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A Pedagogical Framework for Learning Analytics in Collaborative Inquiry Tasks: An Example from a Teamwork Competency Awareness Program

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ABSTRACT
Many pedagogical models in the field of learning analytics are implicit and do not overtly direct learner behavior. While this allows flexibility of use, this could also result in misaligned practice, and there are calls for more explicit pedagogical models in learning analytics. This paper presents an explicit pedagogical model, the Team and Self Diagnostic Learning (TSDL) framework, in the context of collaborative inquiry tasks. Key informing theories include experiential learning, collaborative learning, and the learning analytics process model. The framework was trialed through a teamwork competency awareness program for 14 year old students. A total of 272 students participated in the program. This paper foregrounds students' and teachers' evaluative accounts of the program. Findings reveal positive perceptions of the stages of the TSDL framework, despite identified challenges, which points to its potential usefulness for teaching and learning. The TSDL framework aims to provide theoretical clarity of the learning process, and foster alignment between learning analytics and the learning design. The current work provides trial outcomes of a teamwork competency awareness program that used dispositional analytics, and further efforts are underway to develop the discourse layer of the analytic engine. Future work will also be dedicated to application and refinement of the framework for other contexts and participants, both learners and teachers alike.

CCS Concepts
• **Applied computing~Collaborative learning** • *Human-centered computing~Visual analytics* • Human-centered computing~Synchronous editors • General and reference~Design

Keywords
Teamwork, teamwork competency, collaboration, pedagogical model, learning design, dispositional analytics, assessment, twenty-first century skills, evaluation.

1. INTRODUCTION
Several learning analytics papers have proposed pedagogical models for learning. Greller and Drachsler [14] conceptualize that learning analytics (LA) enable many different types of pedagogies and this can either be implicit or made explicit in the design. Implicit pedagogies refer to pedagogical strategies that are "implicitly contained in the input datasets that encapsulate the pedagogic behavior of users" [14, p.53]. In this paper, we broaden this definition to include any LA model that does not overtly direct learner behavior based on any theoretical pedagogical model. The pedagogy is part of the input dataset or the system that captures the pedagogic behaviors of users. In contrast, LA that make pedagogies explicit in the design address them through the goals and objectives of the design, and this is seen through pedagogic behavior enabled by the LA and system, as well as the consequence of that behavior [14; 24]. However, in our brief review of the emerging field, there are very little LA designs that develop an explicit pedagogical model. Many pedagogical models in LA papers are implicit, or do not focus on any particular model. Although this allows the flexibility and creativity of the stakeholders in its use and sustainability of the system, it may also lead to confusion as well as uninformed, non-ideal or misaligned practice. In this paper, we present a pedagogical framework for LA in collaborative inquiry tasks and demonstrate trial outcomes in a teamwork competency awareness program.

We begin with a brief literature review of the different categories of pedagogical frameworks in learning analytics. Next, we introduce the background of the research problem and the study's context, namely, the increasing focus on 21st century competencies, and the competency of teamwork. Our pedagogical framework was based on several informing theories and the following sub-section (§3.2) provides a theoretical understanding. Subsequently, §4 elaborates on how the framework was used and implemented in a school setting. We detail each stage of the framework. §5 describes the evaluation of the pedagogical framework, drawn from the qualitative accounts of participant students and teachers. In §6, we elaborate on our findings, their implications and future work, and conclude by highlighting several potential advantages of the TSDL framework for the field of LA (§7).

2. PEDAGOGICAL FRAMEWORKS FOR LEARNING ANALYTICS
One of the key challenges in LA is the lack of pedagogic theory [10]. This sparsity of theory is in part attributable to numerous extant LA studies subtly embedding pedagogical models and strategies in the design [11; 42] and/or only providing a broad overarching frame of the general theory [1]. Some LA designs even claim pedagogical neutrality [10].

Knight, Buckingham Shum and Littleton [21] highlight that no learning analytics design can exist without pedagogical and epistemological assumptions. These assumptions determine what methods and types of learning analytics are used. The study

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surmises three forms of learning analytics that stem from various pedagogical lenses: mastering content (generally from transactional and constructivist lenses), evidencing membership and processes (affect-based, apprenticeship, and connectivist lenses), and "success is use" (connectivist and pragmatist lenses).

Besides epistemological assumptions, pedagogical frameworks can be represented more practically through learning designs. These are the "sequence of learning tasks, resources, and supports that a teacher constructs for students over part of, or the entire, academic semester" [24, p.1441-1442]. There are many kinds of learning designs with differing levels of granularity. Chiefly, learning designs should make explicit the planned pedagogical action without going into the details of the specific instructional activity such as in a typical lesson plan. This allows learning designs to be used as a framework for the design of analytics to support educators in learning and teaching decisions. The Social Networks Adapting Pedagogical Practice tool based on the socio-constructivist model of learning is one such instance [24].

Wise et al. [44] provides another example of a pedagogical framework aimed at informing learning analytics intervention design. Based largely on constructivism, meta-cognition, and self-regulated learning, four principles (integration, agency, reference frame and dialogue) and three processes (grounding, goal-setting and reflection) are conceived. Moreover, pedagogical frameworks can and should be made explicit throughout the lifecycle of the teaching and learning curriculum. For instance, in recent work, Rodriguez et al. [31] designed a pedagogical model that aligned scripting and monitoring explicitly throughout the whole development and use process, from planning, to technological deployment, enactment and evaluation of the implementation.

These examples, which explicitly describe their pedagogical frameworks, clearly provide direction for educators and stakeholders. If such pedagogical underpinnings are hidden, it limits the potential of the approach and can cause misaligned practice. Moreover, as these approaches shape the reality they measure, explicitly stating such frameworks makes clear what counts as important. However, not many such examples exist, and this paper intends to present a pedagogical framework for LA in the context of inquiry-based collaborative tasks. The background of our study, the larger research problem and agenda are described next.

3. RESEARCH PROBLEM AND STUDY CONTEXT: ASSESSMENT OF TWENTY-FIRST CENTURY COMPETENCIES

As a response to globalization and the rapid technological changes in the world, educators and organizations have identified that academic knowledge only is not sufficient for learners to thrive in the world. Rather, a suite of competencies, commonly termed as 21st century competencies, are needed. Many competencies have been proposed and highlighted by numerous international organizations and national frameworks. Among all these frameworks, there are many similar competencies namely, collaboration, communication, digital literacy, citizenship, problem solving, critical thinking, creativity and productivity [40]. Also, a number of more recent frameworks and studies attempt to concentrate on the gap area of assessment, while focusing on a few key competencies. For example, the Partnership for 21st century learning (www.p21.org) consortium narrowed its focus to 4 essential skills, namely, creativity, critical thinking, collaboration and communication.

The study presented in this paper focuses on collaboration in small groups in group-based inquiry tasks. This is common across many 21st century competency frameworks and is pertinent in this day and age for school and work. We term this skill--teamwork competency-- a multi-dimensional construct that focuses on the process of members working in a team [34; 37]. Despite many past studies of teamwork and collaboration, the "what to measure" (teamwork conceptualizations) and "how to measure" (methods including analytics) and design of teamwork activities (pedagogical model) have yet to be firmly established to date.

In the next section, we first provide a brief description of our conceptualization of teamwork and the associated analytics methods, after which we turn to focus more squarely on the development, implementation and evaluation of the TSDL pedagogical framework.

3.1 Teamwork competency conceptualization and analytics

Based on past literature and pilot tests, six dimensions of teamwork competency are established: coordination [9; 27], mutual performance monitoring [35], team decision making [13; 38], constructive conflict [38], team emotional support [6], and team commitment [25]. (A detailed explication of these six dimensions is beyond the scope of this paper, but documented in the author's prior and upcoming work [22]).

For the measure of teamwork competency, we adopted a multi-method approach to add rigor and objectivity. In addition, contemporary technological affordances, particularly learning analytics, are being explored for its potential value-add to future scalability

Researchers have increasingly developed several learning analytics techniques and applications to assess competencies as the LA field matures. To assess multiliteracies, Dawson and Siemens [5] identified several learning analytics methods such as modeling and knowledge domain mapping to measure literacies relating to experimentation as well as structured mapping and prediction to measure products and creation multiliteracies.

Ferguson and Shum [11] define five types of analytics that are relevant in this social age: social network analytics, discourse analytics, content analytics, disposition analytics and context analytics. We posit that a combination of these analytics can be meaningfully designed and implemented for the assessment of teamwork. For instance, social network analytics through gathering interaction data could measure the participation and the network of collaborating student teams.

Discourse analytics are also another potent way to identify and infer teamwork competency in online group communication [2; 32]. For instance, Crowston et al. [4] focused on group maintenance behaviors in online groups and showed good performance of a discourse-based system using Natural Language Processing (NLP) rules. They examined the role of group maintenance behaviors in the messages of online discussion lists by applying NLP rules to automate coding, which could be reviewed and corrected by human coders. In their approach, codes were applied based on specific features that were evidences of theoretical constructs of interest. It involved the steps of pre-processing, tokenization, POS tagging and rule-writing.

Dispositional analytics can also make visible teamwork competencies. Dispositional analytics make use of the traditional surveys of the social sciences and represent them as a visual

analytic [2]. This is demonstrated by Buckingham Shum and Crick [2] who conceptualized a learning power model of learning dispositions. This was empirically validated and visualized using the Learning Warehouse system with self-reports of participants from many schools and countries. The analytic could be visualized to show aggregations across groups of learners or across a person over time.

Self-reports can be performed for oneself as well as for others. Besides self-ratings, there is much potential in peer ratings, where participants evaluate how they perceive another person. Peer ratings can allow for a more triangulated and fairer measurement in teamwork [12; 28]. Self and peer ratings are also more scalable than having experts (such as teachers) rate students. A Self and Peer Assessment Resource Kit (SPARK) was developed for college students which provided them with a confidential assessment tool to develop their teamwork skills [12]. Most students found it valuable as it was a fair system of assessing team contributions, especially when the goals of using SPARK were aligned with the learning outcomes of the course. This form of self and peer assessment were also found to encourage the development of teamwork skills such as team cooperation, commitment and team engagement [43].

3.2 Pedagogical model

The learning design of collaborative inquiry tasks can be a complex process. There have been several approaches to facilitate effective teamwork and collaboration. Generally, teamwork activities have their pedagogical roots in collaborative learning which is a socio-constructivist approach of learning [7; 15; 41]. As learners discuss and negotiate, they learn from each other.

Some research has highlighted antecedents and/or task characteristics for successful teamwork i.e., complex, open-ended, and ill-structured tasks, interdependence (the extent to which team members must rely and work together to perform the task), and individual and group accountability [20; 36].

Besides these characteristics, augmenting group behavior using analytics is an emerging and important component in research. Some work in this has been carried out in the area of group awareness. In social group awareness, past research has used visual analytics for both quantitative (e.g. amount of discussion, extent of participation, perception of collaboration) and qualitative (e.g. agreement, quality of group discussions) awareness information [16]. However, a gap area in the research is that analytics use is unregulated. It is up to students to decide if they will view the awareness information and also it is up to them to choose how they will process and use this visualization. This could explain some of the variability in the results of past research experiments. Further research needs to provide a pedagogical model for such group awareness information to be more effectively used by students [17].

In a face-to-face collaboration study, Rummel et al. [33] found that observational learning enhanced collaboration skills more than a collaboration script. This pedagogical model was more effective when elaboration support was conducted. Elaboration support was implemented through having instructional prompts to focus students to relevant underlying principles, and a reflective self-explanation where participants would recall the collaboration process and "explain to themselves what aspects had been important for the collaboration to be successful" [33, p.79]. This suggests the importance of reflection in collaborative inquiry tasks.

Although observational learning has been shown to be effective, research highlights that it is difficult and time-intensive to develop ideal models of collaboration in ill-structured tasks [33]. Instead, a pedagogical approach that focuses the effort on the learners' metacognitive processes would be helpful for internalizing teamwork competency. Reflecting on collaboration processes seems to be an effective pedagogical strategy to enhance collaboration skills [26; 28]. Moreover, reflection is one of the two fundamental objectives in LA, the other being prediction [14]. Reflection is the critical self-evaluation of user's own data to obtain self-knowledge (and may also include other data) while prediction focuses on modeling activities for other activities and interventions.

One of the foundational learning theories that is based on experience and reflection is experiential learning [23]. Experiential learning theory posits that humans learn through a "transformation of experience" [23]. The theory emphasizes a cycle of four stages: concrete experience, reflective observation, abstract conceptualization and active experimentation. It has three major principles: learning is a process not an outcome, learning is grounded in experience, and that learning requires the resolution of the dialectics (experience and conceptualization, observation and action). It has been tested in individual learner contexts as well as in teams [19].

Another related conceptualization is the learning analytics process model [39] which alludes to a concrete experience but emphasizes that awareness is derived from data. In awareness, data is visualized in various ways such as radar charts, activity streams, tabular overviews, to help learners see their activity/interactions better. Verbert et al. [39] also posit a continuous loop of awareness, reflection, sensemaking and impact. Reflection is important to help learners think about the data. This is closely followed by sensemaking which helps generate new knowledge and insights. Lastly, impact aims to create new meaning or change behaviors.

Besides individual reflection, collaborative reflection or co-reflection among team members is a valuable learning process [18; 45]. In a collaborative inquiry task, the "world" includes the views of the team members. An individual reflecting on his own behavior may not be aware of how he is perceived by other group members and a group reflection would be helpful to help learners learn from each other. This is closely related to socially shared regulation [18] and recent research has delineated three learning design principles for providing support for shared regulation: enhancing awareness of learners' own and others' process of learning; making visible the externalization of students' and others' learning process and interaction; and prompting and stimulating regulatory processes.

Integrating these principles, we posit that an experiential, awareness and reflection approach would be an effective pedagogical model to nurture students' teamwork competency. We term this the "Team and Self Diagnostic Learning" (TSDL) framework which primarily aims to develop students teamwork competencies and collaboration skills.

3.2.1 Team and self diagnostic learning framework

The key informing pedagogies of TSDL are experiential learning [23], collaborative learning [7; 15; 41], and the learning analytics process model [39].

The framework broadly follows the experiential learning cycle [23] and integrates learning designs with learning analytics [24].

The TSDL framework comprises four stages: team-based concrete experience, self and team awareness building, self and team reflection and sensemaking, and self and team growth and change (See Figure 1).

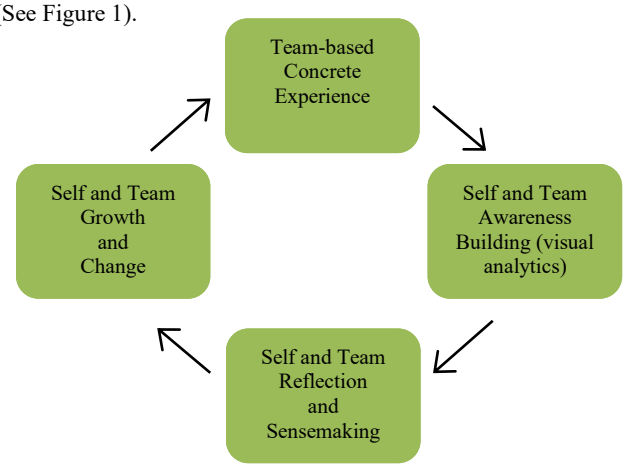


Figure 1: Team and Self Diagnostic Learning Framework.

Learners begin with **team-based concrete experiences** namely, the collaborative inquiry task. This can be in multiple forms such as a team-building ice-breaker activity, the collaborative writing of a report, and a group brainstorming chat. During the process of the experience, learners will at times perform individual work, and at times engage with other team members and learn from each other.

After the concrete experience, we propose that team members can be made more aware of their experience using visual analytics (such as through discourse and dispositional analytics). These make visible the activities in formats such as data aggregations and can trigger an intended change in the learner [8]. Basically, this stage intends to build the **awareness of the individuals' and the teams' learning process**.

The next stage is **self and team reflection and sensemaking**. This is a deliberate set of activities to enable learner reflection, abstract conceptualization and sensemaking of the awareness information. Learners need to evaluate the visual analytics, ask and answer reflective questions, diagnose their learning and create new insights. Goal-setting and future-oriented questions are particular effective strategies [29; 44]. This should be done individually and as a team.

The last stage is **self and team growth and change**. The successful resolution of the dialectics of concrete observation and abstract conceptualization causes internal change in the learner [23]. When learners make sense of their behaviors, and realize areas of change and areas to change, they grow and can enact new behaviors and attitudes. Learner's better self-awareness and change in team behavior can be seen through the differences in earlier and later perceptions and behavior.

Several studies have explicated and shown the cycle of concrete experience, awareness, reflection and sensemaking, and growth and change to be a powerful pedagogical approach that is effective in nurturing cognitive and non-cognitive skills, although these processes have not been previously consolidated into a single framework and termed TSDL [17; 28-30].

For instance, a series of studies by Phielix and colleagues [28; 29] shows the potential of the pedagogical approach for secondary school students. Phielix et al. [28] developed two tools, a peer feedback tool (Radar) and a reflection tool (Reflector) for high school students working together on a collaborative writing task. Participants in dyads or groups of threes and fours, worked over three sessions to complete their task. Students in the experimental group performed peer feedback and reflected after each session (three time points in total). The research found that teams using the two tools (which encouraged awareness and reflection) had higher social and cognitive behavior (between the first and second session), and higher social group performance than the control condition. The study also compared between Radar-only groups and groups with Radar and Reflector, but did not find many significant differences in the self-reported scores. This was possibly due to the reflection questions which highlighted individual contributions.

A follow-up study was conducted where the reflection questions were modified to be more future-oriented, prompting students to goal-set for improved team behaviors [29]. The reflection activity consists of a series of six reflection questions which students type out. For instance, "what is your opinion of how you functioned in the group?" The last question is "Set specific goals (who, what, when) to improve group performance" [29, p. 1094]. Reflection was done individually as well as together as a team. As compared to the control group, peer feedback and reflection resulted in higher self-reported social performance between the first and second session, and between the first and third session. Social performance included team development, group satisfaction, and less group conflict, which are related to teamwork dimensions. These suggest that the TSDL framework could be an effective pedagogical model to enhance teamwork competency.

4. FRAMEWORK IN USE: A TRIAL TEAMWORK COMPETENCY AWARENESS PROGRAM

A two session (a total of 135 minutes) teamwork competency awareness program was designed for 14 year old students in a school. Seven classes with a total of 272 students participated in the study and the program was carried out class by class over 4 months as part of the students' curriculum in 2014. This trial was designed as a blended learning experience using 1-1 student to computers ratio. Students in a class were randomly grouped into teams of 3 or 4 members. In this trial, the researchers led the activities while the teachers co-facilitated the sessions.

The goals of the program were for students to engage in the practice of teamwork and gain awareness of teamwork processes. We hoped that students would learn to work better in future collaborative inquiry tasks.

The different stages of the framework and how it was implemented in our context are described in the following sections.

4.1 Team-based concrete experience

This is the starting stage of the TSDL framework. Students gained team-based concrete experience in session 1 when they engaged in collaborative inquiry tasks in an online environment. We designed an online group chat where students were provided with their tasks and where they discussed and submitted their answer.

Students began with an icebreaker task to help them know their team members and familiarize themselves with the online chat system. This was followed by a dilemma task. The dilemma task was an open-ended task with a scenario that challenged students to make choices to save the environment, the people in a home for

the aged, and/or their father's livelihood. Students had to come up with one final decision as a team regarding how the problem could be solved. Instructions were given by a human-controlled ChatAdmin who typed standardized instruction messages in the chat. After this collaboration experience, students rated themselves and their peers on an online survey portal that we developed. The survey items were constructed based on the teamwork competency dimensions mentioned in section 3.1. Figures 2 and 3 show the online chat environment and the survey interface respectively.

4.2 Self and team awareness building

The next stages of self and team awareness building and self and team reflection and sensemaking took place in session 2. We needed time to calculate and produce the visual analytics. For this trial, we were only able to provide a visual analytic based on the dispositional analytics (i.e., self and peer ratings).

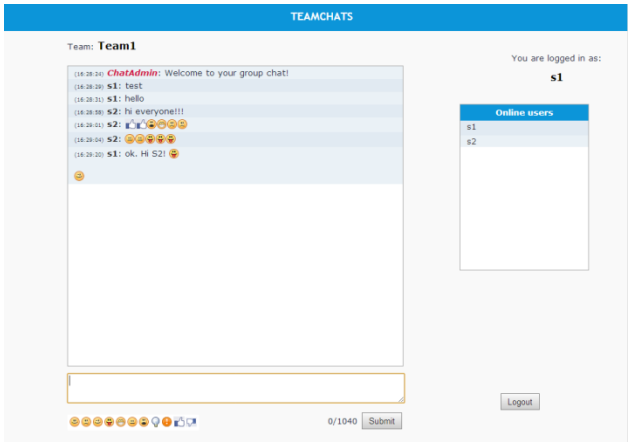


Figure 2: Online chat environment.

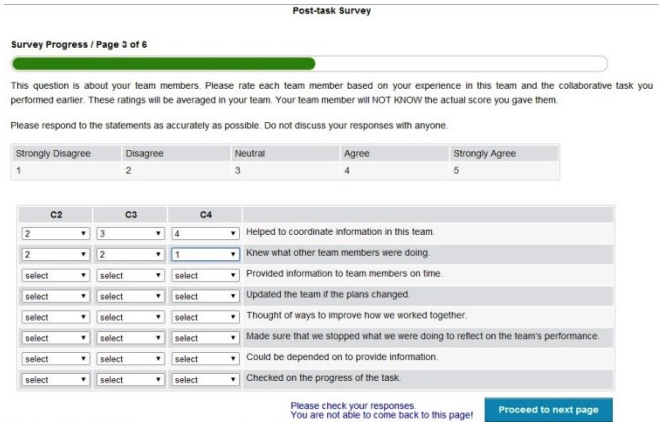


Figure 3: Survey interface for self and peer rating.

The visual analytic was termed a teamwork *micro-profile* rather than a profile to acknowledge that teamwork processes can change, and is not a permanent status of a students' teamwork competency. It is based on the micro-time context, which examines a short period of group processes [3]. The micro-profiles were created from the rating survey based on a Likert scale from 1 to 5 where 5 indicates "strongly agree". Ratings of 3.5 and above are generally considered high. The visualization included the individual student's numeric rating scores of each dimension, separated into self, peer and overall (of peer and self). A radar chart of the student's scores was also presented to allow students to see their strengths and weaknesses easily.

Additionally, an overall similarity score was calculated. This is to enable students to see the difference between their own ratings and those of their peers. We developed this score to compare self and peer scores in line with [43] as it would make the differences between team members more obvious and offer critical reflection. The calculation is:

$$\frac{\text{(Self scores – Peers scores) for each dimension}}{\text{Number of dimensions}}$$

A negative value indicates that the student rated himself lower than his peers (team members). A positive value indicates that the student rated himself higher than his peers. A good range is between -0.5 to +0.5 as it shows a high degree of similarity.

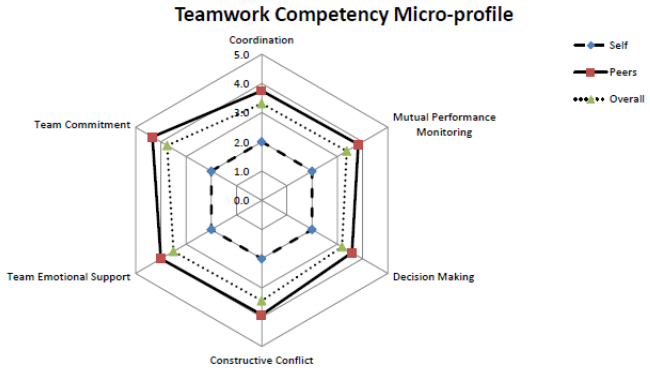
Figure 4 displays our visual analytic of teamwork competency. Students were given their personal micro-profile as a colored printout in class. They were given some time to look at it and subsequently briefed about the aspects of the micro-profile. This was to generate self and team awareness building.

	Rating Scores		
Dimension	**Self**	**Peers**	**Overall**
Coordination	2.00	3.75	3.31
Mutual Performance Monitoring	2.00	3.83	3.38
Decision Making	2.00	3.58	3.19
Constructive Conflict	2.00	3.92	3.44
Team Emotional Support	2.00	4.00	3.50
Team Commitment	2.00	4.33	3.75

Self: How you rated yourself

Peers: How your peers rated you on average

Overall: Average of your self and peer ratings



Overall Similarity Rating: -1.90	A positive value means that you have rated yourself higher than your team members in all dimensions of teamwork competency. A negative value means that you have rated yourself lower than all your team members in all dimensions of teamwork competency. A range between -0.5 to +0.5 means that there is a high degree of similarity in the way you and your teammates have rated your competency.

Figure 4: Visual analytic of teamwork competency: teamwork competency micro-profile for a student.

4.3 Self and team reflection and sensemaking

Subsequently, self and team reflection and sensemaking took place. Students were asked to sit in their teams, and provided with a reflection worksheet comprising 4 questions derived from past research [29].

For individual reflection, students were asked to reflect on:

(1) What differences do you see between the rating that you received from your peers and your self-rating?

(2) Why do or don't you agree with your peers concerning your rating?

For team reflection, students reflected in their groups on:

(3) What does the group think about its functioning in general? Discuss and formulate a conclusion shared by all the group members.

(4) Set specific goals (who, what, when) to improve group performance

The objective of this explicitly scaffolded self- and team-based reflection task was to create the pedagogical conditions for students to assimilate and synthesize their reflections of their experience in terms of both conceptual understandings and very importantly, concrete goal-setting and plans to productively adapt or modify their teamwork behaviors [23; 29]. To end session 2, the facilitator consolidated what students learned by asking students to share in class and closed the session.

One limitation of the trial cycle reported here is that the self and team growth and change, if any, were not recorded and documented in a structured manner, mainly because the focus of the program was on students' gaining awareness of their own teamwork competencies and to learn to work better in future collaborative tasks. We aim to address this limitation in future work. Nevertheless, for the trial cycle at hand, students' writing in the reflection worksheets provided some evidence of their growing awareness and desire for change.

5. PEDAGOGICAL FRAMEWWORK EVALUATION

A qualitative analysis was performed to evaluate the impact and effectiveness of the TSDL framework from the perspectives of both the students' and teachers'.

5.1 Data sources and analysis method

The key data sources were focus group discussions (FGDs) with students and interviews with teachers. Students' written reflection worksheets were also examined. There was a total of 6 FGDS from 6 teams (3 to 4 students each) from different classes. Each FGD lasted between 45mins to 1 hour and was video-recorded. We also had written or face-to-face interviews with the teachers from all the 7 classes. For this analysis, a subset of the 272 participant reflection sheets was examined.

Thematic analysis was carried out where the data was examined and information categorized into codes and then larger themes.

5.2 Findings

5.2.1 Overall program

Generally students and teachers were receptive towards the program. Overall, students felt that the program helped them to know how others saw them, and understand themselves better in terms of the teamwork dimensions.

"[I was able to] find out what others think about me. I was able to find out what I can do more." Student X.

Some students wanted to go through the program again. Student Y said that she would like to get to talk with other people and know other students' ideas. Student Z shared, *"I think it is useful to experience how other people work in a group together with a different group".*

Teachers also found the program useful for their students to be more self-aware and relate to others better.

"Overall the program is just nice, timing is not too draggy. Students enjoyed the first session. As for session 2, it's good for the students to know and express themselves according to their profile". Teacher A.

"The program is okay, but depends on how you execute it." Teacher B.

The execution of the program depended a lot on the skill of the facilitator being able to guide and manage the classroom dynamics. In this trial, the researchers led the program. However, a few teachers suggested that the teachers could play a greater role in leading and facilitating this (and the researchers also concurred). This is because the teachers know their students better which could help in facilitating the whole activity.

The TSDL framework was not made explicit to both the teachers and students, and during the FGDs and interviews, we asked the participants about their perceptions towards the different stages of the framework.

5.2.2 Team-based concrete experience

As session 1 required students' to use the computer, students especially liked this experience. It was a break from their normal classroom lessons. Although there were a few who thought it was *"boring"*, the majority found it *"quite fun"*. It was something new and interesting for them, and they could go out of their normal class. A teacher shared that some students were *"keyboard warriors"* and liked communicating online.

Students were generally receptive towards the collaborative inquiry task, although there were a few who found it confusing, or were not engaged with the task or, did not like the topic. Students suggested task scenarios that could give them more *"life lessons"* or be related to current affairs.

We found that students were not new to teamwork as they had to work in teams for other projects in school. However, for many, what was different was who they were working with, as the research team randomly grouped the students into teams. Many of the students found themselves in teams with classmates they had never worked with before. Some students were unhappy about this initially, but they got used to this and completed their team activity. Still, there were others who enjoyed the opportunity to perform a task with students they normally would not group with.

5.2.3 Visual analytic - self and team awareness building

Students were provided with a personal micro-profile of their teamwork competency based on self and peer ratings. We had feedback relating to the accuracy of students ratings, as well as the clarity and interpretation of the visual analytic.

Some students questioned the accuracy of the peer ratings as they felt that certain team members may not have rated them honestly. Similarly, teachers also felt that certain students might not have rated their team members accurately. This brings into question that perhaps students need to be taught how to rate others. Nevertheless, most students generally agreed with their self and peer ratings and during the session there were very little questions addressed to the facilitator regarding this. Moreover, during the earlier stage, students were also instructed to rate their friends fairly.

As for the visual analytic, there were 3 parts to the analytic, the radar chart comparing self, peer, and overall; the numbers shown in a table; and an overall similarity score.

Regarding the dimensions of teamwork, the facilitator explained and provided realistic examples to students which helped in students becoming more aware of what the concepts meant. Students found the radar chart a powerful visual comparison between self, peer and overall ratings. They could see how their peers thought of them as compared to how they thought of themselves during the task. A student felt that this radar chart could be shown as individual charts, in addition to the comparison chart to make it even clearer.

The table was also useful to see the actual numbers. A teacher remarked, *"my class is quite analytical; they like to see the small details."* Students liked it when they scored highly on the dimensions.

The most confusion was regarding the overall similarity score as the score had negative values. Students were not used to a negative number and tended to interpret that as a negative aspect of their teamwork. Facilitators had to repeatedly explain that it was the magnitude that mattered, not so much the valence. This value can probably be improved in the future with a more user-friendly visual.

5.2.4 Self and team reflection and sensemaking

In this stage, students were guided in their reflection and sensemaking with a reflection worksheet with four questions as mentioned earlier. Students' written individual reflections ranged widely. There were students who agreed with their peer ratings:

"I do [agree with my peers concerning my rating] as I spammed the group".

"I think that maybe my teammates' didn't see that I was committed to the task so they rated me lower than I did. My team might have a less biased point of view and may actually be more accurate".

There were also students who disagreed with their peer ratings:

"I don't agree with them as they have different views".

"I don't agree because I did contribute a fair bit".

Many students felt that their peers rated them higher than they actually should, *"I don't agree with my peers rating as I should have got [a] lower [score] because I did not contribute a lot."*

However, there were other students who seemed to care less or were more philosophical in their responses. One student wrote *"the ratings do not matter to me"* while another explained *"I do not mind what they rate me as I think that it does not matter that much and I think that since they do not know me that well, what they rate might be wrong or might be true, there is no definite answer".*

For the team reflections, we found that many students wrote the same answer for the whole team in their reflections, suggesting a consensus in their team reflection. E.g., "*I want to be more helpful and communicate better"* was written by all members of team G.

Some students were slightly vague or did not answer the question, for instance, *"be more supportive and have more teamwork".* There were others too that felt that they did not need to change and could function as what they had functioned.

Nevertheless, most students reflected and stated specific goals to improve future team performance, for instance:

"I will try to make peace with everyone and try to get them to discuss and give opinions. When the team is not discussing the topic, I will remind them to stay on task."

"I can cooperate better with my teammates and listen to their views more often. I will be committing more to the team and be more active. I will be giving suggestions to the members to improve the answer and participate in the discussion more."

"We would put all our differences aside and work together as a team."

These positive goal-directed responses indicated that students became aware and understood how they could grow their teamwork competency.

Overall, the activity for this stage was slightly more difficult for students. Students were not as responsive as compared to the earlier stages. During the FGD, a student shared that he found the reflection questions straightforward but explained that it was *"hard to think of something"*, to *"write something down"* when he *"did not have any opinion of it"*. Another student, student X, stated that students need to know the purpose of the reflection and suggested having more examples to help them reflect, and also to structure it in a format likened to that of a classroom discussion.

Still, most students during the FGD shared that they were clear about the six dimensions of teamwork and the activity helped them to understand more about teamwork. One student shared that she became more aware that she did not know how to share and explain her ideas and the reasons for why she disagreed with her teammates. This is the area she would like to work on to enhance her teamwork competency.

These findings suggested that students individually and as a team were able to make-sense of the dimensions of teamwork competency and set goals to change.

5.2.4.1 Teachers' views of the reflection and sensemaking stage

A teacher acknowledged that while important, students are not used to reflecting and expressing their opinions. He found that this was also the case in other lessons as students were not prepared or reluctant to share their opinions. He attributed it to the students' maturity and believed that it would require a lot of time and effort to develop the metacognitive skills of the students.

Other teachers were less skeptical and felt that this part of the program could be emphasized more. Teacher A commented that it served two purposes. It was "*useful for students to know themselves, and it sets them to think about how to work in a group."* It was also *"useful to the teachers because we are able to better identify what kind of team players our kids are. With that we can customize grouping to increase efficacy and learning."*

Teacher C felt that there could be *"more room for discussion"* to allow all groups *"a chance to present"* to *"know what students are thinking"*. She was concerned that the visual analytic could be *"too remote"* and suggested allocating more time for reflections over a series of lessons to give teachers time to analyze students' micro-profile, in order to provide more *"specific advice to students"*, so that students *"can work better in their teams*". Similarly, another teacher commented that students might *"know the number [the survey scores in their micro-profile] but they need more time to digest the significance so that it can be useful".*

On the whole, the findings pointed to the fact that teachers recognized the challenges of implementing the reflection and sense-making stage, but at the same time, they generally concurred on the importance of the activity and highlighted that

more time was needed for students to reflect and make greater sense of their teamwork competency.

6. DISCUSSION, IMPLICATIONS AND FUTURE WORK

The findings reveal both the challenges and potentialities associated with the trial implementation of the TSDL pedagogical framework in a teamwork competency awareness program. Both students and teachers were found to be generally receptive towards each stage of the framework, despite identified challenges. In this regard, there was evidence that the broad goals of the program were met, in that students were able to (a) gain awareness of their personal teamwork competency and (b) state possible ways to improve their teamwork. The pedagogical framework contributed to a large extent in overtly scaffolding the activities, which in turn points to the pedagogical value and usefulness of the model.

In the beginning of this paper, we argued for a more explicit pedagogical model for LA. Our work demonstrates one such model where the pedagogical activities were planned as stages according to the TSDL framework. Moreover, in the framework, LA served as a visual analytic to build the awareness of students' teamwork competency, and for subsequent reflection and sensemaking. This work spurred us to consider two questions: Is such a directed theoretical model necessary? Would this be considered a good alignment of LA and learning design?

To this end, we would argue that such explicit models are necessary, and that these frameworks should show good alignment of LA and the learning design, echoing the works from [24; 31]. Our findings indicated some advantages of such a stance. The framework provided the general direction for the program and theoretical clarity of the learning process. The LA and learning design was also adequately coupled and prevented serious misalignments in implementation. More importantly, we saw that the use of the TSDL framework brought about perceptual change in students' teamwork competency, meeting the goals of the program.

Our findings also revealed that different aspects of the pedagogical framework were welcomed by students and teachers. Students enjoyed the team-based concrete experience, and found the reflection and sense-making activity difficult. On the other hand, teachers recognized the reflection and sense-making stage as important and wanted more time for their students to fully engage in this.

The depth and duration for the implementation of the different stages in the TSDL framework is an area that the research team found challenging. We were constrained by the amount of curriculum time that the school provided us with to carry out the program. The research team was cognizant of the trade-off of time especially for the reflection and sensemaking stage. We acknowledge that more time should be provided for the reflection stage, where possible, and will take this into account in the planning and design of our follow-up trial cycle iterations.

Relating to this issue of curriculum time, we are planning for greater integration of our program with the schools' normal curriculum. We hope to embed the TSDL framework into a curriculum subject that employs collaborative inquiry tasks. Plans are underway but this integration would inadvertently require other types of concrete experiences, visual analytics as well as reflection and sensemaking activities. This is complex and challenging, at the same time offering more room for research, as requiring careful and principled execution. The principle of integration as conceptualized in [44] would be helpful in tying analytics to the curriculum and authentic learning goals. We also foresee that we might need to develop more fine-grained instructional activity for each stage of the framework for different contexts, as guided by the overarching theoretical frame.

At this stage in our research, we only managed to employ dispositional analytics. The plan is to include other forms of analytics, with the upcoming phase being discourse analytics. However, the nature of semi-automated text analysis has been tedious and challenging for the research team to date. The team is in the process of devising a reliable analytic engine for the indicators of teamwork dimensions. The discourse analytics will add another layer to the existing visual analytic, such as through a scaled score of the sum of each coded message of each dimension in the micro-profile. Also, for the dispositional analytics, we are working to improve the scale validation results of the questionnaire items and also to enable a real-time system. Besides the discourse layer, we see potential in using trace data of the students' online usage (such as searches, browsing websites) and also in identifying the network of interactions among students to provide further evidences of teamwork and collaboration.

In this study, we focused on TSDL framework for students, but the teachers were also involved in the whole process as facilitators. The TSDL framework can also be theoretically extended for teachers such that teachers are provided with a clear set of principles of their role in the learning process. In our implementation, teachers were provided with a class micro-profile to see their students' teamwork competency scores and help them flag out students that might need early or adaptive intervention. This was well received by teachers, many of whom found the class micro-profile to be a useful form of validating their more tacit and/or intuitive observations of their students. Many teachers were able to guess the names of the students before they saw the actual names. Further work would go toward equipping teachers with learning design guidelines especially in this area of teamwork competency.

This study proposed and implemented a pedagogical framework focused on the 21st century competency of teamwork. The findings are limited to one specific instance. Still, the findings lean towards a collective appreciation for the pedagogical usefulness of the program and TSDL framework, although there are challenges to be addressed. This serves as the impetus for us to move forward by taking into account the students' and teachers' suggested refinements to further improve and develop the program. There may be potential for the TSDL framework to be applied to other team-related outcomes too, such as other cognitive skills and knowledge, which constitutes an area that may benefit from future research.

7. CONCLUSION

Many pedagogical models in LA papers are implicit which could result in misaligned practice. This paper presents an explicit pedagogical model for teamwork competency, the TSDL framework, and describes its implementation and evaluation by students and teachers in the context of collaborative inquiry tasks. The framework was implemented in a teamwork competency awareness program for 7 classes of 14 year old students. This paper qualitatively evaluates the program from students' and teachers' perspectives. Findings reveal positive perceptions of the stages of the framework suggesting its pedagogical value. Some challenges associated with its implementation within school-based learning contexts were also highlighted. In light of the findings,

we make the case that this framework goes some length to provide theoretical clarity of the learning process, and also aligns learning analytics and the learning design. The current work provides trial outcomes of a teamwork competency awareness program that used dispositional analytics, and further efforts are underway to develop the discourse layer of the analytic engine. Future work will also be dedicated to application and refinement of the framework for other contexts and participants, both learners and teachers alike.

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