How Teachers Implement Active Learning: Typologies of Orchestrational Flow

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Abstract: The term, Active Learning (AL) is commonly used in describing pedagogical approaches that engages learners actively in classrooms, with an emphasis on problem solving, inquiry and reflection. While a growing body of evidence supports the effectiveness of such an approach, there is great variation in defining the specific strategies and approaches, making it difficult to advance the field. We examined 19 college instructors for over 220 hours using AL methods. We coded the observed classroom activities according to teacher- and student-centered behaviours. On average, these teachers allocated over 50% of class time to group work. A cluster analysis revealed four distinct patterns of student-centred activity: (1) frequent, short duration; (2) longer duration; (3) less frequent, short duration; and, (4) mixed. Two approaches to workflow were identified: 1) tightly orchestrated and 2) front-loaded with less structured periods of work. Results suggest typologies of instructional patterns, growth trajectories and new directions for examining AL.

Introduction

Most educators now recognize the need to foster "21st century knowledge skills", such as critical thinking, collaborative problem solving, and evidence-based reasoning (Hargreaves, 2003; Pellegrino & Hilton, 2012). Science educators have responded to this challenge, exploring new modes of learning and instruction, such as peer instruction (PI), where students in large lecture courses respond to multiple choice conceptual problems using "clickers", with the tallied results introduced as a powerful mediator of whole class discussions (Crouch & Mazur, 2001). While PI methods hold promise for improving large lecture courses, a movement is now underway to reduce large lectures, emphasizing smaller, recitation-sized sections, led by TAs or instructors. In the "flipped classroom" approach, students spend time at home preparing for class by watching video lectures and reading texts, and class time engaging in active forms of problem solving, small group work, tutorial and recitation (Brookfield, 2012).

Referred to broadly as "Active Learning" (Bishop & Verleger, 2013; DeLozier & Rhodes, 2017), this approach has now engaged many STEM educators, resulting in professional societies (e.g., SALTISE.ca) and university-based centers to support the design of active learning courses. Pioneered by Beichner and his colleagues (e.g., Beichner, Saul, Abbott, Morse, Deardorff, Allain & Risley, 2007), the Student-centered Activities for Large Enrolment Undergraduate Physics, or SCALE-UP method, emphasizes small group tables for student engagement with hands-on activities, physical or digital manipulatives, structured and conceptual problems). SCALE-UP was adapted by MIT for its introductory physics curriculum, known as Technology Enhanced Active Learning (TEAL; Dori et al, 2003), which has provided an important referent for many new initiatives in undergraduate science education. Ruiz-Primo, Briggs, Iverson, Talbot and Shepard (2011) summarize active learning (AL) as comprising four dimensions: conceptually oriented tasks, collaboration, technology, and inquiry based projects. Several studies have measured the benefits of AL (e.g., Dori & Belcher, 2005; Linton, Pangle, Wyatt, Powell & Sherwood, 2014). A large meta-analysis of AL in STEM, shows that exams scores improved by 6% and students were 1.5 times less likely to fail compared with traditional lecture approaches (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt & Wenderoth, 2014). Moreover, AL has been shown to improve critical thinking, motivation and communication skills (e.g., Kim, Sharma, Land & Furlong, 2013), and increase students' use of metacognitive processes such as decision making and questioning (Lin, Hmelo, Kinzer & Secules, 1999).

Despite this evidence of success, however, AL remains largely ill-specified and difficult to study with any control (Ruiz-Primo et al., 2011; Brownell, Price & Steinman, 2013). For example, while specific group strategies are often invoked (e.g., group work, gallery walks, collaborative projects, or problem solving) very little definition is provided about the learning processes within those groups, the materials or assessments, or the instructor's role during the activities (Henderson & Dancy, 2007). Simply naming collaborative strategies fails to provide sufficient detail about the content, structure or sequencing of activities, nor how they must be configured to ensure efficacy. What makes a hands-on lab activity effective? When should it be used within the AL sequence? How will students collaborate, and to what end? How should design projects be structured, and how should they be assessed? Additionally, AL instruction places new demands on teachers' management and responsibilities for learning, referred to by Dillenbourg (2013) as *classroom orchestration.* Practitioners and researchers require more detail about AL designs, in order to develop a deeper understanding of how to create or adapt them for their own learning designs.

The recent interest in building innovative "Active Learning classrooms" (ALCs) offer an opportunity to gain insight into the instructional patterns used by instructors who purport to engage in AL. Instruction that takes place in these classrooms relies heavily on collaborative learning and student projects, providing opportunities to observe the corresponding teaching practices in a "natural habitat". By examining the nature of teaching and learning in such environments, we can gain an understanding of what instructors are doing and how they integrate AL strategies into their courses. Are there meaningful patterns and/or trends? Are they intentionally designed to produce specific learning and/or instructional outcomes?

We conducted a study of AL "in the wild" to inform our understanding of active learning, and to improve our own approaches to AL design. Our observations and survey of 19 instructors, reported in this paper, can serve as an important referent, informing how we make sense of AL in terms of its patterns of activity structure, discourse and interactions. In many ways, examination of these authentic implementations are akin to what Bereiter (2014) calls for when he described principled practical knowledge, "a type of knowledge that has characteristics of both practical know-how and scientific theory" (p. 5). This research thus aims to inform theoretical perspectives on AL, as well as instructional design and principled instructional practices (authors, 2010).

Methods

Design and data collected

This research used a case study design (Yin, 2013), involving mixed methods and ethnographic approach (Denzin & Lincoln, 2000), and part of a larger study involving student group practices and artifact production. The data used included classroom observations consisting of field notes, video recordings, teacher interviews and the pedagogical commitment self-reporting survey - i.e., Post-secondary Instructional Survey (PIPS; Walter, Henderson, Beach & Williams, 2016). PIPS consist of 24 items categorized into student-centred and teacher-centred statements, that indicate a score describing a teacher's practice along the two factors. Two indices were generated from PIPS scores: A student-centred index (SCI) was created from the ratio of the instructor's student-centred score and teacher-centred score; and classification of SC (student-centeredness) based on the SCI such that Level 1 included SCI less than 2, Level 2 included SCI from 2 to 3.5, and Level 3 included SCI greater than 3.5.

Participants and setting

The study used a purposeful sampling to recruit a total of 19 instructors from three colleges, situated in a metropolitan city in eastern Canada. This sample was selected from a total population of approximately 70 teachers across the three colleges, who voluntarily select to teach their one or more of their courses in active learning classrooms. Their data corpus represents 33 course sections, from 13 courses, and eight disciplines - Physics, Chemistry, Biology, Mathematics, Psychology, History, Humanities and English. Class sizes ranged from 15 to 47 students. All 19 participants had taught in these types of classrooms multiple times, ranging from 5 - 12 semesters (Mean = 9 semesters). Additionally, each institution has some level of support and expectation that teachers using these classrooms will use a student-centred approach and engage with an appropriate professional learning community.

Procedure and analysis

Observations were conducted by members of the research team, carefully following a common protocol that included field notes and video recordings using GoPro cameras to document the teacher's activity. Multiple class sessions were observed for each teacher, based on an established schedule that set conditions - e.g., accommodation of the teacher preferences, minimum number of classes to observe, timing between observations. In all instances, efforts were made to schedule observations to ensure obtaining a representative sampling of the teacher's practices and their instructional implementations (avg.# of observations = 8.3).

Quantitative data analysis was performed using R (v3.4.1), an open source analytic software environment. Analysis of the classroom observations was performed using StudioCode and a protocol similar to the COPUS approach (Classroom Observation Protocol for Undergraduate STEM; Smith, Jones, Gilbert & Wieman, 2013). However, our coding sought to elaborate on the types of classroom behaviours during the class session, as well as to document the amount of time spent in each kind of activity. *Capturing the distinct kinds of instructional interaction -- including various forms of lecture, small group, and individual learning activities -- was a primary goal, with the aim of providing a clear account of the frequency, duration, sequence and mix of interactions that occur.* Each class session was coded for presence of the following categories: (1) teacher-centered (lecture/demo); (2) student-centered (group/individual/whole class/student presentation); and, (3) other (administrative work). Actual time spent in each activity was then calculated and recorded for each teacher. We also recorded the type of classroom as being either high-tech "active learning space" (e.g., interactive writable surfaces) versus low-tech "active learning space" (e.g., traditional whiteboards and writing surfaces), in order to investigate whether this variable influenced the nature of classroom interactions.

Results

Entering into this effort, we recognized that instructors would vary appreciably in how they put the ideas of AL into practice, and for purposes of this paper, we include any student-centred instruction occurring within these classrooms as a form of active learning. A total of 157 observations were obtained, with average class times of 85 minutes, and an average of 8.3 observations per teacher.

We found that instructors spent 59% of their time in student-centred activities (ranging from a low of 24% to a high of 76%), and 40.8% in teacher-centred activities (see Figure 1). A box-plot of these observational data (Figure 2) reveals that student-centred approaches were the primary instructional mode for 15 of the 19 teachers observed. This is in clear contrast to other studies such as Lund et al. (2015) whose sample of 73 teachers spent less than 20% of class time in student-centred activity, with lecture as the primary instructional mode. Even in cases when professional development (PD) training was provided (e.g., Stains, Pilarz & Chakraverty, 2015), lectures remained above 60%, and returned to 80% within two years of the PD intervention. Thus, it is encouraging that AL-oriented instructors exhibit such a clear pattern of student-centred learning designs.

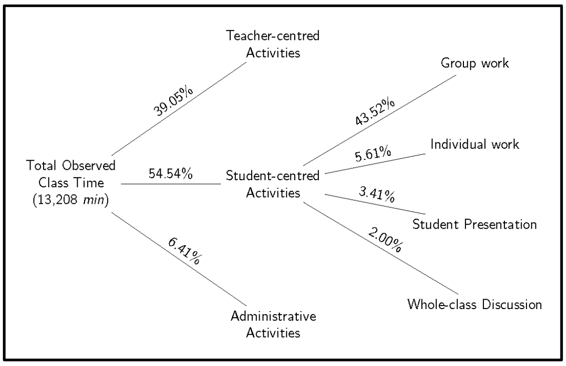


Figure 1. Average proportion of class time spent on different activities by the 19 teachers.

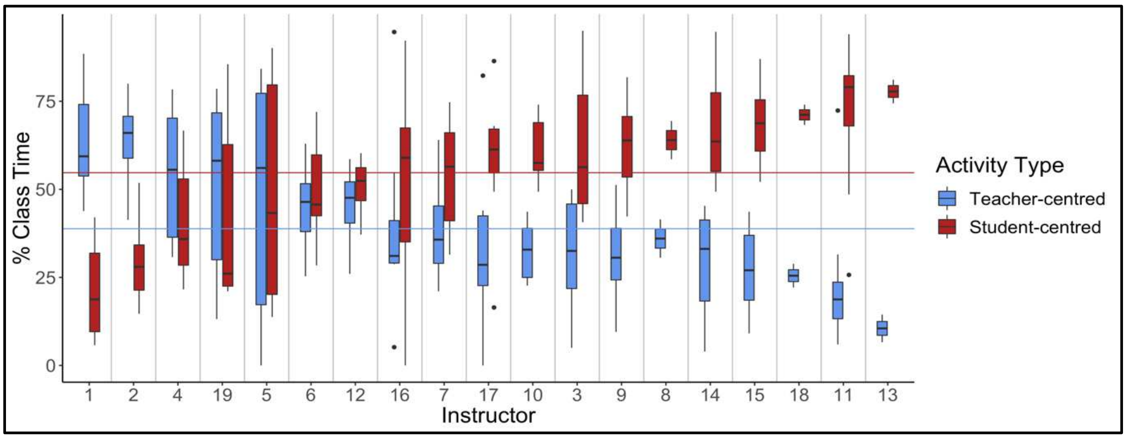


Figure 2. Box plot comparisons of the 19 instructors, ranking by time spent in student centered activities within their observed classes. Horizontal lines are grand means for each activity type.

What factors impact instructional patterns?

To determine whether the observed patterns of instruction depended on particular characteristics of the teacher or classroom, a MANOVA was performed with activity type (lecture, group work, individual work, student presentation, whole-class discussion) as the dependent variable. Independent variables were teacher, classroom type (high-tech ALC or low-tech ALC), course section, course content and semester (fall or winter session). There were no main effects of classroom type (low-tech or high-tech), course section, or semester, nor significant interaction effects, however there was a significant main effect of teacher, with Pillai's Trace = 1.23 ($F_{(18, 131)}$ = 2.37, $p < 0.05$). This is unsurprising, as different teachers would likely have characteristic instructional patterns, which would give rise to such a significant effect. To further test whether teachers' instructional patterns are stable across contexts, we examined the 7 teachers who were observed multiple times in different contexts. For each of these teachers, a MANOVA was performed to examine whether or not the different contexts led to different instructional patterns. In all but one teacher, no statistically significant difference was found, suggesting that teachers within our cohort use similar instructional patterns regardless of the course context. Post-hoc analysis of the one exception indicated that the difference is attributable to a small dependence of "student presentation" activities in the observed course. This overall lack of variation across contexts suggests that it is safe to aggregate our observations across context for the remaining analyses.

We sought to further understand the characteristics of these active learning designs by focusing on the most commonly occurring form of student-centered activity: group work. One question that could be addressed from our observation data was concerned with the average duration of groupwork. We performed a *partitioning around medoids* cluster analysis (Reynolds, Richards, de la Iglesia & Rayward-Smith, 1992). Findings show that 18 of the 19 teachers fall into one of four clusters (Figure 3). Cluster 1 indicates very frequent but short activity sessions; cluster 2, moderately frequent but long activity sessions; and Cluster 3 shows moderately frequent but shorter activity sessions; finally the two teachers in Cluster 4 employed moderately frequent and moderately long activity sessions.

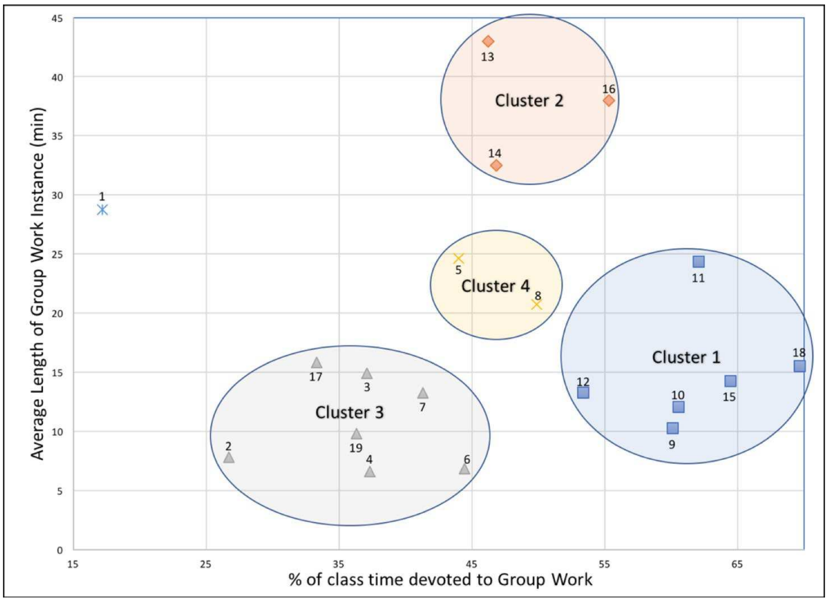


Figure 3. Cluster analysis revealing four clusters of student-centred pedagogy organized by % of class time devoted to group work and average length of group work assigned within class session.

Looking within clusters, we found different orchestrational flows. In Cluster 1 teachers were generally observed as designers of many short duration activities engaging students in collaborative tasks that included group problem solving, peer review and editing, peer instruction (reciprocal teaching), orchestrated by task termination (or interruption) after 10-15 minutes to provide feedback at the class-level. Observations of teachers in Cluster 2 revealed longer group activities with orchestration involving the teacher circling around the classroom, providing feedback to individual groups. Generally, such activities engaged students in project work, sometimes with a distribution of labour and sometimes working jointly to build and/or add to a shared artifact. Cluster 3 teachers orchestrated with shorter activities and fewer of them, appearing to have less experience with student-centred instruction or teaching in disciplines with lots of content to learn (e.g., biology, history). Much like the earlier cluster, these tasks engaged students in problem solving and peer instruction. Cluster 4 is more difficult to describe because the two teachers appear to engage in different orchestrational flows or styles, teacher 8 being more aware of using group work but hampered because of the student under preparedness (described in interviews).

What characteristics are shared by teachers within the clusters?

To understand the factors that might account for these clusters, we examined characteristics of the 19 teachers (see Table 1). We found that Cluster 1 teachers were predominantly from a common discipline (physics), as compared with the other clusters, which were more heterogenous. Cluster 1 teachers also generally shared a high commitment to student-centred interactions like small group work, with 4 out of the 6 cluster members at Level 3 on the SCI classification. We examined other factors, such as years of teaching or experience in AL classrooms, but those did do not vary systematically (i.e., in any way that could offer explanation for the clusters). Still, in Cluster 3 we recognized that two of the disciplines found there (biology and chemistry) have a strong tradition of focusing on content at the undergraduate levels, particularly as these were introductory courses with multiple sections, where teachers expressed feeling external pressures to prepare students for the common final. This could may explain why their SC index scores are high compared to their actual implementation patterns – i.e., cluster allocation.

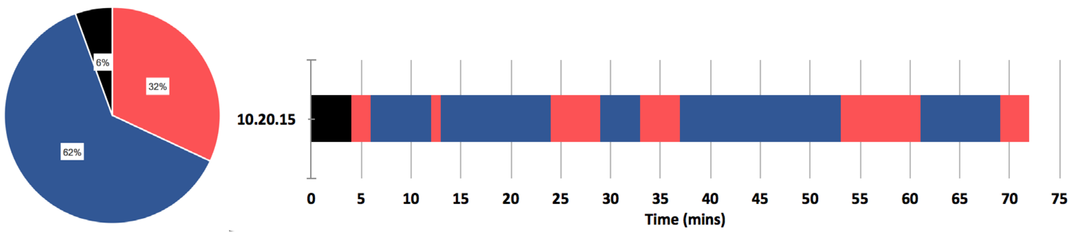
Table 1: Breakdown of individual teachers information organized by their association to the cluster analysis

cluster	Teacher ID*	Teaching experience	AL experience	SCI	SCI Level	Discipline
1	9	11	3	6.1	3	physics
1	10	9	2	3.5	3	physics
1	11	9.5	2	4.5	3	physics
1	12	17	3	10.4	3	physics
1	15	11	2	3.4	2	physics
1	18	n/a	n/a	n/a	n/a	math
2	13	15	1	4.6	3	english
2	14	7.5	2	2.5	2	sociology
2	16	13	3	2.8	2	physics
3	2	7.8	2	1.8	1	chemistry
3	3	6	1	1.6	1	psychology
3	4	9.5	2	2.0	1	physics
3	6	16	2	10.6	3	biology
3	7	23	2	3.1	2	sociology
3	17	9	1	n/a	n/a	history
3	19	11	2	n/a	n/a	biology
4	5	15	2	1.8	1	chemistry
4	8	10	2	5.4	3	physics

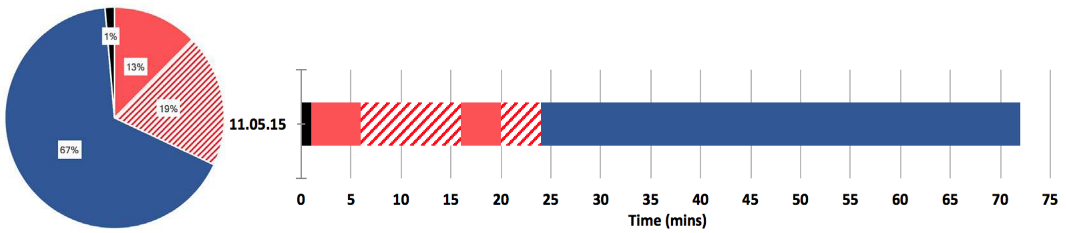
Notes: Teaching experience, numbers of years teaching; AL experience (proxy used: request to teach in AL classrooms) 1 = low (>2 yrs), 2 = medium (3-5 yrs), 3 = high (> 5 yrs); SCI, student-centred index, see Methods section for details; SCI Level, see Methods section for details. *Teacher 1 not presented here, b/c not part of cluster analysis.

Characterizing orchestrational flows

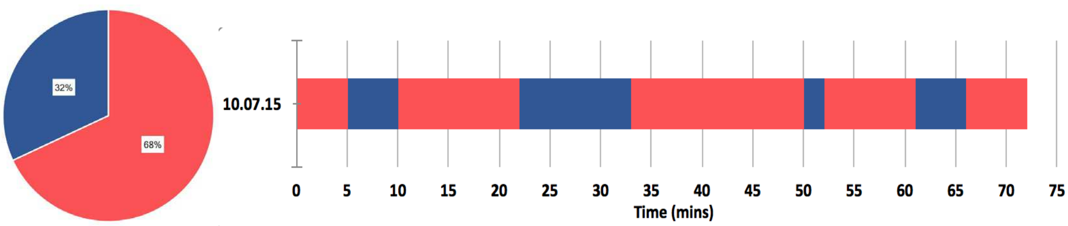
Several studies have focused on teachers' pedagogical implementation, which is sometimes referred to as "pedagogical flow" (Schmidt, 2007), and more recently subsumed within the broader notion of classroom orchestration (Dillenbourg, 2013). Inspired by these notions, we explored the implementation patterns of our cohort of teachers, selecting one teacher from the three main clusters (i.e., Clusters 1, 2 and 3). In an effort to minimize differences in implementation that might be associated with content, we selected the three teachers who teach the same discipline (physics) and specific course (Mechanics), but who fell into different clusters. Because we conducted multiple observations for each of these teachers, and the timeline descriptions for each observation were somewhat distinct (i.e., based on topic of the day and what the students were asked to do), we had to develop some measure of a teacher's "characteristic implementation," which we obtained by selecting the most representative of their respective implementations. This is captured through a pair of graphs – a pie chart to show total proportions of time spent in different forms of interaction (i.e., small group, lecture, or demonstration), combined with a timeline showing the distribution of those interactions over a representative class period. Figure 4 shows the three sample teachers, whose respective pedagogical flow can be seen reflecting the three distinct clusters.



Phy_9_cluster 1



Phy_16_cluster 2



Phy_4_cluster 3

Figure 4. The orchestration of AL by three teachers, each representing one of the three main clusters identified. Teacher Phy_9, is representative of cluster 1, teacher Phy_16, of cluster 2, and teacher Phy_4, of cluster 3. Colors, blue=group work; red=lecture; red stripe=demonstration; black=administrative work.

Interestingly, while teachers Phy_9 and Phy_16 allocate over 60% of their class time to group work there is a stark difference in their implementations. Phy_9 has a "stop and go" pattern that is a heterogeneous mix of lecture and student group work – creating a rhythm almost like an up-tempo musical piece. Meanwhile, Phy_16 shows a two-stage pattern that is "front-loaded" with the teacher lecture and demo followed by a prolonged period of group work. Teacher Phy_4 illustrates the near inverse of the Cluster 1 teacher. This pattern too is "stop and go" but substantially less time is allocated to group work.

Interviews with these teachers also revealed differences in their instructional objectives and pedagogical commitments. Teacher Phy_9 stated that he had a pair of aims: (1) to guide students through a series of activities that engage them in exploring the concepts, but also (2) to maintain control over the student's interaction with the content as a means of giving them an opportunity to apply their knowledge but then moving them along. Teacher

Phy_16 stated that his aim was to allow students to explore the content, and preferred to work with the groups themselves to better understand the individuals and their concerns. The interview with teacher Phy_4 revealed that while he was also interested in having students try out what they were learning, he was more concerned with moving things along and controlling "the chaos that comes with group work" in active learning classrooms.

Discussion

Under the assumption that this cohort of 19 college teachers is adequately representative of student-centred teachers, we set out to examine their practice and implementation of AL strategies. Examining the allocations of time to different instructional activity revealed four patterns: high group work with frequent interruptions (Cluster 1), high group work with few interruptions (Cluster 2), moderate group work with interruptions (Cluster 3), mixed (Cluster 4). The Cluster 2 pattern suggested a front-loading of lecture before handing over longer durations of time for students to work on activities. Such implementations appear similar to inquiry-based approaches. On the other hand, Cluster 1 and 3 patterns revealed types of "stop and go" tempos, or what might be considered a heterogeneous mix of lecture and group work – though clearly Cluster 1 is more student-centred.

These identified patterns offer new opportunities to extend the CSCL research on orchestration in empirical ways. For instance, the two types of AL patterns call for very different management of resources and learning – group level versus class level. Additionally, the patterns of Clusters 1 and 3 offer opportunities to explore how and what teachers do in interweaving the lecture and group work and how they integrate AL strategies. The limits of this paper do not allow for the expansion of this investigation but interviews with these teachers reveal clearly different intentions behind these designed implementations. Lastly, the inverse of patterns identified between Cluster 1 and 3 raises the question of whether or not these might not be representative of growth trajectories along the continuum of AL adoption. As such, we might further ask whether or not teachers adoption of this new approach takes on such trajectories and could provide insights on professional development. This study has begun the process of shaping what is to be explored as CSCL and the Learning Sciences begins to consider AL as an instructional practice. We argue that by examining authentic implementations we gain a better understanding of how collaborative learning is orchestrated to meet the needs of integrating group work and lecture, and more importantly, how our findings might be adopted by everyday practitioners. Such investigations also bring us closer to understanding how we might follow up on Bereiter's challenge of designing with *principled practical knowledge* (Bereiter, 2014).

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