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Cultivating and Leveraging Continuous Accountability Through Mundane Infrastructures for Critical Thinking

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Abstract
Technology-enabled collaborative learning had been shown to be useful for improving student cognitive performance, promoting social interaction, and positive learning behavior. In this chapter, a utility to manage the logistics of group learning was explored to support collaborative learning and leverage a sense of accountability among group members. In particular, this chapter discusses efforts to (a) develop critical thinking as a general framework for classroom discourse, (b) appropriate infrastructures to support real-time/routine debate and other critical discussion and writing, and (c) develop computer support for group formation and management inclusive of peer evaluation. Based on the findings of this case study, an approach based on critical and dialectical thinking is suggested where students can take an active role in their own learning by creating and modifying their own perspectives.

Introduction
Engaged learners do better, but engagement is not a single thing. In collaborative learning, one source of engagement is accountability to group outcomes, the belief that one’s active participation matters. One goal in designing educational tools and activities to support collaborative learning is to cultivate, develop, and leverage a
sense of accountability in group members. In this chapter, we reflect on our own efforts to create and support group-based critical thinking activities that integrate and leverage debate in postsecondary classes. Such activities naturally engage meaning making and accountability; groups of learners build facts, claims, and anticipated rebuttals into arguments, while other groups are building counterarguments. Participants are continually reminded of their own contributions, and those of their teammates and of members of other groups.

The chapter focuses on our efforts to (1) develop critical thinking as a general framework for classroom discourse, (2) appropriate mundane infrastructures to support real time/routine debate and other critical discussion and writing, and (3) develop computer support for group formation and management, including management of peer evaluation. We leverage existing literature on collaborative learning, especially on dialectical constructivist learning as background and foundation for our chapter.

**Critical Thinking as a Classroom Discourse**

To explore how critical thinking activities can be configured to evoke accountability in team members, we have developed courses around debate and critical discussion at Pennsylvania State University. For example, a freshman seminar in Information Technology focused on reading and deconstructing authoritative but argumentative popular books, such as Carr’s “The Shallows” or Michel and Aiden’s “Uncharted,” and a Ph.D. core course focused on identifying claims and counterclaims that constitute foundational theories. These activities were implemented as learning jigsaws to cultivate and leverage public accountability in the class. In other words, engaging in collaborative activities helps hold students accountable for their work as they are supposed to take responsibility for their part in a group project. Further, students were engaged by these dialectical constructivist activities and sometimes identified dialectical analysis as a skill they had encountered for the first time.

**Online Debates as Learning Activities and Learning Objects**

We have reappropriated various tools to support this approach in the previously mentioned courses. We chose these mundane platforms because they are straight-
forward to use and are useful to support students’ collaborative discussion and
dialectical constructivist activities.

For example, we adapted the Q/A system Piazza as an interactive debate plat-
form and then developed our tool, Critical Thinker, based on that experience. Both
Piazza and Critical Thinker could easily allow people to build question–answer dis-
courses, contributing to establishing dialectical activities, and support students’ critical
thinking. We appropriated the online debate system Kialo as a platform. Kialo is similar
to Piazza; the platform is set up more as a social network for debating. Its management
and accessibility are greater than both Piazza and Critical Thinker and are more robust
than Critical Thinker (no longer maintained), but weaker as a pedagogical tool. More
recently, we have engaged the wiki functionality of Canvas for student debate and
deconstruction, and more generally, for argumentative student writing. Students
publishing short position papers to the class can be a quick starter for accountable class
discussions. In this chapter, we will discuss these tools in depth by comparing their
strengths and weaknesses.

**Collaborative Learning as Scalable**

Most of our classroom studies were conducted in relatively small classes (16–25
students). However, classes are often larger than this, and indeed, these larger classes
often incorporate no group learning. Our hypothesis is that if collaborative learning was
easier to manage than traditional isolated-learner models, then faculty would be more
likely to adopt collaborative approaches. If group formation and management were just
easier for faculty, and peer evaluation well-defined and easy to learn from for the
students, perhaps collaborative learning practices would be more widely adopted. We
have developed a utility to manage logistics of group learning designs, including iterative
assignment of students to small groups (that is, students participate in several different
groups in the course of a semester) and management of peer review for group products
(including automated appeals resolution). A single case study was carried out in fall
2018 and was encouraging. We are continuing to refine and extend our software and
enlist more faculty. In the next three sections, we develop (a) motivations for
considering critical thinking as a general framework for classroom discourse, (b)
describe how we appropriated mundane computational infrastructures to support routine
debate and critical discussion and writing in classes, and (c) analyze and develop
computer support for challenges of group formation and management, including
management of peer evaluation, that can be obstacles to faculty adoption of
collaborative learning.

**Critical Thinking and Dialectical Constructivism**

Critical thinking is an important skill that students need to acquire, as it facilitates
synthesis of multiple ideas, making logical deductions, and becoming capable problem
solvers. This section synthesizes existing literature review regarding pedagogical
practices that support critical thinking and how these can aid students in improving their
critical thinking abilities through engaging them in meaningful dialectical learning
activities.

Critical thinking is a higher level of cognitive ability that enables people to
analyze, synthesize, and evaluate information (Duron et al., 2006). More than merely
remembering knowledge and applying it, critical thinking involves questioning
knowledge and its applicability to given circumstances, identifying key issues, claims,
and empirical evidence that bear on them, and synthesizing and reconciling ideas with
other ideas (Basseches & Gruber, 1984; Duron et al., 2006; Fisher, 2011; Glaser, 1985).

Dialectical thinking is a kind of critical thinking that focuses on articulating and
resolving conflict (Brookfield, 1987). As an approach to learning, it emphasizes debate
and logical deconstruction as constructive learning activities (Carr, 1988; Herreid,
2004). For example, in debate, a student or a team adopts a pro or a con position on a
proposition or an argument. Learners elaborate and/or criticize the bases for claims and
deductions, present positions and argumentation, and try to understand the positions
and arguments developed by other students representing opposing and diverse
positions. They resolve conflicts through qualifying and/or synthesizing diverging
positions, ultimately creating new ideas (Carroll et al., 2016).

Dialectical constructivism can be contrasted with other constructivist pedagogies
in three respects. First, dialectical constructivism specifically emphasizes argumentation
and debate among learners. The student’s role is to challenge and modify perspectives,
not just to learn them, or even just to put them into practice (Carr, 1988; Herreid, 2004). Sanders et al. (1994) showed that college students could be systematically instructed to effectively and non-aggressively deconstruct arguments. Through putting students in a dialectical activity, they would learn how to build up persuasive arguments and how to collect strong evidence to support or rebut others’ ideas.

Second, relative to other constructivist pedagogies, dialectical constructivism emphasizes the synthesis of new perspectives. This stance varies from both exogenous constructivism, which emphasizes adoption and enactment of preexisting (authentic) knowledge and practices, and endogenous constructivism, which emphasizes the coordination and reorganization of preexisting knowledge and practices (Land, 2000; Moshman, 1982). Further, dialectical constructivism depends on bottom-up anchoring and appropriation, but further engages conflict in understanding (Piaget & Inhelder, 1969) and in cultural-material values (Vygotsky, 1978) to evoke sense making. As Kuhn (1999) put it, “The developmental goal is to put people in metacognitive and metastrategic control of their own knowing” (p. 24).

Finally, relative to other constructivist pedagogies, dialectical constructivism emphasizes that knowledge is problematic and contingent, that people are responsible for constructing it and critically assessing it, and that the challenge of problematic and contingent knowledge is unending (Dalgarno, 2001; Land & Hannafin, 1996). Articulating questions, recognizing information needs, positioning relevant information resources, and synchronizing theories and evidence are all effective practices for developing critical thinking skills (Land, 2000; Land & Hannafin, 1996; Rakes, 1996). In problem-based learning, in contrast, the focus is on learning and enacting authentic concepts and practices, but not necessarily on reflecting upon the limitations and ephemeral validity of the authentic materials.

Mundane Infrastructures in Support of Critical Thinking

It can be difficult for instructors to guide and support students’ collaborative learning activities, particularly when the activities are substantial—involving significant reading and analysis that might take place over days or even weeks. In this section, we describe a series of mundane infrastructures that we have investigated to support
debate-like critical thinking activities. The infrastructures are “mundane” in the sense that they are relatively straightforward to adopt. Existing platforms for learning management can be reappropriated to support critical thinking activities. For example, Piazza is a widely available platform for developing question–answer dis- courses as learning activities and resources. We remapped Piazza’s “Question” field to the role of arguing a “pro” position in a debate and remapped Piazza’s “Student Answer” field to argue the corresponding “con” position. Students were taught Toulmin’s (1969) rhetorical categories for structured argumentation and then encouraged to label the propositions in their pro and con positions with Toulmin “tags.” As illustrated in Fig. 1, this allowed us to host a collaborative pro–con debate activity in the Piazza Q/A workspace: in the figure, students developed their pro position in the Question field (1) and con position in the Answer field (2), labeling their propositions with Toulmin tags (3). Piazza’s content management tools (5,6) provide students with an overview of their argumentation.

The strategy of reappropriating an existing and widely available platform leverages many efficiencies. For example, our students already had free access to Piazza, and several already knew how to use Piazza. Piazza already had created and was maintaining a secure and reliable platform; if there had been any technology issues, Piazza provided a robust technical support infrastructure. More specifically, Piazza had implemented the core “wiki” functionality that our concept of online debate required; that is to say, students could access the debate activity anytime and any-where and edit their pro and con position. Piazza also tracks editing histories of student content, making it clear who contributed what to debates, encouraging students to feel accountability for their participation in the debate activities, and provides an associated discussion forum for each debate so that all members of the class could participate broadly in the activity. In sum, Piazza provided a comprehensive online space for students to post their ideas and keep track of their debate process. Importantly, students were able to reappropriate Piazza for the debate activity. They were able to effectively carry out the debate activity in a platform designed, developed, and labeled for other learning objectives and pedagogical activities (Carroll et al., 2016). Our reappropriation of the Piazza platform also helped us identify further design possibilities. For example,
we noticed that students had to work to directly contrast pro and con argumentation—in Fig. 1, pro and con points that correspond are numbered to make it easier to contrast corresponding points. This suggested to us that presenting argumentation in two columns might be significantly more effective in encouraging students to critically contrast corresponding arguments. Thus, we designed the Critical Thinker tool to support the same pro/con critical analysis of argumentation, but to display pros and cons in a horizontal layout, as depicted in Fig. 2.

![Fig. 1 Pizza platform in support of dialectical activities (Carroll et al., 2016)](image)

Indeed, it was easier to understand and contrast pro–con argumentation that was presented in the two-column format, illustrating the importance of visualization to support critical thinking (Sun et al., 2017). Further, we were able to support synchronized collaborative or team-based editing in Critical Thinker, allowing for more than one student to have the ability to edit shared text simultaneously, supported by real-
time notifications that provided team members awareness of changes other users were contributing and allowing for a better coordinated activity.

Instead of reappropriating some else’s platform, we created Critical Thinker specifically to support pro/con critical analysis of course reading. Critical Thinker itself, though, can also be considered a mundane infrastructure in the sense that it was a relatively small software project and provided a fairly specific set of functionalities to create and edit pro/con argumentation. One reason to create a tool like Critical Thinker is that it allows users to have a high level of control; for example, control over the exact placement, timing and wording of the real-time notifications used to enhance awareness of other students’ activity. The cost, however, is that the instructor must provide system maintenance. Thus, we had to support user accounts and authentication, server management, and regular updating driven by updates in software we used to create Critical Thinker.

![Critical thinker platform in support of juxtaposed pros and cons (Sun et al., 2017)](Fig. 2)

**Fig. 2** Critical thinker platform in support of juxtaposed pros and cons (Sun et al., 2017)

In the previous example, the course supported with Piazza and Critical Thinker
was a freshman seminar in information science. Students would read and analyze fairly accessible and controversial topics such as the PRISM surveillance program (Fig. 1), possibilities and risks, and “big data,” and effects of the Internet and apps on cognitive development. We were interested in exploring the generality of online debates to other kinds of courses. We used the same kind of pro/con debate activity to support a Ph.D. core course that surveyed concepts and frameworks used in human–computer interaction research, for example, gesture and tangible interaction, design of implicit interactions, and sense making (Fig. 3). Students used a free online debate platform, Kialo (Beck et al., 2019). As is shown in Fig. 3, Kialo structures debates with parallel pro and con columns, though the individual points are not aligned (that is to say, the con displayed to the right of a pro point is not necessarily a response to that pro point). In this regard, it is different from both our reappropriation of Piazza and our subsequent Critical Thinker design.

Fig. 3 Kialo platform in support of pros and cons discussion
An interesting feature of Kialo is that it allows students to develop a pro/con deconstruction of any proposition in an argument, thus, each of the pro and con points displayed in Fig. 3 could also have its own separate, embedded pro/con analysis. Indeed, if there were an embedded pro/con analysis, say, of the first pro point in Fig. 3, the pros and cons of that analysis could also be analyzed by further and deeper pro/con analysis. Also, associated with every pro or con point, there is a discussion forum in which participants in a debate can discuss where they think that particular point should be positioned in the overall argumentative structure.

The Kialo platform hosts a large online debate community (Beck et al., 2019). The range of debate topics and the richness of the various debates throughout the community are impressive. This makes Kialo a great mundane infrastructure for adoption by instructors, allowing for both students and instructors gain the pedagogical benefits of a standard platform that we identified earlier with respect to Piazza, but also the additional potential benefits of becoming associated with the Kialo community, which has adopted critical thinking and debate as an integrative community focus.

The fourth and final example of mundane infrastructure for critical thinking is an activity designed in Canvas, a widely used learning management platform. One of the simplest objects in Canvas is the page, typically used by instructors to present static information. However, Canvas pages can be configured to permit student editing, and when configured to allow editing by multiple authors, possess simple wiki functionality, which possesses a number of pedagogical benefits for collaborative and team learning. Like Piazza, Canvas maintains a history stack, which supports awareness and documentation of all user contributions to the pro/con argumentation. Like Piazza, Canvas does not manage buffers, allowing contributors to accidentally overwrite one another’s contributions, while also documenting such actions. As illustrated in Fig. 4, a two-column table template was implemented using Canvas pages and then students were asked to carry out a debate. As in Critical Thinker, horizontally aligned pro–con pairs are logically related; the pro point defends or strengthens the arguments of the reading the students are analyzing (in this case, *The App Generation*), the con questions, criticize or refute arguments from the reading.
### Pro/Con Wiki for "The App Generation"

<table>
<thead>
<tr>
<th>Purple Team List of PRO points with evidence</th>
<th>Blue Team List of CON points with evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>(defend/strengthen arguments of the book)</td>
<td>(question/criticize/refute arguments of the book)</td>
</tr>
</tbody>
</table>

Generations have been defined by the moments when we are born in this world to when we mature over the years. The App Generation has not been defined by any significant political and/or economical events but rather, by the technology people utilize. The App Generation is a generation that is pushing forward the concept of finding out what people specifically want, when people want it, how people are processing these information, as well as what comes next and where people will end up. There are two ways in which this generation is being characterized as the "App Generation".

One sense would be how people are utilizing these applications. Either digital or nondigital, people are utilizing these applications with hopes that they will instruct them on how to accomplish what they want as quickly and as efficiently as possible. If one of these "apps" does not work to their advantage, they will simply look for another. And if they cannot find or invent one, they'll quit on our concerns.

The final characterization would be how they are examining their lives. While every individual's experience is extremely different, each of their lives will follow some specific pattern of high school, college and then concluding with a job at their dream company.

The authors make a solid argument that we are currently in the “App Generation” and how the current youth are becoming dependent on applications that are found are their smart devices. Although, the current youth are relying on technology to grow and develop, has that been proven yet to be a completely terrible thing? Yes, the book provides countless studies how the current generation is more self-focused and tend to be less sociable compared to previous generations due to technology. Apps and smart devices and social media are still "new" compared to the rest of modern history and we do not know what effects they will have in the future as of now. There is no data to support that using apps to determine how to something is a bad thing. What apps are allowing the current generation is to problem solve. Like mentioned in the pro argument if there is not an app that does a specific task, then someone invents it. The use of apps and technology is making people more intuitive and still giving the same knowledge they would get from learning in a school setting just in a different form.

In terms of individual experiences the authors argue that the current is following the same pattern of high school, college, and then finding a job, and although for a majority of people that is the path they are taking is that...
Group Formation and Management

We view small-group collaborative learning, such as the debate activities described above, as touchstones for education. Learning in groups naturally creates significant interaction among students in which students take initiative to organize and coordinate work, to explain things to one another, and synthesize collective outcomes. As we mentioned earlier, most of our own experience with such learning collaborations involves relatively small class contexts of a couple dozen students or fewer. Many university courses have higher enrollments than this, and the contemporary landscape of education includes extremely large courses such as MOOCs (Massive Open Online Courses) which can have tens of thousands of students. Additionally, we know specifically that such large courses often do not effectively address group formation, management, or peer evaluation (Zheng et al., 2016).

We posed to ourselves the question of how larger classes can benefit from incorporating small-group learning activities, and what modifications or considerations are needed to effectively implement these activities with larger numbers of both students and groups. There are several key challenges. One is group formation, or the assignment of students to specific groups. For several reasons, this challenge is greater than that of dividing a class of $n$ students into $k$ groups. The first reason is enrollment turbulence; which occurs when students add and drop for several weeks early in the term or semester. This turbulence usually does not have a significant negative impact on the overall class context, but at the group level, 1–2 student withdrawals can significantly undermine a small group of 3–4 students, requiring a refactoring of groups, potentially multiple passes of refactoring. For a class with ten times greater enrollment, this challenge is at least ten times greater.

A second potential concern for forming groups is consideration of the diversity among students: For example, in the information science discipline, it is typical that students vary enormously with respect to their motivation and skill in project planning and coordination, graphic design, software design and programming, and writing text. As for enrollment turbulence, the challenge of accommodating student diversity rises with class size; the range of student differences will be greater in a larger class, and it will be more challenging to organize groups that optimally accommodate diversity. Students
also have an amazing range of curricular and extracurricular activities that create scheduling complexities for engaging in group activities outside of class. Here diversity becomes a bigger challenge in larger courses as it just amplifies the challenges that can be already present in smaller classes.

Beyond group formation is the consideration of group management. A key challenge in managing groups is interpersonal conflict. Conflicts in small groups can escalate from a mere failure to connect or effectively collaborate, to more serious scenarios in which some members ostracize one another, withhold their participation in the group, or even stop participating. These patterns have consequences for grades, of course, which brings the group conflict to the instructor. The unpleasant-ness of such situations, and the problems of moving students around in groups mid-semester is a reason why faculty members sometimes prefer not to embark on collaborative learning designs. This is more notable in courses where the enrollment size is bigger as it requires more micromanagement of a bigger amount of student groups.

Hence, instructors who incorporate small-group learning into their courses will face the challenge of grading group papers, presentations, and other outcomes. A default approach is often to assume that students contributed roughly equally and to assign all group members the same grade. However, this approach may aggravate existing group conflicts, where there are tensions around group participation, while also potentially disenfranchising individual group members. In other cases, the default of assigning the same grade to all members could help to create or exacerbate group conflicts, because contribution was not equal. More generally, assigning the same grade to all group members implicitly suggests free riding, allowing for a general feeling of unfairness to emerge from the poorly managed collaborative or team-based pedagogical approach.

A more comprehensive and articulated approach to team management is to externally validate the equal contribution assumption through self-and peer-assessments. For example, using the online tool CATME can be an effective approach, allowing each member of a group evaluate the contribution of themselves, as well as of their fellow group members. Self-evaluations of group contribution can be useful and illuminating, but can also be defeated by students who assign the same scores or
contribution ratings to all group members. Interestingly, using a tool such as CATME can often still result in student frustration and complaining that group members are contributing too little.

The challenges of enrollment turbulence/group refactoring, of accommodating diversity in group formation, and of tensions around self-evaluation of group contribution motivated us to investigate scale-free small-group learning (Zhu et al., 2018). This approach employs frequent pseudo-random reassignment for group formation and management, for example, randomly assigning students to groups and then to reassigning them to other groups (that is, with different students, insofar as that is possible) for each separate assignment in the course. This approach leverages the idea of refreshing the groups frequently as a way of mitigating the chaotic impacts of enrollment turbulence/group refactoring and tensions around self-evaluation of group contribution, increasing each student's chance of having positive, albeit briefer, collaborations with other students. It addresses the challenge of diverse student preferences and skills by exposing each student to the greatest possible (random) variety of classmates. Importantly, this approach to group assignment and reassignment also minimizes instructor management; if there is a conflict within a group for a given assignment, the problem will be addressed for the next assignment anyway. The concept of pseudo-random permutation can be extended to peer grading. Peer grading evokes metacognitive reflection on an assignment a student has recently completed themself, especially when the grading requires comments and suggestions, not just judgements. For each assignment, a set of peer graders is assigned to each group—again, with the pseudo-randomization constraint that the graders did not grade any of the group members before, or immediately before, and that none of the group members graded them, etc. The peer graders make comments and assessments, which are anonymized and collated for the group that was graded. In turn, the group members assess the grading feedback they received. Grading disputes can be escalated to a second round of grading. Ultimately, disputes would be reviewed by the instructor, but it is likely that even after two rounds of grading, a consensus would emerge. On the other hand, students receive a lot of feedback on their work, and they also reflect metacognitively on the assignment and provide feedback to others. This design involves relatively
modest direct group assessment from the instructor.

This work is predicated on the assumption that if collaborative learning were easier to manage and were more scalable, then more faculty would adopt collaborative approaches. We have started to test this assumption (Zhu et al., 2018), but we are still at the stage of demonstrating that our approach meets its technical goals. Computer and networking infrastructures to enable broad use of scale-free small-group dialectical learning activities is fairly standard in American universities currently. Thus, while there is still a “digital divide” in the world, technology access is not a critical obstacle on American campuses (in the sense of Ertmer, 1999). A more formidable obstacle is the pedagogical belief and practice of faculty, views about what is possible, reasonable, or easy to do in teaching (Ertmer, 2005; Kim et al., 2013).

Discussion

Identifying authentic and engaging learning activities is a continuing challenge in education. Today, pervasive digital mediation makes it obvious that an important learning resource for authentic and engaging learning activities is other learners. Thus, the challenges of active learning pedagogies are now social as well as cognitive. Here we suggest an approach based on critical and dialectical thinking where students can take an active role in their own learning by creating and modifying their own perspectives. We argue that, pedagogically, this approach can help students create authentic knowledge and learning not based solely on mere remembering. A key difficulty of initiating and sustaining various collaborative learning regimes is an issue insofar as students as well as faculty often see class management time as an overhead or tax on learning time. However, effective interventions ought to be appropriable pretty much instantaneously and/or through activity that students and faculty can understand as directly related to the core mission of the course. Still, this remains a prevalent issue in that there is still a need for mundane tools that can be effectively used for instructors with this purpose in mind. We have talked about reappropriation of tools, such as Piazza, and the use of Kialo, the latter being a better suited tool and a more widespread one. Nonetheless, we argued that even if we were to use other tools for debating, those should be easy to adopt and straightforward to use. Moreover, in thinking about using
these types of tools, they need to facilitate class management and not create another set of issues.

Students are uncertain about whether outcomes they come to on their own are valid. They seem to want and need critical input. They want the instructor to work through their ideas critically, but they also want constructive suggestions about where to go further with their own initiatives. This learning dynamic should be researched further. To minimize this constraint, we have suggested the use of pseudo-random permutation on peer grading. Knowing that peer grading creates metacognition reflection of one’s learning can help students settle their doubts or concerns about their own learning and whether the interactions have been meaningful and valid. In this scenario, students are able to provide feedback to each other, while at the same time able to receive feedback from the instructor to further validate their ideas.

Our works imply that students could engage with the course contents and the instructors in different modes. However, the technology may not be well-prepared today, which requires future studies and developments. The technology-enabled collaborative learning had been shown useful for improving student cognitive performance, promoting social interactional, and positive learning behavior. Several solutions (e.g., the two services we mentioned in this chapter) have been employed in classroom and online teaching—the interaction between different teaching modes worth studying further to respond to future educational needs and goals.

References
question/answer system to support dialectical constructivist learning activity. 
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