Orchestrating Learning Together and Development of Team-Trust in Neuro-Typical and Neuro-Atypical Students: A Multi-Case Study

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***Abstract— Contribution:* This multi-case study compares Computer Orchestrated Learning Together (COLT) and Student Orchestrated Learning Together (SOLT) in cooperatively preparing first year university students for collaborative activities. COLT using Computer Orchestrated Group Learning Environment (COGLE), was perceived efficient, effective and inclusive for team effectiveness as it helps build domain knowledge and trust between neurotypical (NT) and/or neuro-atypical (NAT) teammates. This study confirms existing and identifies two new antecedents for trust, namely: resolving cognitive conflicts and real-time updates to domain knowledge. *Background:* Industrial and organizational psychology literature links effective teamworking with domain knowledge and trust. Building team-trust within a short period can be challenging, in particular in mixed teams of NT and NAT students. Facilitating teamwork can be resource hungry. Educational studies on trust and teamwork are therefore rare. *Research Questions:* This study investigates how orchestration affects teamwork by asking: 1) How does computer and student orchestration affect domain knowledge acquisition in neuro-typical and neuro-atypical students? 2) How does computer and student orchestration affect the development of trust between neuro-typical and/or neuro-atypical students? *Methodology:* Both qualitative and quantitative data were captured at multiple points within multiple (literal and theoretical replication) cases. Case summaries and a cross-case analysis provided further data and the methodological triangulation needed for analytical generalization. *Findings:* COGLE's scaffolding and non-social prompts for cooperation, shared goal orientation, shared monitoring, and shared working not only helped NT and NAT students learn together but also helped develop team-trust quickly. Delayed interactions, low team-trust, and clique formation were seen in SOLT teams.**

***Keywords*—Cognitive Conflicts, Computer Orchestration, Flipped classroom, Mastery Learning, Problem Based Learning, Project Based Learning, Teamwork, and Trust.**

I. Introduction

The effectiveness of work based teams has been shown to be dependent, amongst other factors, on team-trust [1]-[5]. Trust can help resolve conflicts between team members [1], [3]. There is extensive research on how trust builds within work teams, but due to the short-lived nature of many educational teams, trust is understudied within educational settings [3], [5]-[7]. Psychological safety, a more common focus than trust in educational studies, represents a perception where students feel happy to open up to peers as they no longer feel vulnerable working with them [5]. In addition to trust, team effectiveness also relies on the relevant domain knowledge and the self, co, and shared regulation skills of teammates [8]. One of the many purposes of higher education is to prepare graduates with the knowledge, skills, and attitudes needed for modern inclusive workplaces. Engineering courses often use collaborative approaches like Problem based, Project assisted, Project oriented, Project Based Learning (PjBL) and flipped classroom to help develop domain knowledge, graduate skills, and attitudes. However, as detailed later, these approaches may face many challenges relating to effectiveness, efficiency, and inclusiveness.

This research compares the use of cooperative Computer Orchestrated Learning Together (COLT) with Student Orchestrated Learning Together (SOLT) on perceived efficiency, effectiveness, and inclusiveness when used as preparation for collaborative activities. This study highlights the factors that may lead to team effectiveness, including those that may lead to the development of domain knowledge and trust. Teams here included either a mix of neurologically typical (NT) and neurologically atypical (NAT) students or just NT students. NAT refers to those with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD). A focus on supporting NAT students is getting increasingly more relevant to engineering education as more diagnosed and un-diagnosed NAT students join engineering courses [9]-[12]. Due to socio-communication challenges, NAT students may find it difficult to correctly place their trust in other teammates [13]-[14]. As studies looking at trust and supporting NAT students in educational settings are rare, this study addresses these gaps. To this end, two literal replication cases of COLT, each using a Computer Orchestrated Group Learning Environment (COGLE) were studied. COGLE runs within a web browser and orchestrates Group Wide Mastery (GWM) using a combination of a shared goal script and flexible peer instruction script. COGLE asks a series of questions and through textual prompts, pairs specific teammates to support each other, and orchestrates GWM in each team. GWM is achieved when all teammates correctly answer the same ten consecutive questions. When anyone makes a mistake the GWM script resets the count, and the team must continue to learn together until GWM is achieved. However, flexibility in the peer instruction script also allows students to help each other as they see fit instead of always being orchestrated by the script. COGLE shares performance data with teammates as well

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This work benefited from the Dean's fund to research collaborative learning.

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as play remedial videos based on the knowledge gaps specific to a team. No real-time interventions from a lecturer were needed, which if effective, could help see COGLE as an efficient intervention. In this study, students from two different first year cohorts used COGLE to prepare cooperatively in teams, over multiple COLT sessions. Later, in a Student Orchestrated Working Together (SOWT) session, they worked collaboratively on set activities, without COGLE. The SOWT represents a student orchestrated collaborative session, where they can apply their recently acquired knowledge and skills to set tasks, problems or projects. A third, theoretical replication, case representing a commonly used approach provided a comparison, as a different cohort of first year university students managed their own interactions (without COGLE) over 7 cooperative SOLT sessions, before engaging collaboratively in a SOWT session.

II. Background

A. Benefits of collaborative approaches within Engineering Education

Staff or student orchestrated collaborative activities within flipped classroom and project-assisted or PjBL projects are common in engineering education [15]-[20]. They are often adopted as a response to the increasing demands from industry and professional, statutory and regulatory bodies for an increased focus on graduate skills, in particular teamworking skills [17]-[19]. A collaborative approach has been reported to be more effective than individualistic approaches, in enhancing standardized mean difference in performance, with effect sizes ranging from moderate-to-large, i.e. Cohen's d=0.25 [21] to d=0.85 [22]. However, such results can be mistaken as a panacea, often drawing academics towards collaborative learning [23], while masking the accompanying challenges.

B. Challenges to Effectiveness, Efficiency, and Inclusiveness of collaborative activities

Research also highlights challenges with collaborative approaches [24]-[27]. For example, in flipped classroom, collaborative activities replace lecture time, but some students do not adequately prepare for these activities [24]-[25]. Students who prepared well may perceive it as unfair and be unwilling to engage, when asked to interact with underprepared peers in a flipped classroom session [24]. After investing the time to learn and prepare for orchestrating and facilitating peer-interactions, having to revert to previous ways of teaching when faced with underprepared students [25]. This can threaten the effectiveness and efficiency of the flipped classroom approach.

Teamworking skills and independence through interdependence in acquiring knowledge needed by a project are key to success in project assisted and PjBL [26]-[27]. Knowledge acquisition in collaborative settings does depend heavily on the domain knowledge of teammates and staff who can act as "more knowledgeable others" [26]. Such involvement of staff can be seen as resource intense. For teamworking skills, institutions often provide separate training, in addition to content and tutorial support, adding to the inefficiencies of PjBL [27]. Yet, social loafing is often cited as a factor in reducing team effectiveness [3]. To this end, Comprehensive Assessment of Team Member Effectiveness system (https://info.catme.org/) may prove useful. However, the ineffectiveness and resource intensive nature of project assisted and PjBL has led to internal criticism and decreasing management support within engineering schools [26]-[29].

Inclusiveness within collaborative activities can be a problem, too. If a mix of vociferous and quieter students are in the same team, it can lead to unresolved conflicts [1], [13] [30]-[32]. ASD is a condition where atypical emotion recognition, reduced eye contact, and lack of socio-emotional reciprocity can interfere with communications and understanding of social situations [33]. Even high-functioning ASD students may struggle with cognitive flexibility and may become emotionally charged or completely quiet as conflict emerges [34]. Furthermore, problems with trusting others, may affect their success in collaborative activities. ADHD students may find it hard to stay on task, fidget, be distracted easily, get bored quickly, interrupt others too often, and have difficulty keeping their attention on a person talking [32]. These attention and impulsive behaviors can interfere with social interactions for the ADHD student, which in turn could affect their knowledge acquisition and the development of trust in them by their teammates. In mixed NT and NAT teams, lack of trust can easily derail the positive effects of collaborative approaches. Commonly used reasonable adjustment for NAT students, such as using alternate individualized assignments, may actually deprive both NT and NAT students of a chance to work and develop skills together [35]-[36]. Separate teamwork training for NT and NAT students further add to the inefficiencies of PjBL [37]-[39]. Besides, separate training is a missed opportunity from an inclusion perspective. In fact, the challenges faced during teamworking are not just limited to NAT students but are faced by many NT students too [11]. Engineering educators need to challenge the status quo and prepare students for more inclusive workplaces.

C. Rationale for this work

Socio-communication challenges, lack of trust, poor conflict handling, and clique formation leads to ineffective teams [6], [39]-[40]. Very few engineering education studies on team effectiveness focus on psychological constructs of trust and conflict [3], [5]-[7]. Improving the support for developing skills and attitudes, is likely to benefit teamwork as both NAT and some NT students who may struggle with these skills. Inefficiencies and lack of inclusiveness of collaborative approaches and corresponding reasonable adjustments used, all call for a rethink on how NT and NAT students are supported within engineering education settings. Research has shown that children with ASD respond well to non-social cues when evaluating their ability to place their trust in peers correctly [40]. A COLT intervention with such cues thus represents a new direction in developing collaboration skills and attitudes as well as acquiring domain knowledge for NT as well as NAT students together. COGLE uses text-based prompts (non-social cues) presented by its interaction scripts, in addition to the social-cues that are naturally present. Whereas SOLT relies on the naturally present social-cues alone. This study improves the understanding of preparing engineering education teams in an inclusive, effective, and efficient way.

III. Methodology

This section describes the three cases, the use of COGLE, the theoretical framework, research design and students, research questions, measurement instruments, and types of analyses carried out in reaching the conclusions. Given the dialectical nature of knowledge and skills development at the heart of this study, the underlying ontology and epistemology is pragmatism, a research paradigm that embraces both qualitative and quantitative methods. Both authors share an interest in pedagogically inspired use of technology within engineering education. Ethical approval for this study was granted by the host institution.

A. Three real world cases

Two COLT and one SOLT real world cases, form the literal and theoretical replication cases in this study [41]. The cases were purposefully selected, with students in their first year, first semester, of a course in a UK university. Table I, shows the replication logic related to the eight-semester BEng in Engineering and Technology (case 1), the six-semester BEng in Electronic Engineering (case 2), and the six-semester BSc in Physics courses (case 3).

TABLE I
Three real world cases

Case	Cohort	FC/PjBL	Replication logic
1	BEng Engineering and Technology	FC	Literal (Used COLT)
2	BEng Electronic Engineering	PjBL	Literal (Used COLT)
3	BSc Physics	PjBL	Theoretical (Used SOLT)

All three cohorts take a year-long electronics module in their first year. Traditionally, case 1 uses flipped classroom approach to prepare students for a project assisted SOWT session. In this session, they design, build, and test circuits such as RC bass and treble filters within their designated teams. They learn about Ohm's Law, potential dividers, and RC circuits on their own before coming to the flipped classroom style SOWT session. Likewise, in addition to above topics, cases 2 and 3 traditionally cover transistors and Op-Amps as well. They prepare either on their own or in a SOLT way before they design, build, and test the RC filters and a headphone amplifier in a PjBL course.

In case 1, two teams of 3, cooperatively learnt in 4 two-hour COLT sessions using COGLE. They then designed the filters in their designated teams during a two-hour SOWT session. In case 2, three teams (of 3 or 4) joined the literal replication case and studied cooperatively in 7 two-hour COLT sessions using COGLE. The same 4 two-hour sessions as case 1 were used here in addition to 3 new two-hour sessions on the extra topics needed for the PjBL project. They then designed the filters and the headphone amplifier, within their designated teams during a two-hour SOWT session. Case 3, a theoretical replication case, represented the traditional case of SOLT. Here the students learnt using the same 7 two-hour content videos and questions (albeit without options) as used by COGLE cases. Here, two teams (of 3 or 4) prepared together (without COGLE), before designing the filters and the amplifier in a two-hour SOWT session. Students in all cases later progressed with the rest of their class to build and test the circuits they designed as part of this study. The electronic engineering topics used are representative of many first-year engineering courses, which should help with the transferability of the findings of this study.

B. Theoretical Framework

Team effectiveness is dependent on domain knowledge of teammates and team-trust [1]-[7]. This research uses a dynamic and formative model of trust. A formative model of trust assumes causality from the indicator in a survey item to the latent construct of trust [42]. Trust has three such formative facets namely affective trust, cognitive trust, and conative trust [43]-[46]. Cognitive trust forms as knowledge of past performance of teammates increases [7], [44]. The feeling of being genuinely cared for and supported by teammates (citizenship) helps form affective trust; and the frequency of such interactions feeds into conative trust, but it also feeds back into affective and cognitive trusts [7], [13]-[14], [43]-[45]. Within educational settings, affective and cognitive trust has been reported to take at least 8 sessions to develop [7].

C. Research Design

The study ran over a maximum of first eight weeks of the year-long electronics module the students were on. This minimized the effect of friendship on trust measurements and the impact of the module on domain knowledge. Most students had studied electronics at secondary school, so a pre-test was used to get a base-line measurement on what the students already knew. Those who took part included 5 female and 18 male students (N=23) aged 18 to 54, who volunteered and completed the study. There were: 6 students in case 1, 10 in case 2, and 7 in case 3. During their first week at the University, all students from the non-probabilistic and purposeful sample were randomly assigned to their teams. Several teams of purely NT or a mix of NAT and NT teammates were formed, which is representative of practice within engineering education. Case 1 had one student who self-declared as having ASD (Alex). Case 2 had a student (Harry) diagnosed with ASD (comorbid with ADHD) and another (Giles) diagnosed with ADHD. Case 3 had one student (Dee) diagnosed with ASD. All other students were assumed to be NT. All names reported here are pseudonyms. Informed consent was obtained from all students.

Students completed a two question, free text, Daily Events Survey (DES) adapted from another engineering education study 10[47]. It captures the effects of scripting interactions on teamworking. The two questions were "*Describe things that went really well and also things that did not go so well for you and/or your teammates today.*" and "*Also, describe how the recent use of COLT/SOLT, by you or others in your team, further improved the group interactions in situations you described as 'did go well' above. Likewise, for things that did not go well, do you see any role that COLT/SOLT may have played in it not going so well today?*" The daily self-reporting survey, although not without its limitations, was chosen over more commonly used video-based approaches as it generates focused data from key events leading to quicker thematic analysis without losing the time dimension.

After the SOWT session, 22 of 23 students were interviewed individually using a semi-structured interview that lasted from

1 hour for NT students and up to 2 hours for NAT students as needed. The key questions asked them about their learning experience, trust in their teammates, and teamworking. For example, "*How was your experience of the teamworking during the SWOT session?", "How was your sense of trust (conative, cognitive, and affective aspects) in your teammates?", "How valued did you feel?",* and when asking about the C/SOLT "*How did the sessions support your learning/team-building?", "How did ice-breaking happen in your team?",* and "*How did conflicts emerge and how did your team resolve the same?"*. Only one NT student in the literal replication case (case 2) was not interviewed as theoretical saturation was achieved by the penultimate interview. The first author transcribed first six interviews to get familiarized with the data. A professional transcriber transcribed the rest of the interviews verbatim. Qualitative data were analyzed line by line using Braun and Clark's grounded theory inspired Thematic Analysis to generate qualitative themes [48]. The first author coded and discussed the codes iteratively with the second author until both agreed. To enhance the trustworthiness of the research two levels of coding were used for each line of qualitative data: semantic coding and latent coding. The former represented what was being said by the student and the later what was being interpreted by the coders. This separation was important to illuminate any researcher bias as COGLE was developed in-house. Only when the two codes were the same, were they used in building themes and sub-themes. Later on, the bucket themes from the theoretical framework, described in section III B, were also applied to the analyzed data to expose any discursive gaps [49] between the existing theory and the practice in COLT and SOLT. Interview themes were given counts to reflect how widespread they were in each case. Likewise, DES themes were counted only where a student gave a relevant account repeatedly for the majority of the COLT or SOLT sessions.

In addition to the above two sources of qualitative data, trust data were collected from all students at the start of the study and before the SOWT session, but also after the fourth and the seventh COLT/SOLT sessions as relevant. Trust is a multi-faceted construct with various contested models in the literature [43]-[46]. Its multiple facets do not necessarily correlate with each other. Trust therefore was modelled formatively in this study [42], [46]. It was measured by selecting and modifying one item per facet known to form trust from pre-existing surveys [44], [46]. For formative items the direction of causality needs to be from the indicator in the item to the latent facet of trust. For cognitive trust a reflective item was converted to a formative item, with reliability as measured by Cronbach's alpha of 0.88, from a pre-existing survey [44]. For the remaining two facets, formative items were found and modified to suit the context. The three items (shown in brackets) were: affective (*my teammates help me when I need it*) [46], cognitive (*my teammates are knowledgeable in the topic area we are studying together*) [44], and conative (*my teammates can be counted on*) [46]. Reliability score is not applicable for formative items as only one item is used per facet. Construct validity in formative measurements can be demonstrated if the Variance Inflation Factor (VIF) is below 3.33, the bivariate correlation is below 0.8 and the weights are all positive, as suggested by Cenfetelli and Bassellier [42]. Using SPSS®, the VIF scores were calculated to be below 3.33 for affective, cognitive, and conative trust items, however, due to the ordinal nature of Likert scale, Spearman's correlation, rho, was considered an appropriate test to use here. It resulted in values of 0.40, 0.46 and 0.72 for the three pairs. All were below 0.8, indicating no multicollinearity, and that the three items measure three different formative facets of trust.

Team effectiveness is also dependent on relevant domain knowledge acquisition by the teammates [1]-[7]. A pretest was administered before the first COLT and SOLT sessions and the posttest before the SOWT session to capture the test scores. In the absence of a suitable concept inventory to test the topics taught during the sessions, the first author, an electronic engineering lecturer, developed a pre/posttest. The module coordinators in each case reviewed all the content and assessments used in this study and confirmed them as appropriate to prepare and assess their students. Due to small sample sizes, a two tailed non-parametric Wilcoxon's signed rank test ($p<0.05$) and correlation effect size, r, were calculated to test whether there was a significant difference between the pretest and posttest scores on the domain knowledge test. To enhance the content validity, the pre/posttests and the S/COLT sessions used the same questions, albeit with different values. The qualitative themes from the DES and the interviews, for all three cases, were used to triangulate the findings from the test scores.

Different data sources and types along with multiple cases helped with data and methodological triangulation, and also improved the trustworthiness (dependability and transferability) and validity of this research [50]. The case summaries and cross-case analysis assisted with analytical generalization, discarding rival theories, and deliberating on transferability of findings [41], [50]-[52] related to team effectiveness, domain knowledge, and trust. In particular, the SOLT case was part of this study to explore the rival theory explanation that trust building takes over 7 sessions, by students merely learning together [7]. As shown in section III. B, team effectiveness, domain knowledge, and trust are well developed theoretical concepts, therefore a *"gaps and holes"* approach to theory building from case-studies was adopted to confirm existing interrelations and identify new ones [51]. In particular, this study makes contributions relating to the new antecedents of trust and appears to be the first within engineering education settings to study trust and team effectiveness. It also highlights the impact of the GWM approach on team effectiveness and its link with acquiring domain knowledge and self-reported or perceived self-efficacy. Given the number of students and the use of a multi-case study design, statistical generalization to a population was not the aim of this research. Instead, the aim was to achieve analytical generalization to theory, through pattern matching between the propositions from existing theories, linking team effectiveness with domain knowledge and different facets of team-trust, and the corresponding empirical findings from the three cases [50]-[51].

D. How was COGLE used?

The carefully designed questions used in GWM encouraged discussions between students and trigger cognitive conflicts, similar to peer instruction [53]-[54]. COGLE's GWM script targets mastery of concepts by the entire team. Peer instruction script orchestrated interactions, which when combined with the

GWM script extends Bloom's concept of mastery [55]-[56] into the social. COGLE played videos, hosted for example on YouTube®, for teammates to watch together [57]. COGLE also help teammates monitor real-time performance updates of each other. The monitoring, GWM and peer instruction script prompt students to learn together within a shared physical space and engage in repeated cooperative interactions using textual cues. These scripts may eventually become internalized by students and may be transferred to un-orchestrated learning and teamworking sessions such as the SOWT session. COGLE is also able to identify mistakes that are prevalent within a team, thanks to the careful question design. It plays a remedial video to scaffold learning in each team to address the mistakes. It uses multi-media (short video, textual questions, and orchestrated peer-interactions), which can help students, particularly ADHD students with their concentration, as it breaks the monotony of learning just by watching a video or doing a quiz. The repetitiveness could help ASD students feel comfortable by knowing what to expect. COGLE encourages balanced and frequent interactions between NT and/or NAT teammates using non-social/textual prompts. Such prompts have been shown to be beneficial for trust development in NAT children [40].

E. *Research Questions*

This study investigates how orchestration might affect teamwork by asking:

1) *How does computer and student orchestration affect domain knowledge acquisition in neuro-typical and neuro-atypical students?*

2) *How does computer and student orchestration affect the development of trust between neuro-typical and/or neuro-atypical students?*

IV. RESULTS

Quantitative data were triangulated with the qualitative themes on student perception of domain knowledge, trust, and team effectiveness in all three cases. This added rich insights into how students learnt together and developed trust. Having multiple cases helped with analytical generalization to theories linking domain knowledge, trust, and team effectiveness.

A. *Case 1*

The non-parametric Wilcoxon's signed rank test resulted in Wt =0, which is the same as the critical value, Wc=0 (n=6). A Z-value of -2.20 (p value not computable due to small sample size), meant that COGLE as an intervention has a large (r>0.5) [58] two series correlation coefficient effect, r = 0.64. Large effect size and small sample sizes call for triangulating the results with the qualitative themes.

Tables II to III show repeating themes and sub-themes with counts, from the DES and the interviews, relating to domain knowledge, perceived self-efficacy, and trust. The quotes show that GWM builds perceived self-efficacy (5/6) and enhances learning (4/6). Only the NAT student reported needing more time to enhance their perceived self-efficacy.

Fig. 1 shows that a majority of students (5/6) developed all 3 facets of trust in their teammates within just 4 COLT sessions. The teammates of NAT student trusted all their teammates at the start of the SOWT session. The NAT student, on the other hand, was over trusting before the study but after 4 sessions, had updated their cognitive trust from 7 (over trusting) to 5 (still trusting) on a 7-point Likert scale, based on *real-time performance updates*. Late arrivals to the SOWT session caused one student to temporarily change their *conative* trust to neutral.

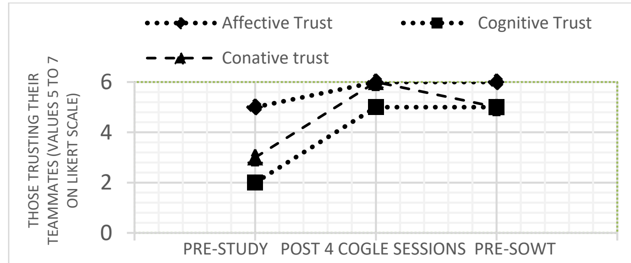

Fig. 1. How widespread facets of trust were over time when using COGLE in case 1 (n=6).

TABLE II
THEMES AND SUBTHEMES IN DAILY EVENTS SURVEY – CASE 1

Theme/ Sub-theme	Description	Count
Orchestrates GWM	COGLE enabled GWM of topics.	6/6
Reduces social awkwardness	Early pairing of NT or NAT students helped with turn taking and natural communications flowed later.	5/6
Builds self-efficacy	Repeatedly answering questions until GWM builds self-efficacy.	5/6
Builds trust	GWM builds trust in each other.	5/6
Team effectiveness and satisfaction	Felt teammates worked well together.	4/6

TABLE III
THEMES AND SUBTHEMES IN INTERVIEW DATA – CASE 2

Theme/ Sub-theme	Description	Count
Builds trust	Interactions frequency, helping each other, cognitive conflicts, relevant past performance all helped.	6/6
Encourage natural communications	Quickly overcame social awkwardness and made communications feel natural.	6/6
Enhance learning	GWM helped learn topics well.	4/6
Team satisfaction	Teamwork led to meeting the specifications.	4/6
Builds self-efficacy or corrected it	Achieving GWM helped build self-efficacy or corrected it.	5/6

The theme counts in Tables II and III, trust survey results in Fig. 1 and quotes below, show that COGLE orchestrated *several interactions (high frequency)* when discussing each question during GWM from the *very first session*. The teammates *helped each other (citizenship), were able to monitor real-time updates on each other's knowledge* and *resolved several cognitive conflicts together*. These aspects of COLT help develop different facets of trust, and all NT and NAT students trusted (6/6) each other during SOWT session.

Bob and Cyrus were NT teammates of the NAT student Alex. The quotes show how COGLE orchestrated the teams and help build trust:

"[COGLE's GWM and tailored support] allowed people to *be more confident* when *discussing* questions and to build on *everyone's knowledge*." (Cyrus, Session 2)

"As we *all talked* [during COGLE orchestrated interactions] *we got the input of each of our strengths* of the subject applied before answering [each question]." (Frank, Session 1, DES)

"I think [to] start *building confidence* [trust]...2 or 3 [COGLE sessions] would be really good to… start *getting into it properly as a team*." (Bob, Interview)

"*I could see where my logic was incorrect*… that's for my *learning*... but... from the *team* side of things... *it [resolving cognitive conflict] was good*… it *increased the relationship [trust]*" (Alex, Interview)

The SOWT session was also perceived as effective, efficient, and inclusive. Both teams were successful (team design scores 85% and 94%) in completing the SOWT task within the set time and the NAT student did not feel left out.

In summary, effective teamwork was observed as domain knowledge and trust developed quickly without any teacher orchestration, thereby increasing the perceived efficiency of COGLE. Triangulating data from all sources suggests that GWM and peer instruction scripts in COGLE helped improve domain knowledge of most students. Practicing multiple choice questions and achieving GWM help build their perceived self-efficacy [59]. The NAT student, who returned to education after several year's gap, had increased their posttest score but reported that they needed more time to feel the same way. Likewise, triangulating data from all sources suggests that team-trust builds quickly as *frequent interactions* involving peer *help* (*citizenship*) and *cognitive conflict resolution* were orchestrated and when *relevant past performance* of NT and NAT teammates were shared in real-time in COGLE.

B. Case 2

The non-parametric Wilcoxon's signed rank test resulted in Wt=0, which is less than the critical value, Wc=3 (n=10). A Z-value of -2.80 (p=0.005), is significant, and equates to a large (r>0.5) [57] two series correlation coefficient effect, r = 0.63 due to COGLE. Similar to previous case, Tables IV to V show repeating qualitative themes and sub-themes with counts, from the DES and the interviews, showing that COGLE can orchestrates GWM (10/10) and enhances learning (7/9). A majority, including the NAT student, reported improved perceived self-efficacy (7/9). Note that in Table IV, only 8 out of 10 students completed the DES post SOWT session, whereas all ten completed the DES post COLT sessions. Table V shows themes from 9 students who were interviewed.

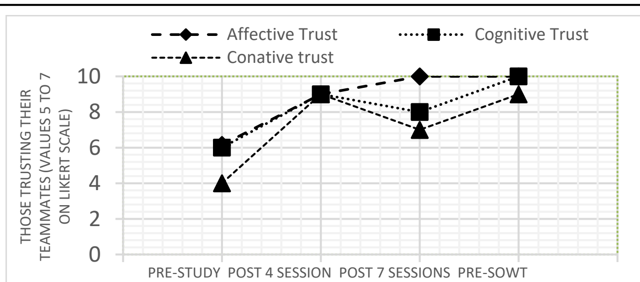

Fig. 2. How widespread facets of trust were over time when using COGLE in case 2 (n=10).

Fig. 2 shows that a majority of students (9/10) developed all 3 facets of trust in their teammates within just 4 COLT sessions. The teammates of NAT student trusted all their teammates by this time and continued to do so even at the start of the SOWT session. One of the NAT students was under-trusting and after 4 sessions, had updated their trust from 4 (neutral) to 6 (trusting) on a 7-point Likert scale, based on the *real-time performance updates.* Although some fluctuations were noted in cognitive and conative trust as topics became more involved and teammates arrived late to some COLT sessions.

The theme counts in Tables IV and V, trust survey results in Fig. 2 and quotes below, show that COGLE provided *several interactions (frequency)* from the *very first session*, where all teammates *helped each other (citizenship), got real-time updates on each other's knowledge,* and *resolved several cognitive conflicts together*. These aspects of COLT help develop different facets of trust, and all NT and NAT students trusted (10/10) each other during SOWT session. The perceived *self-efficacy* and *trust* were up by session 4, and despite fluctuations held before the SOWT session too.

Rita and Ira were NT teammates of NAT students Harry and Giles and Cathy, Ben and Andy were NT teammates. The quotes show how COGLE orchestrated the teams:

"It [COGLE] was good because *it made me understand* what I had done *wrong*." (Cathy, session 2, DES)

"The system *provided analytics*…to showcase our group's *rough road to mastery*…so the *system helps us build strong bonds*… may even *surpass Hydrogen Bonds at this rate*." (Ben, session 4, DES)

"It [COGLE] just… made it easier for us to talk to each other …, *make everyone on the same level*… *I kept on getting it wrong*… it would just be Giles or *Harry, depending on whoever like* [knows the topic will explain it to me]." (Rita, Interview)

"*We trust each other's work*…based on previous [COGLE] sessions *we could see who was good at what*." (Andy, Interview)

"*We were working quite well together* by that [last COLT session] point… a lot of the *social aspects* of… COGLE I think are really, really good." (Giles, Interview)

TABLE IV
THEMES AND SUBTHEMES IN DAILY EVENTS SURVEY – CASE 2

Theme/ Sub-theme	Description	Count
Orchestrates GWM	COGLE enabled GWM of topics.	10/10
Reduces social awkwardness (where present)	Early pairing of NT or NAT students helped with turn taking and natural communications flowed later.	3/10
Build self-efficacy	Repeatedly answering of questions until GWM builds self-efficacy.	10/10
Builds trust	GWM builds trust in each other.	10/10
Team satisfaction	Felt that outcome was good.	7/8
Team effectiveness	Felt that teammates worked well.	5/8

TABLE V
THEMES AND SUBTHEMES IN INTERVIEW DATA – CASE 2

Theme/ Sub-theme	Description	Count
Builds trust	Interactions frequency, helping each other, cognitive conflicts, relevant past performance all helped in building trust.	9/9
Encourage natural communications	Quickly overcame social awkwardness and made communications feel natural.	9/9
Builds self-efficacy or Confidence corrected	Achieving GWM helped build self-efficacy or corrected confidence.	9/9
Team satisfaction	Teamwork led to meeting the specifications.	8/9
Enhances learning	GWM helped learn topics well.	7/9

The SOWT session was perceived effective, efficient, and inclusive. All teams were successful (team scores 87%, 55% and 77%) in completing the task within the set time and the NAT and NT students worked well with each other.

In summary, effective teamwork was observed as domain knowledge and trust developed quickly without any teacher orchestration, thereby increasing the perceived efficiency of COGLE. Triangulating data suggests that GWM and peer instruction scripts helped improve domain knowledge of all and perceived self-efficacy of the majority of students through repeated practice [59], including for NAT students. Likewise, triangulating data from all sources suggests that team-trust builds quickly as *frequent interactions* involving peer *help* (*citizenship*) and *cognitive conflict resolution* were orchestrated and when *relevant past performance* of NT and NAT teammates were shared in real-time in COGLE.

C. Case 3

Wilcoxon's signed-rank test resulted in Wt=1, which is greater than the critical value, Wc=0 (n=6), i.e. the null hypothesis cannot be not rejected. Tables VI and VII show that 5 students felt underprepared ("All in the same boat") for the SOWT activity and 6, including the NAT student, reported low perceived self-efficacy. Differences in the maximum count in Table VI reflect the fact that only 6 students completed the DES after SOLT sessions, whereas all 7 completed it post SOWT session. Triangulating quantitative results with these themes, supports that SOLT was not good for knowledge acquisition.

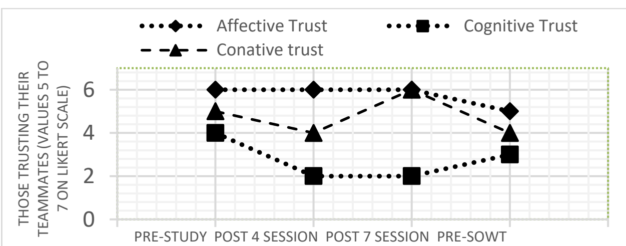

Fig. 3. How widespread facets of trust were over time when using SOLT in case 3 (n=7).

Fig. 3 shows how cognitive trust was not widespread unlike some other facets. The theme counts in Tables VI and VII, trust survey results in Fig. 3 and the quotes, show that SOLT may resulte in low perceived self-efficacy (6/7) and low trust (5/7) in NT and NAT students alike and poor team outcomes. NT students were *unable to trust the NAT student*. Besides, the NAT student remained over trusting and was the only one to have increased their trust (all 3 facets at 5 or above on 7-point Likert scale) over the 7 SOLT sessions. *Limited interactions*, mostly within *cliques*, excluded NT and NAT students alike. *Only one or two cognitive conflicts* emerged here.

Bill, Adam, and Chi were NT teammates of NAT student Dee. The quotes show the experience within SOLT teams:

"When things were easy [first 3-4 sessions], *we didn't talk to each other*… when things *get more… complex*, *we start to talk together*." (Bill, Interview)

"The video [used in 4th SOLT session to learn] … was not very engaging …*we struggled with answering the question*. On the other hand, because we were all confused and *on the same boat*…" (Chi, Session 4 DES)

The *social awkwardness* eventually disappeared as *psychological safety* developed. In the last two sessions Adam orchestrated learning together by using the overhead projector:

"*But*, if it was all upon the [shared screen]… *we were all*… [discussing]." (Dee, Interview)

Dee could not answer the questions in some of the SOLT sessions and was seen as an outsider. He arrived underprepared and late to the SOWT session, assumed that his teammates had learnt well, and that they were making good progress:

"He [Dee] didn't really communicate… Would he be *considered external [/trustworthy]?* Like he was *not really… completely in the group*." (Adam, Interview SOLT part)

"Yeah, *they*-, all-, those three *were coming together really well*." (Dee, Interview SOWT part)

All except Dee, had realized they were in the same boat (5/6), i.e. developed *psychological safety* [5], which helped them in the SOWT session, albeit within a *clique*:

"*We did try* and make *a few jokes*, saying like he… was quite confused… like, yeah, *we all felt the same way as well*. But… he thought [only] *he* didn't know…" (Chi, Interview)

"We started to do it [the SOWT task] together, but then *we started to* do it, *do it separately* [as Chi and Adam for a clique] … and that was the problem." (Bill, Interview)

"We … easily… work (sic) out the low and high pass filter *but not the amplifier* [taught in last 3 sessions]." (Adam, Interview SOWT part)

When informed of the outcome of his team, Dee reflected in the interview that he may have wrongly assumed again, that his teammates were capable of finishing the work. He recalled past team experiences, which had broken down similarly:

"I may have just committed the *sin* that they… knew what they were doing… *assuming things*, 'cos that *usually leads to just big (sic) problems*." (Dee, Interview)

TABLE VI
THEMES AND SUBTHEMES IN DAILY EVENTS SURVEY – CASE 3

Theme/ Sub-theme	Description	Count
Delayed and varying communication	Worked on their own, until psychological safety developed	4/6
All in the same boat.	Realized late, that they knew little.	5/6
Partial completion	Felt could not complete the full task.	4/7
Partially satisfied	Felt learned more than they could have	3/7
Partial knowledge	Felt they did not learn enough	3/7

TABLE VII
THEMES AND SUBTHEMES IN INTERVIEW DATA– CASE 3

Theme/ Sub-theme	Description	Count
Delay in reduction of social awkwardness	Many felt interactions awkward till later SOLT sessions	5/7
Low self-efficacy	Felt they were not ready for the task.	6/7
Low trust in teammates	Felt they were in the same boat and did not know enough to do the task.	5/7
Ineffective teamworking	Students felt that their teams were ineffective in different ways	5/7

The SOWT session itself, was only partially successful (team scores 21% and 25%) and SOLT was not perceived to be as effective, efficient, and inclusive as the COLT cases.

In summary, teamwork was only partially effective. Triangulating data, suggests that SOLT did not improve domain knowledge or perceived self-efficacy in many students. SOLT did not mask or help with the socio-communication difficulties NAT student Dee faced. *Psychological safety* made students comfortable to work together in sessions 6 and 7. Coincidently, here they used the projector to share solutions, similar to how COGLE orchestrated interactions, as one student acted as the team orchestrator. Just two such sessions were not enough and the cliques that formed earlier, reappeared in the SOWT session. Although, affective and conative trust developed over time, limited student-orchestrated *interactions*, fewer naturally occurring *cognitive conflicts* and limited sharing of *performance updates* between teammates could account for the less widespread cognitive trust when going into SOWT session. Lack of trust, perceived self-efficacy, and domain knowledge could explain the partial effectiveness observed in the SOWT session.

D. Cross-case similarities and differences

The three case summaries show some key similarities and differences in how individual students developed their knowledge and trust in each other.

In both COLT cases, achieving GWM for each topic, before moving on, had a large effect on each teammate's domain knowledge and help build their perceived self-efficacy (see quotes and Tables in section IV) through mastery as in [59]. Wilcoxon's signed rank test results and corresponding large effect sizes in both COLT cases as well as high SOWT scores suggests domain knowledge was improved through GWM in COGLE. Although a mature NAT student reflected on the need for more practice using COGLE at home on their own [59]. In both COLT cases, COGLE can successfully orchestrate *early pairing of NT and/or NAT students*, which helped with *turn taking*, as shown by the counts in the themes in Tables II and IV and related quotes. Early DES and interview quotes show how regular pairing helped overcome the *social awkwardness* in NT and NAT alike, *and natural communications flowed later*. Themes show that COGLE encouraged goal-oriented *citizenship* behavior. Resetting the count on mistakes, affected the whole team and made them work together to achieve GWM. The question design was such that *cognitive conflicts* emerged during the peer instruction. However, through feedback on correct answer and remedial videos, students were able to resolve them peacefully and without the needs of a teacher or a student to do the orchestration. Furthermore, the feedback provided teammates *a real-time update on the performance* of their teammates. These aspects of COGLE can help develop trust between teammates in just 4 COLT sessions (see quotes and Fig. 1 and 2 in section IV). Whereas, previous research suggests 8 sessions are needed to build trust, which is based on a rival explanation linking trust with time spent together [7]. However, the conative and cognitive trust built in the early sessions was fragile. Depending on specific events such as a teammate turning up late to sessions (affecting conative trust) or varying difficulty of the content being learnt (affecting cognitive trust), trust levels fluctuated as shown in Fig. 1, Fig. 2 and Fig. 3 and supported by qualitative comments in all three cases.

COGLE prompts masked some of the socio-communication challenges NAT students faced. The prompts also provided relevant cues for all students to take turns, thereby *encouraging natural communications* between *everyone* as shown by the relevant themes and counts in Tables III and V and the quotes from teammates of NAT students. All this helped NT students trust other NT and NAT students alike, as shown by the quotes in section IV A and B. Furthermore, the quotes also show that the *real-time updates* and *cognitive conflicts* that COGLE orchestrated, provided information on the progress and domain knowledge of teammates. This information enabled NT but also NAT students to develop cognitive trust in teammates. As a result, NAT students benefitted, as deciphering the same information from social-cues can be a challenge for them. Similarly, the over and under trusting tendencies of ASD students meant that they also benefitted in both cases. In terms of teamwork, COLT teams were perceived to be effective in flipped classroom and PjBL tasks as shown by good SOWT scores, collaborating well without any cliques formed, and the themes from the interviews and the DES.

In contrast, the SOLT case (see Section IV C, Tables VI and VII and quotes) saw *delayed* and *fewer interactions.* There were much less *citizenship* opportunities realized or naturally occurring *cognitive conflicts* resolved. Affective and conative trust were widespread after 7 SOLT sessions. However, *cognitive trust* was less prevalent as shown in Fig. 3. Therefore, the rival theory that time helps build all facets of trust was not supported [7], [43]. Instead, students opened up to each other much later than in COLT due to *psychological safety ('all in the same boat')* being developed [5]. Lack of improvement in posttest scores, Wilcoxon's signed rank test result and quotes in section IV C, show that in SOLT not all students improved their domain knowledge and many had *low perceived self-efficacy* to complete the task. '*Social awkwardness',* where present, did reduce over time. But, SOLT could not mask or help with socio-communication challenges. Quotes from teammates show that the NAT student *was perceived as different.* Furthermore, the quotes show that the NAT student remained over trusting, a trait linked to people with ASD [40], and could not place trust correctly in their teammates. Difficulty in understanding social cues could explain why the NAT student was the only student who actually enhanced their trust scores in others. He was not aware of the feeling of *psychological safety* that the others had developed. Highlighting the need for facilitation, during the last two sessions, Adam, unprompted, orchestrated team interactions using a shared screen much like in COGLE. But lack of knowledge, perceived self-efficacy, and cognitive trust, meant it was too little, too late as shown by low SOWT scores and partial task completion. Also, *cliques* that formed in the SOLT sessions continued into the SOWT session. This shows the importance of a knowledgeable other, either a teacher or a student or even a COLT system in orchestrating interactions. COLT can flexibly orchestrate, using textual cues, the development of trust, knowledge, and perceived self-efficacy. The cases suggest that trust and domain knowledge are needed for effective teamworking in these first-year teams.

V. DISCUSSION AND CONCLUSIONS

COLT scripts were perceived as beneficial for an individual's acquisition of domain knowledge, building trust, and development of perceived self-efficacy of teammates. With the absence of a GWM script and a flexible peer instruction script, the learning activities, the feedback and the support were perceived as less targeted in SOLT than in COLT sessions.

In relation to research question 1, COLT scripts had a large effect size on domain knowledge acquisition. GWM scripts in COLT efficiently engaged students in multiple rounds of peer instruction using multiple-choice questions, enabling self-assessment and immediate feedback. Repeated self-assessment using such questions has previously been shown to enhance self-efficacy [59]. In addition, SOLT did not use a GWM and was not perceived as effective for domain knowledge acquisition as COLT.

In relation to research question 2, *trust* quickly developed between teammates as COGLE made teammates *interact frequently* with each other in *a helpful way (citizenship)* confirming the two existing antecedents [43]-[45]. Knowledge exchanges during peer instruction and immediate shared feedback in COGLE were linked to *cognitive trust* development. COGLE helped improve knowledge of *past performance* of the teammates, confirming another existing antecedent of team-trust [44], but in a *real-time way*. Like in other studies, resolving cognitive conflicts together was good for learning and collaboration skills. No other engineering education studies were found to show that resolving cognitive conflicts can improve *cognitive* trust or one that links COLT and SOLT interactions with *affective* and *conative* trust. This research study appears to be the first to find evidence suggesting that COLT helps reduce *social awkwardness* between teammates by promoting repeated pairings and interactions from the very start of teamwork. And also, to identify *cognitive conflict resolution* as a potential antecedent for team-trust. In particular, the *resolving of cognitive conflicts* had a strong impact on *enhancing trust* (cognitive as well as affective trust) between teammates. As COGLE triggered several antecedents of trust together from very early on, team-trust was developed efficiently in just 4 sessions (see Fig. 1 and Fig. 2) compared to 8 sessions reported in literature [7]. Within this study too, in the SOLT case, not all three facets of trust were widespread even after 7 sessions. Cognitive conflict resolution and interactions were limited in SOLT teams. They took time to develop the feeling of *psychological safety*, which helped them open up to each other [5]. Furthermore, COGLE uses non-social cues and textually prompts interactions between teammates. This study appears to be the first, within an engineering education context, to highlight the importance of non-social cues in developing team-trust in NT and NAT students, whilst correcting the trusting behaviors of NAT students [40]. NT students valued their NAT teammates and vice-versa as they took part in COGLE orchestrated interactions. Whereas, in SOLT settings cliques were formed and some NT students did not develop trust in other NT and the NAT student. However, the NAT student over trusted his teammates, due to missed social cues [40] in the SOLT case.

In conclusion, triangulating data from multiple sources within and across the literal and theoretical replication cases, this study makes the following contributions. It shows that learning together cooperatively before working together collaboratively, in first year PjBL and flipped classroom settings, can be perceived as beneficial for domain knowledge. Regular self-assessment and achieving GWM can lead to high posttest scores and enhanced perceptions of self-efficacy [59]. COGLE scripts can orchestrate frequent interactions and citizenship behavior, both of which are known antecedents of trust [43]-[45]. This study additionally identified new potential antecedents for trust by illuminating the discursive gap linked to *resolving cognitive conflicts* and providing *real-time past performance updates* in developing team-trust. Improved domain knowledge and trust can lead to effective teamwork in SOWT sessions even when computer orchestration had been deliberately removed. Inclusive orchestration can be seen as key to effective teamwork. In terms of implications for practice, off-loading domain knowledge and teamworking skills acquisition to COLT could provide an effective, inclusive, and efficient solution to overcome the resource-intensive nature of collaborative approaches like PjBL and flipped classroom.

Future research could be carried out in different contexts to strengthen the analytical generalization shown here. Large effect sizes in this study warrant other research designs, such as quasi-experimental studies, with more students where statistical generalization of the findings could be investigated. Analysis of qualitative data suggested perceived self-efficacy, however, a pre-validated survey could be used in future studies to reduce socially acceptable responses. Further research that extends understanding of how developing trust, links to the development of self, co, and socially shared regulations skills [8] in students, will be published separately.

Acknowledgment

The contributions of several French interns who developed COGLE over several years under the first author's guidance are thankfully acknowledged. The valuable comments from the reviewers of this paper are also gratefully acknowledged.

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