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Determining Useful Tools for the Flipped Science Education Classroom

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Abstract

This paper reports the results of a 3-year longitudinal study on the perceived utility of supplying elementary science teacher interns with four asynchronous tools to assist them in creating their first lesson plan of a constructivist nature. The research accessed qualitative and quantitative measures to sample intern reaction to the notion of a flipped classroom. As cited by the Flipped Learning Network (FLN, 2014), "Flipped Learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter." Of the flipped resources supplied to support the constructivist lesson framework of Driver and Oldham (1986), students found the handbook on formative assessment strategies to be the most helpful. Overall the implementation of the four supplemental resources in a flipped classroom mode culminated in at least 10% better grades on the first lesson plan (over 3 years) by comparison to the 2 years prior to the intervention.

What Is Flipping?

The notion of "flipping" as it relates to educational practice has recently grown in popularity (Arnott, 2013; EDUCAUSE Learning Initiative, 2012; Saban, 2013; Tucker, 2012; Ullman, 2013). The Flipped Learning Network (FLN, 2014) has provided important distinctions between *flipped learning* and *flipped classrooms*. Whereas flipping a class may be as simple as providing a range of resources to supplement and modify content engagement sequences, flipped learning has been defined as "a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter."

In addition and more specifically, flipped learning is said to adhere to four fundamental pillars (FLN, 2014). The first of these pillars is a flexible environment, the criteria that learning spaces (time and place) must be flexible for the student. The second pillar is learning culture, which means that the learning be student centered, with classroom instruction time representing unique opportunities to extend the learning through rich discussions.

Pillar three is intentional content, referring to the instructor's proactive approach to delineating what is to be formally taught versus what is to be the student's role in personal engagement of the content. The final pillar, professional educator, indicates that teachers must actively scaffold learning with timely and continuous feedback to students as they negotiate self-directed learning.

In practice, while flipped learning may take different forms in the classroom, it is most often characterized by supplying lecture notes, readings and supplemental resources before class, thereby maximizing in-class interaction through hands-on activities, problem solving, or Socratic discussions of key questions, for example. Clearly, flipped learning bears a distinctive and far-reaching definition by comparison to the flipped classroom. Defining the associated pedagogy related to the oft-used terms makes it much easier to consider the potential the approach has to empower learning.

Research on Benefits and Challenges

Fulton (2012) suggested the following positive potential for the flipped classroom:

- Students define learning pace.
- Scaffolding of homework in the classroom allows for teacher as diagnostician.
- Content is customizable for students.
- Classroom time is more efficient and engaging.
- Teachers report improved student motivation.
- It is consistent with current pedagogical trends.
- Technology as a tool is a natural fit.

The positive attributes of this approach have been documented in recent studies of engineering, nursing, pharmacy, physics, and statistics (Deslauriers & Wiemen, 2011; McLaughlin et al., 2013; Missildine, Fountain, Summers, & Gosselin, 2013; Papadopoulos & Roman, 2010; Strayer, 2012; Warter & Dong, 2012)

This praise has been balanced with critiques that (a) no significant difference in student performance has been demonstrated,(b) students might be unprepared or unwilling to do the necessary preliminary work,(c) the teacher has a significant task to orchestrate and coordinate materials access and activities, and (d) the format may diminish opportunities for a Socratic approach to teaching (Herreid, & Schiller, 2013; Lape et al., 2014; Strayer, 2012). Although applications haved ranged across content areas, science represents a compelling context for investigating this pedagogical approach.

Flipping and Science Education

Science education has a long history of providing supplemental materials to augment active learning in the classroom. With the onset of the constructivist movement (Brooks & Brooks, 1993) and the establishment of teaching standards (i.e., Next Generation Science Standards; Achieve Inc., 2014), the concept of the flipped classroom or flipped learning might be expected to be a logical extension of current science pedagogy. Nonetheless, educators (Bergmann, Overmyer, & Wille, 2013; Bergmann & Sams, 2012; Brunsell & Horejsi, 2011, 2013) continue to address the misconception that flipping in the context of science classrooms means more than offering asynchronous video resources or podcasts to students. Based on the work of Lape et al. (2014), Yarbro, Arfstrom, McKnight, and McKnight (2014) asserted that “the question is not whether this model is or is not effective, but rather, under what conditions can it be most effective” (p. 12).

Analogously, as with many studies of technology in classrooms, it is the integration with good foundational pedagogy that will ultimately determine the impact of this model. Berrette (2012), from a biology teaching perspective, highlighted a most prevalent use of flipped approaches in science. He provided students with engaging materials before class, ideas he expected them to tease out before arriving to class. He then allowed class time for student group analysis, where he provided scaffolding as students continued to interact with important questions in the curriculum.

As alluded to by Berette (2012), frequently instructors will provide reading materials or media resources in advance of a classroom meeting so that student-teacher interaction is maximized through attending to (a) conceptual understandings and (b) computational problems. This “thinking out loud” as the teacher works through issues not only demonstrates problem solving skills but also provides valuable opportunities for just-in-time learning (Halverson & Collins, 2009). It remains for science teachers to investigate the nature of content materials that can be provided and the pedagogy that best promotes meaningful learning. What and how do educators flip the traditional classroom? As per established definitions (FLN, 2014) the study described in this paper is that of a flipped classroom.

Study Context

An action research study (Beaulieu, 2013; Stringer, 1996) was conducted in a science teacher education course over 3 consecutive years. The instructor (and author) prepared various supplemental materials that might support a constructivist teaching model (Driver & Oldham, 1986) introduced in the class. The study accessed both quantitative and qualitative measures in an effort to define the more productive tools to use in a flipped science teacher education classroom. While the sample is limited to particular student groups by design, generalizability may be extended to similar contexts, an approach to interpretive work that is inherent to classroom action research (Beaulieu, 2013).

The study was undertaken at a small Canadian liberal arts institution of approximately 3,500 students and 220 full-time faculty members. In 1996, Acadia University was recognized by the Smithsonian for its laptop initiative, the first campus-wide laptop integration project of its kind in Canada. The School of Education offers an after-degree 60-credit-hour bachelor of education in two formats over 16 months or 24 months.

All teacher interns in the elementary school stream are required to take introductory science education as a teaching methodology course. The sample alluded to in the ensuing research discussion was drawn from this select group over a 3-year period.

The teaching of this science education course was grounded in an inquiry-based constructivist approach (Martin, 2011). Teacher interns experienced science in this course through activities that prompt cognitive dissonance (Wicklund, & Brehm, 2013) and focused discussions that served to force students to accommodate their newfound knowledge within prior learning schema (as in Posner, Strike, Hewson, & Gertzog, 1982). Over a 10-week period, interns met with the instructor once a week for 3.5-hour classes. In this timeframe typically 2.5 hours was dedicated to activities/investigations.

What Was Flipped?

A sample of 97 teacher interns over three consecutive iterations of the introductory science education course were supplied with four distinct tools to supplement their 3.5-hour lecture and subsequent lesson planning around the topic of constructivist teaching and learning. The model taught is outlined in Figure 1.

These tools included the following:

- Lesson plan examples on an instructor-prepared CD-ROM entitled "Teacher as Planner and Presenter," which included lessons of poor quality submitted by students in the past. Lesson parts as per Figure 1 were presented to students, who then had to decided what was problematic and then select on the CD-ROM a suggestion or solution description by the instructor. The recurring issues from some 12 years of plan submissions formed the database of examples for students to access.
- A voice-over PowerPoint presentation entitled "Diagnosing Lesson Plan Problems." This resource categorized common lesson plan inadequacies, and the instructor provided comment through an audio recording synchronized with the slide presentations. Students could choose to revisit or pause the presentation slides at will.
- A compiled mini-handbook entitled *Strategies for Formative Assessment in the Science Classroom*. Science education students in this course (typically with educational histories steeped in summative assessment) have difficulty generating formative assessment tools (Angelo & Cross, 1993) for "assessment for learning." To this end, the instructor created a small handbook of multiple strategies for all learning contexts, which students were supplied in paper format prior to the lecture.
- A video-recorded lecture on contextualizing learning entitled "Developing the Need to Know." The rationale for this resource was the recurring problem of establishing context for lessons. Often teacher interns create lessons where the primary reason for learning is that, as interns would say, "It is in the curriculum." In an effort to promote more relevant lessons generating cognitive dissonance and of societal interest, a focused lecture was video recorded. This lecture included a range of strategies for students to consider.

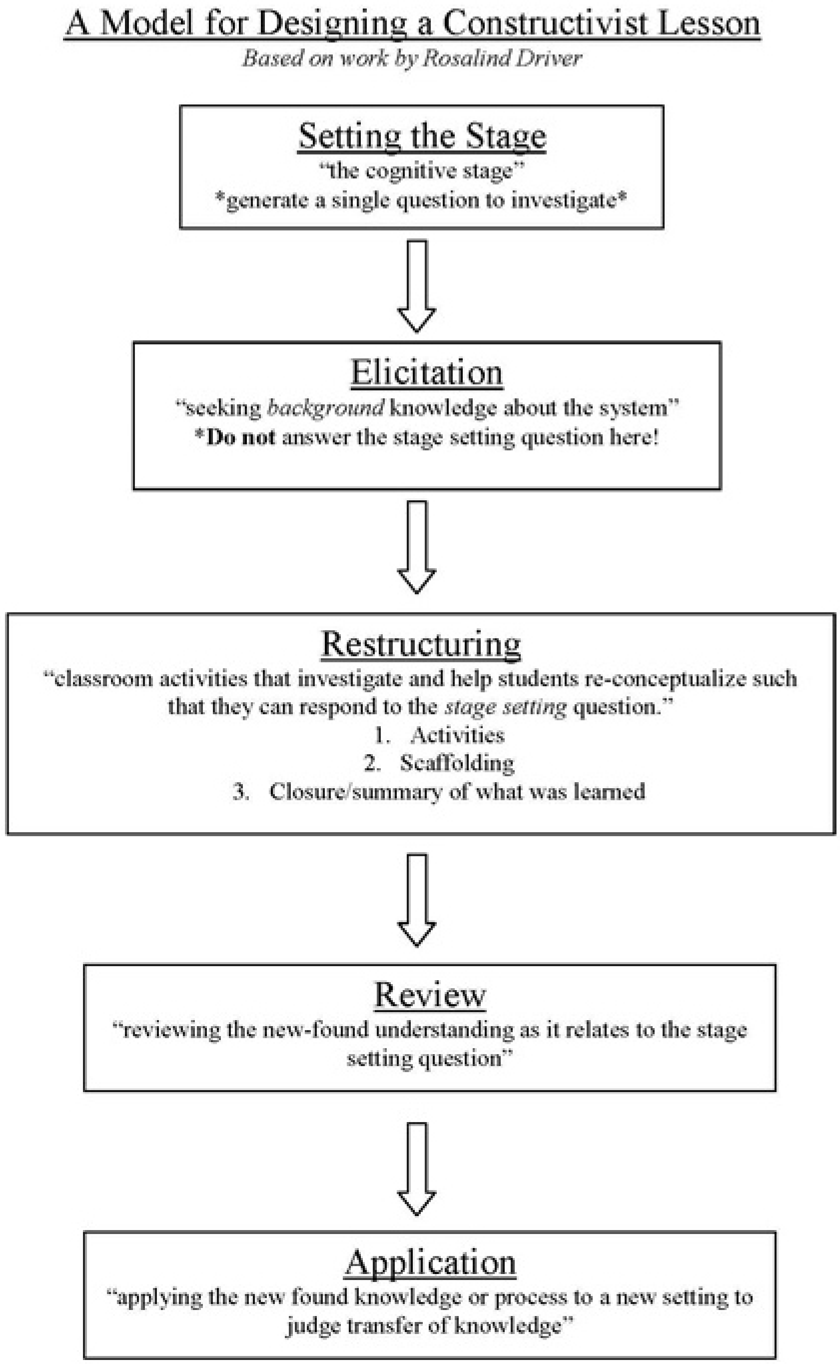

Figure 1. *A model for designing a constructivist lesson (adapted from the work of Driver & Oldham, 1986).*

Each of these tools was supplied to teacher interns before the lessons on constructivism and their concomitant lesson planning assignments. In the class time afforded by flipping these resources, the instructor (a) engaged discussions of the components of a constructivist plan and the inherent rationale based on the work of seminal psychologists (Piaget, Vygotsky, Ausubel, Bruner, Posner, etc.), (b) modeled constructivist activities followed up with a revisiting of the Driver and Oldham (1986) model, (c) coordinated brainstorming sessions to unearth a range of strategies for creating cognitive dissonance, (d) engaged interns in role plays to demonstrate the importance of studying societal issues in science, and (e) investigated the nature of science in process skill activities.

Based on their lived experience of constructivism, interns were assigned the task to create a constructivist lesson plan which they submitted 1 week later. In an effort to improve these plans, individual intern-instructor sessions were scheduled in which plans were deconstructed around key constructs such as (a) learning objectives, (b) restructuring activities, (c) scaffolding, and (d) assessment strategies. These sessions culminated in a second submission of an improved plan by the intern.

Research Methods

A 20-question electronic survey (in 5-point Likert format, spanning *strongly agree* to *strongly disagree*) was designed and field tested with 5 teacher interns to promote clarity and remove ambiguity of question intent. The edited survey sampled students' opinion on the relative helpfulness of the four tools as they embarked on their first constructivist lesson plan. Teacher interns (n = 97) from three consecutive course iterations responded to the survey.

Based on the collated survey results, a standardized open-ended interview guide was developed (Patton, 2002). From the larger sample, 20 interns were randomly invited for a 30 minute audio-recorded interview. Of that group, 14 interns responded to invitations for interview sessions, 4 from Year 1, 4 from Year 2 and 6 from Year 3. Transcripts of the audio interviews were coded in an iterative process (Huberman & Miles, 2002), which included revisiting quantitative trends from the electronic survey. It is duly recognized that mean determinations for Likert data are arguably not continuous variables; however, in this research context, the survey results served only to direct more trend-oriented focused questions for the interview guide.

The cumulative empirical materials and interpretive framework were "member checked" (Guba, 1981) with two focus groups (Krueger & Casey, 2009) of 5 interns each in an effort to corroborate findings and/or discard outlier qualitative feedback. The overall data set was reconsidered in a peer debriefing session (Guba, 1981) with a research colleague unconnected with the action research study. For the benefit of comparison only, the first lesson plan scores of the study participants was compared to those of students in course iterations over 2 years prior to the flipped classroom study. It should be noted that the identical scoring rubric was used to score plans from that 5-year period, that is, 2 years prior and 3 years during the study.

Results

In studies involving some level of technology intervention, it is important to establish participants' predisposition to technology use. In this way the researcher can decide whether this predisposition is reflected in the overall survey of opinion regarding the intervention. In this action research study, the electronic survey found only 10% of students suggested that using the technology to access supplemental materials for the flipped classroom impeded their learning. This result would suggest that any negative attitude toward an intervention is likely due to the intervention itself (in this case a resource for the flipped classroom) and not frustration associated with the technology.

The data in Figure 2 represent those students who agreed or strongly agreed that the flipped supplemental resources were useful in preparing their first constructivist lesson plan. For the last three resources, at least 75% of interns found that providing this type of resource before the associated lecture was useful in preparing the first lesson plan.

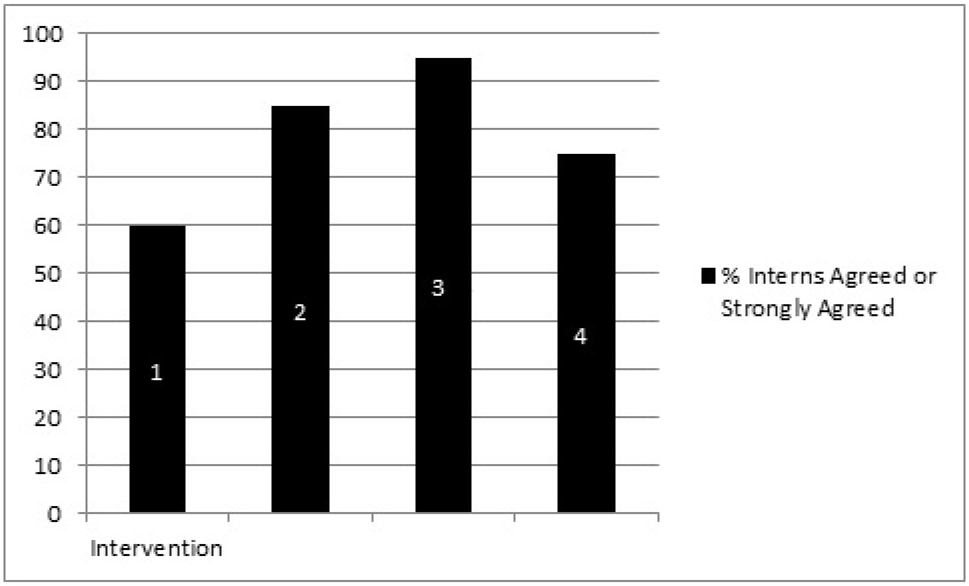

Figure 2. *Percentage of interns who* agreed *or* strongly agreed *that the intervention (1-4) was helpful in planning their first constructivist lesson.*

From the data presented in Figure 2 it is clear that the first intervention (the CD-ROM) had the least impact on students in terms of planning their first lesson. In interviews interns were asked why they thought some of their peers found the CD-ROM resource less useful than the other tools in terms of preparing their first lesson plan. Over half of the interviewees suggested it took more time to access the CD-ROM. In addition, interviewed interns from the last year, in particular, suggested that their laptop computers did not house CD disk drives. The choice of medium was heavily influenced by the standardized laptops that were supplied to students at the onset of the laptop initiative. In later years, students were given a choice of laptops to purchase and bring to class. This meant there was a mixture of computing machines within the student sample over the period of 3 years. These computers had different capabilities, with early machines housing CD drives (MacKinnon, 2007, 2011)

Interns in the future will be supplied smaller files on the course Moodle® site, while the larger electronic files will be placed on USB thumb drives. The majority of the interviewed group said that the PowerPoint slideshow with voice-over explanations of problematic areas was easier and faster to access and involved more explanation than the text version on the CD-ROM.

In focus groups, students were unanimous in suggesting that the formative assessment examples had more impact because that was an area of particular difficulty. One intern said, “We have been exposed to summative assessment, but the idea of assessing for the purpose of judging ongoing learning is new to us. We needed samples.”

In interviews interns said they had challenges invoking a state of disequilibrium in their students. Focus groups articulated this point more clearly. One student offered the following comment that captured the consensus of the group. “It’s so difficult to generate a good hook, you know, to catch their interest, to pose a good question.” This statement led to a productive discussion suggesting that interns have a propensity to choose an entertaining or sensational demonstration (students love explosions, lights, and smoke) before they even consider the learning outcomes.

The data represented in Figure 3 indicate that first lesson plan scores (using the same rubric) were higher in the 3 years using the flipped approach than those 2 years prior to the intervention. It is important to note that number of students used to calculate the mean score on this plan varied from Year 1 to Year 5 as follows: 55, 54, 49, 25, 23, respectively. This variation was due to the number of sections of the course being offered in corresponding years.

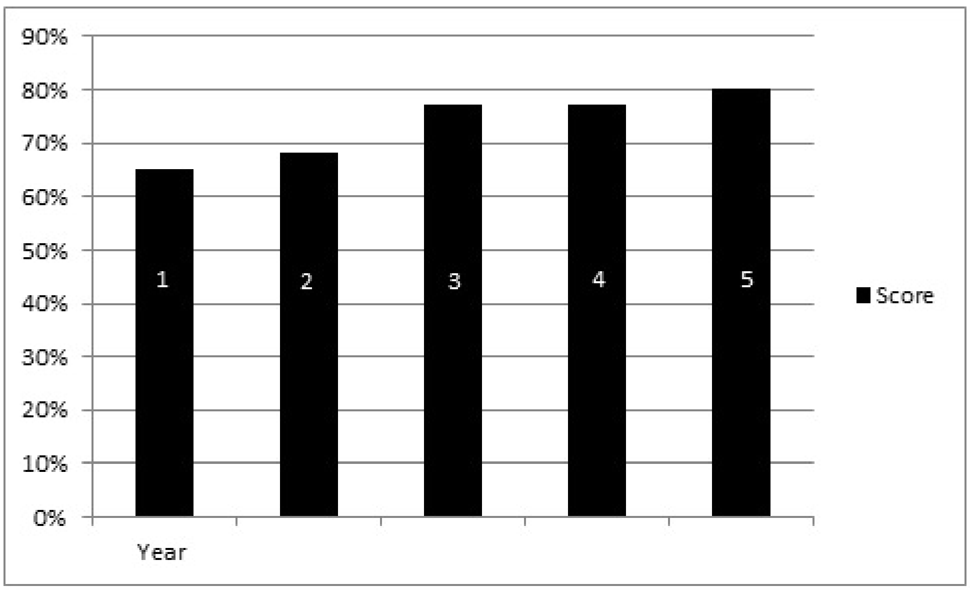

Figure 3. *Lesson plan grades 2 years before and 3 years during the flipped classroom (1-5 represents the years that grades were drawn from).*

Conclusions

As with all action research, the ultimate aim is to improve a system. In this investigation, teacher interns provided both quantitative and qualitative feedback that was useful for making improvements in future offerings of the elementary science methods course. Specifically students offered the following suggestions:

- All resources, where possible, should be supplied online and in cases of large files on a USB drive.
- The resources supplied in advance should be directed to assist interns with problematic lesson planning areas identified in the past.
- The database of examples of substandard lesson plans should be extended.
- Examples of formative assessment strategies should be extended.
- Breaking the lesson suggestions into components, as per Driver's model (Driver & Oldham, 1986), makes it easier to focus on one aspect of the plan at a time.
- The examples of stage setting, including context building and use of discrepant events, was helpful. These examples should be extended.
- The in-class sessions should continue to emphasize the practical examples of constructivist activities so that the experiencing of these learning modes informs later planning.

Further Work

After these suggestions are implemented, the action research cycle (Stringer 1996) will again be employed to identify, through longitudinal studies, further improvements in the potential for flipped approaches in the course offering. The inevitable addition of new technologies will pose new possibilities for providing students with learning materials before and after the formalized face-to-face class time. The ultimate aim will be to identify those categories of resource intervention that demonstrate a tangible improvement in the conceptual understanding on the student's part.

Using a submitted lesson plan as an assessment tool is arguably open ended, but it is possible to highlight key areas of deficiency particularly within the broader notion of creating plans that promote constructivist learning environments. This goal can be accomplished by meeting with students one on one and discussing their objectives and their strategies for achieving said aims. These microteaching opportunities assisted in the analysis of the relative utility of flipped classroom tools.

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