The framework clearly played a central role in shaping both the structure and interpretation of the study. In their conclusion, the authors note that the Tuckman's model remains valuable due to its communicability, suggesting it may still be the "best" model for bridging research and practice.

Stepping back from individual studies, a broader observation can be made regarding the types of theoretical frameworks used across the dataset. Firstly, As this study has shown, frameworks from other disciplines, such as the Big Five and MBTI, are used in this research domain. Notably, both were equally popular, even though the MBTI has been widely criticized in the field of psychology in recent decades (e.g., McCrae and Costa Jr., 1989; Boyle, 1995; Gardner and Martinko, 1996). This may indicate that there is room for further reflection on the use of personality theories in our field.

Secondly, based on the data in Table 2 and Figure 1, we conclude that Tuckman's Model of Group Development and Kolb's Experiential Learning Theory are frequently used in the background sections but have less impact on analysis and results compared to other frameworks, though there are notable exceptions, such as the study by Kearney et al. mentioned above. This pattern is particularly noticeable in the first heatmap on inductively developed classification, where a notably lower intensity of depth in theory usage is observed in many papers. The observation underscores the value of employing inductive analysis in a specific domain for revealing such trends.

The above-mentioned finding regarding Tuckman and Kolb aligns with an observation by Malmi *et al.* (2019): they observed that many papers merely cite theoretical constructs without explanation. We did not observe this pattern with the other frameworks in our study. Instead, the other frameworks were not only cited but also discussed more substantively in the related work sections, indicating a deeper level of engagement. This suggests that Malmi et al.'s observation may not apply to the other frameworks in our dataset. However, given the low number of papers per framework, these conclusions should be interpreted with caution.

Our analysis of group work in PjBL within CER aligns in part with earlier observations in the literature. Malmi *et al.* (2014) noted that CER frequently draws on theories from other disciplines, and Lishinski *et al.* (2016) observed a growing trend in the use of theories external to computing education. The frameworks examined in our study were likewise external to CER. However, in contrast to Lishinski et al.'s observation of increasing theoretical engagement, we did not see evidence of growing use over time. This may reflect the maturity of the five frameworks we focused on, which are already well-established within the field.

In our content analysis, we employed three approaches following Hsieh and Shannon (2005) and Elo *et al.* (2014): inductive, deductive, and summative. The integration of these approaches resulted in the final coding schemes shown in Table 2 and the theory depth visualization in Figure 1.

As an alternative approach, our content analysis might have benefited from incorporating a more general classification scheme during the deductive phase. For instance, the classification by Gregor (2006) from the Information Systems field could have been a viable option. This scheme includes classes for different types of theories, such as theory for analyzing, explanation, prediction, both explanation and prediction, and design and action. Using these broader categories could have simplified the process due to their general nature. While Gregor's classification alone might have been too broad to uncover notable trends specific to this domain, combining it with our inductive analysis could have facilitated various visualizations and cross-sectional analyses, enriching the insights gained from blending the two approaches. In contrast, such cross-sectional analyses and visualizations were not as applicable with Malmi et al.'s classification due to the detailed nature of both our inductive classifications and Malmi et al.'s scheme, making it difficult to find a meaningful way to combine them for additional insights.

Additionally, we question whether this type of research can be conducted without subjective interpretation by researchers. Regardless of how Inter-Rater Reliability (IRR) indicators are calculated, they only indicate that we were in agreement with each other in our interpretations, which are influenced by our discussions. This does not guarantee that another research group conducting a replication study would have similar discussions or make similar interpretations, even if their IRR indicators were also good. On these grounds, studies like ours are reflective of the authors' interpretation of the subject, rather than aiming to establish universally fixed truths. This subjectivity is not a weakness but an inherent characteristic of qualitative inquiry. Our findings should be seen as contributions to the ongoing dialogue about theory use within the field.

We believe that the present study can usefully complement the mapping study by Kokkoniemi and Isomöttönen (2023b). The mapping study authors envisioned future research directions along with discussing rarely used theoretical frameworks in their mapping results. The present study adds to this discussion by providing insights into *how* the more popular theoretical frameworks and constructs have been utilized.

5.1. *Recommendations*

Drawing from our analysis, we offer the following recommendations as contributions to strengthen the role of theory in PjBL group work research and practice:

1. *Integrate Theory into PjBL Group Work Pedagogy and Evaluate Its Impact*
   Our analysis of the Pedagogical Perspective category showed that the integration of theoretical frameworks into teaching was frequently associated with positive impacts on learning. Reported benefits included enhanced student reflection, improved collaboration, and greater group awareness. While these findings were mostly based on authors' conclusions rather than formal assessments, the outcomes were consistently described as beneficial (see., Section 4.4). Our findings provide illustrative examples that educators can draw on when incorporating theory into practice.
   We encourage educators and researchers to continue using theoretical frameworks to support Project-Based Learning. At the same time, we see value in original studies including systematic evaluation of the pedagogical impact of theoretical frameworks, as this would help clarify how effective they are in practice and further strengthen the connection between theory and classroom use.

2. *Develop Community Resources for Theoretical Integration*
As discussed in the Introduction, project-based learning and group work literature is often dominated by descriptive course reports, reflecting an interest in course design among educators. At the same time, PjBL offers ample room for educational design, making it a fertile ground for exploring the use of theoretical frameworks. To support theory-informed design work, the community could benefit from accessible shared resources—such as taxonomies of commonly used frameworks, annotated examples demonstrating theory integration, and step-by-step guides for applying theory in research and teaching. In particular, taxonomies could group frameworks according to their primary function—for example, as teaching tools or design tools, a distinction we have already demonstrated in this study. Frameworks could also be organized by their relevance to specific areas of group work. These resources could make theory easier to apply, especially for early-career researchers, and support more transparent and well-founded use of theory in the field.
3. *Structure Research Papers for Reusability in Secondary Research*
During our analysis, we came across studies that required thorough reading to grasp their methodology and goals accurately. We suggest that clearly outlining the methodological approach early in the paper can be beneficial, as this can significantly aid in more effective analysis in secondary research contexts like ours. The lack of explicit direction in the abstract or introduction, possibly stemming from the research tradition in question (emphasis on the qualitative side), initially complicated reading what these studies were methodologically about.

5.2. *Limitations*

We acknowledge several limitations in our study. While our study provides deeper insight into theoretical usage, our dataset was derived from a pre-existing systematic mapping study by Kokkoniemi and Isomöttönen (2023b). As such, we were constrained by the inclusion and exclusion criteria of that mapping. Our decision to focus only on the five most frequently used theoretical frameworks allowed for meaningful comparative analysis but may have excluded emerging or niche theories that could offer relevant perspectives. Although we reached a high level of inter-rater agreement (98%), a degree of subjectivity in interpreting theoretical use, particularly when it comes to identifying implicit usage, is an inherent aspect of this kind of qualitative content analysis.

5.3. *Future Work*

We found instances where theoretical constructs were applied as direct teaching vehicles. For example, Tuckman's Model of Group Development was utilized in a student-team retrospective to demonstrate that potential "storming" is a normal phase in group development. This use of theories as direct teaching tools is an interesting topic, showing that the gap between theory and practice can be bridged with relative ease in certain situations. When a suitable theory, model, or framework can be directly applied in practice, it can arguably become inherently more engaging and valuable for students, making the theoretical concepts tangible and relevant to their group work experiences. This was evident in how authors of the inspected papers favorably commented theory impact.

Future research could benefit from a focused and comprehensive investigation into the use of these constructs as practical teaching vehicles in PjBL group education. Such exploration could result in creating a taxonomy that organizes theoretical constructs, including those from neighboring disciplines, by their teaching applications and areas of group work, such as group formation and assessment. This taxonomy could be valuable to educators for designing coursework and group activities, and might also be useful for industry practitioners in similar planning efforts.

Finally, the question of theory depth remains an intriguing and worthwhile area for further investigation. Even this initial effort demonstrated that visualizing the presence of theory can prompt new reflections on how theory is engaged with and applied in this area of research.

6. Conclusions

This study conducted a qualitative content analysis of literature published between 2010 and 2021 to examine the use of prominent theoretical frameworks in group work research within PjBL in computing education. We demonstrated that frameworks were used either as teaching tools or to inform course design. In studies where frameworks were applied in these ways, authors frequently reported positive pedagogical outcomes. While computing education can reasonably be positioned as a design-based field—focused on discovering instructional designs that enhance learning (e.g., Nelson and Ko, 2018)—this perspective can and should coexist with the thoughtful use of theory in group work research within this context. Our findings highlight that theoretical frameworks, when used with clear pedagogical purpose, can meaningfully enrich both teaching and course design and should not be overlooked.

Frameworks such as Tuckman's model were frequently cited but often applied superficially, appearing mainly in background sections rather than being meaningfully integrated into research design, analysis, or pedagogical practice. In contrast, Social Loafing was more commonly used in a substantive way. Overall, however, many frameworks remained in the background, with limited integration into the core of the research. Inductive analysis proved especially valuable for identifying whether frameworks were used merely as background references or integrated more substantially into the studies.

We conclude that a more deliberate and theory-driven approach to both research and pedagogy is recommended to strengthen the conceptual foundations and impact of future work. Additionally, the creation of shared community resources and improvements in research reporting practices could facilitate deeper theoretical engagement and make it more accessible across the field.

The takeaway message is this: In research on group work within PjBL in computing education, theory use varies greatly in depth and is most often limited to brief mentions or related work sections. There is clear potential for more substantial engagement with theory, whether to support analysis and reporting, inform course design, or serve as a teaching tool.

Acknowledgments

The authors declare that there are no financial interests or personal relationships that could have influenced the work described in this paper.

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