INQUIRY & INVESTIGATION

Flipping the Classroom Using the 5E Instructional Model to Promote Inquiry Learning in Online & Hybrid Settings

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Abstract

Nontraditional teaching modalities have become the new normal, where hybrid and online education are bound to become an integral component of education at all levels. This paper suggests the coupling of the flipped classroom model with the 5E instructional model for students to develop science understandings and practices in a hybrid and online environment. We demonstrate our model through a middle school unit on animal adaptation and natural selection. In our model, the teacher involves students with asynchronous online activities that raise students' curiosity and help them develop the concepts before the face-to-face or synchronous class activities. The complementary interactive online asynchronous and face-to-face or synchronous activities aim to promote critical thinking and communication on one hand and NGSS Core Ideas and Science Practices on the other. This paper concludes that science teachers can benefit from this model to engage students in inquiry-based activities in both hybrid or remote learning.

Key Words: *flipped classroom model; inquiry-based learning; 5E instructional model; science practices; animal adaptation; natural selection.*

○ Introduction

The COVID-19 pandemic made salient the need for equitable science education and a science literate society that understands scientific concepts and processes required for personal decision making (Mohlhenrich, 2021; Gordon, 2020; Verma et al., 2020). Even though the shift to remote instruction posed challenges to inquiry-based learning (IBL), it also provided opportunities for reimagining new teaching methods for science classrooms, as the educational landscape is likely changed forever. The unique educational experience of the pandemic years can be adapted and leveraged to produce quality hybrid and online teaching and learning of science (Mohlhenrich, 2021), whereby science teachers' exposure to accessible technological tools can be harnessed and made more structured and purposeful through innovative hybrid and remote teaching models that promote IBL.

Combining the flipped classroom model with the 5E model helps us realize more effectively meaningful inquiry-based learning for higher levels of scientific literacy.

In this paper, we propose combining the flipped classroom model (FCM) with the constructivist-based 5E instructional model that structures IBL across five phases: engage, explore, explain, elaborate, and evaluate (Bybee, 2014). The FCM is a pedagogical approach in which the class-time lecture and the homework activities are reversed. Typically, students view short video lectures at home before the class session. As such, class time is devoted to exercises, projects, discussions, and participation in active problem-solving activities (Love et al., 2015). As a hybrid learning model, the FCM provides students with access to a variety of digital instructional material for independent remote learning before teachers engage students in individual or group problem-solving activities in the classroom (Sezer, 2017). By coupling the FCM strategically with the 5E model, IBL would be promoted into both hybrid and remote science learning. Therefore, our proposed model works best in either a fully online classroom or in a face-to-face web-enhanced classroom. In face-to-face web-enhanced teaching, the homework activities are not limited to lecture material (as in the traditional FCM); there are also interactive online activities with an inquiry component. As for a fully online learning classroom, our model can be adapted by designing autonomous asynchronous (not real-time) online activities that students complete within a set time frame before the synchronous (real-time) activities, within which science teachers and students work real-time on inquiry-based activities.

○ Congruence between the Flipped Model & the 5E Model

The 5E instructional model aims to promote students' active engagement in science inquiry and provide them with opportunities to explore, explain, and elaborate on science

The American Biology Teacher, Vol. 84, No. 8, pp. 478–483, ISSN 0002-7685, electronic ISSN 1938-4211. DOI: https://doi.org/10.1525/abt.2022.84.8.478.

concepts. Accordingly, the 5E model involves students in the Next Generation Science Standards (NGSS) science practices (Bybee, 2014), for example, identifying problems and formulating questions, planning investigations and carrying them out, constructing explanations, and communicating information (NGSS Lead States, 2013). Likewise, the FCM draws on students' active learning and engagement and aims to promote students' higher-order thinking and problem-solving skills by designating face-to-face time or synchronous class time (as in the case of remote teaching) to the development of such skills; more basic factual knowledge is usually presented before the class through digital resources (e.g., videos and websites). In a previous study conducted in a Lebanese school, we explored combining the FCM with the 5Es for promoting IBL, especially within test-driven and traditional educational contexts such as the Lebanese one, and found that coupling the two models enhanced opportunities for students to engage in inquiry and science practices (e.g., constructing explanation and engaging in arguments) (Nader, 2020). In this article, we further adapt the FCM and expand its flexibility, whereby face-to-face or synchronous activities are complemented with asynchronous activities to promote IBL and the NGSS.

In our proposed combined model, the teacher involves students with asynchronous online activities that raise students' curiosity and help them develop the concepts of interest before the face-to-face or synchronous class activities. This can done by using brainstorming and mind-mapping tools (e.g., MindMeister, https://www.mindmeister.com, or Coggle, https://coggle.it) or by watching and commenting on interactive video lessons (e.g., Padlet, https://padlet.com, or EdPuzzle, https://edpuzzle.com/home-). Then, during the face-to-face or synchronous sessions, the science teacher devotes class time for student-centered inquiry-based activities and explorations. In the next section, we demonstrate our combined model through a sample middle school unit on animal adaptation and natural selection. After that, we further explain features of the 5E model phases with sample student work and handouts from the unit.

○ A Unit Combining the 5E & Flipped Classroom Models

To demonstrate our model, we developed an IBL middle school unit that targets NGSS standard MS-LS4-4, Biological Evolution: Unity and Diversity: "Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment" (NGSS Lead States, 2013). Natural selection was chosen purposefully because understanding its importance as an essential biological concept requires a student-centered pedagogical approach rather than traditional teaching, which often fails to address students' persistent misconceptions on the topic (Mohammadi et al., 2020). The sample unit provides several experiences, especially virtual ones, for students to explore and construct explanations around natural selection and its significance to the natural world (Gordon, 2020). The unit plan is summarized in Table 1 with face-to-face / synchronous and asynchronous activities outlined for each phase of the 5E instructional model. As per the FCM, the unit demonstrates how face-to-face / synchronous activities and asynchronous activities complement and build on each other to promote critical thinking, problem-solving, and communication. Simultaneously, the unit activities are aligned with the NGSS standards, science practices, disciplinary core ideas, and crosscutting concepts. Several technology tools are used within the different phases of the 5E, such as Padlet, Flip (https://info.flip.com), and EdPuzzle.

In the next sections, we elaborate on each of the 5E phases, explaining how the unit progresses to develop students' understanding of adaptations and natural selection.

○ Engage

The "engage" phase aims to elicit students' prior knowledge and raise their interest in the lesson's science concepts (Bybee, 2014). In this phase, the teacher raises questions for students to uncover prior knowledge related to the lesson without seeking any kind of correct answer(s). The purpose of this phase is to stimulate students' thinking about the content of the lesson to give the teacher a chance to identify students' misconceptions (Bybee, 2014). In our sample unit, we start with an asynchronous engaging activity on Padlet, a virtual bulletin board, where the teacher includes a scenario, material for students to explore, and questions to respond to (Figures 1 and 2). Students are also provided with a note-catcher to summarize their observations in preparation for the exploration phase (see Appendix 1 in the Supplementary Material available with the online version of this article).

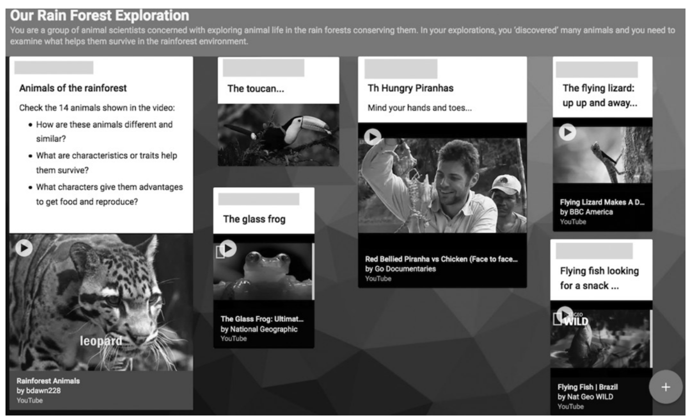

Figure 1. Unit introduction on Padlet.

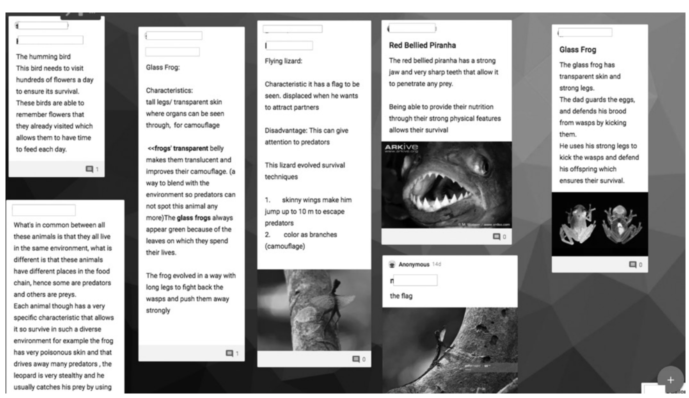

Figure 2. Students' response before the face-to-face/ synchronous meeting.

Table 1. Sample unit that couples the 5E and flipped classroom models and addresses NGSS standard MS-LS4-4 (Biological Evolution: Unity and Diversity). SEP: science practices. DCI: disciplinary core ideas. CC: crosscutting concepts.

5E Phase	Feature of 5E Phase	Synchrony	Activity Summary	Connections to NGSS Standards	Information and Communication Technology Tools
Engage	Activity to elicit prior knowledge and raise curiosity.	Asynchronous	A scenario, short videos, and pictures of rainforest animals are introduced to students on Padlet. They examine these for characteristics that help animals survive and share responses on Padlet before the synchronous meeting.	SEP: Constructing Explanations and Designing Solutions	Padlet
Explore	Activity to investigate and inquire with teacher's guidance.	Face-to-face or synchronous	Students work in groups using Google Docs to outline different characteristics that help animals survive and reproduce. They construct an initial model to group characteristics or adaptations.	SEP: Constructing Explanations and Designing Solutions DCI: LS4.B: Natural Selection CC: Patterns; Cause and Effect	Google Docs
Explain 1	Students explain their explorations with teacher guidance.	Asynchronous (or can be face-to-face / synchronous)	Groups present their models remotely through Flip and comment on other group presentations.	SEP: Obtaining, Evaluating, and Communicating Information	Flip
Explain 2	Teacher highlights key elements in students' explorations.	Face-to-face / synchronous	Teacher synthesizes students' explanations through an interactive presentation with polling tools for formative assessment and introduces adaptation types (structural, behavioral, physiological).	DCI: LS4.C: Adaptation	Google Classroom, Jamboard
Elaborate 1	New related experiences are presented.	Asynchronous	Students explore websites and watch EdPuzzle videos with questions on adaptation types. Natural selection is introduced.	SEP: Constructing Explanations and Designing Solutions DCI: LS4.C: Adaptation CC: Patterns	EdPuzzle
Elaborate 2	Disciplinary terminology and knowledge are developed.	Face-to-face / synchronous Asynchronous (optional)	Teacher synthesizes concepts, from students' responses to the videos. In groups, students explore a Phet simulation on adaptation and natural selection. Students manipulate variables and collect population change data using Google Docs to infer causes and effects of natural selection. Students present findings on Flip.	SEP: Planning and Carrying Out Investigations; Analyzing and interpreting Data; Constructing Explanations and Designing Solutions DCI: LS4.C: Adaptation CC: Patterns; Cause and Effect	Phet
Evaluate	Students create products that demonstrate the concepts.	Face-to-face / synchronous and asynchronous	Students create and present mini documentaries that connect real or imaginary animal adaptations to their survival in an environment.	SEP: Obtaining, Evaluating, and Communicating Information	Animoto, Movie Maker, iMovie

○ Explore

The "explore" phase provides students with opportunities to investigate, inquire, and clarify puzzling elements about the phenomenon through hands-on or online science investigations and lab activities (Bybee, 2014). In this phase, learners participate in activities that allow them to use prior knowledge for generating new ideas, to raise and explore questions, and to design and perform investigations about the problem presented (Bybee, 2019). The exploration experiences should be carefully designed to serve the introduction and description of the concepts, practices, and skills of the lesson, with opportunities to investigate phenomena, build models, gather and analyze data, study patterns, formulate explanations, and come up with and revise predictions (Bybee, 2014). Bybee (2014) underscores the importance of these opportunities for developing learners' cognitive and physical/technological abilities. In our sample unit, students are asked to use their notes from the engage phase (Appendix 1 in the Supplementary Material) and work in groups to recognize patterns and come up with their own initial model of how to classify the characteristics or adaptations that help animals survive; the teacher here acts as a coach or a guide who stimulates the development of students' cognitive abilities through questions that extend thinking and challenge misconceptions (Bybee, 2014).

○ Explain

The scientific explanation of the phenomenon is highly significant in the "explain" phase, as the scientific concept(s) is/are made clear and comprehensible (Bybee, 2014). In this phase, the teacher highlights the key elements of the first two phases and asks the students to explain them. Building on students' explanations and previous experiences, the teacher briefly introduces the scientific concepts (Bybee, 2014). The teacher's role is to raise questions that guide students to analyze, construct, clarify, and modify their understanding of the scientific phenomenon (Jackson et al., 2020). In our unit on animal adaptation and natural selection, the students' present, explain, and compare their classification models remotely through Flip, which is a video discussion online tool. Afterward, the teacher briefly introduces the different types of adaptations through Jamboard (Figure 3).

○ Elaborate

In the "elaborate" phase, the students are actively engaged in new learning experiences that extend, expand, and enrich the concepts and skills that have been developed in the previous phases (Bybee, 2014). The main point of this phase is to help students transfer prior knowledge to new learning contexts and experiences through challenging yet achievable activities. These activities present new situations that boost interaction, enhance class dynamics, and help students develop deeper understanding and sharpen their skills (Bybee, 2014). In the sample unit, we first utilize EdPuzzle asynchronously to solidify students' understanding of adaptation of types through a video from EdPuzzle, which includes questions to check for understanding (Figure 4). (The teacher can also edit and add their own questions and notes.)

The second part of this phase connects adaptations to natural selection through an inquiry-based Phet simulation that allows students to track the frequency of certain traits over generations (activity handout in Appendix 2 in the Supplementary Material). Adaptation types are introduced in the unit before natural selection for two reasons, one practical and the other historical. First, examining different adaptations provides students with opportunities to analyze concrete observations. Second, historically, even though scientists had discussed adaptation prior to Darwin and Wallace's work in the 1800s, the law of natural selection was not developed until the two scientists' work was independently presented at the Linnean Society in 1858 and later published in its proceedings (Kutschera & Hossfeld, 2013). Figures 5 and 6 present screen shots of students' work on the activity through breakout rooms, where they completed the activity synchronously with a Google Doc handout.

○ Evaluate

This phase helps students assess their understanding and allows the teacher to evaluate their progress toward meeting the learning objectives (Bybee, 2014). The teacher's feedback is an essential element in helping students acquire the concepts and meet the objectives. The purpose of this phase is to evaluate students' knowledge of the scientific phenomenon. The teacher's role is to provide the students with feedback based on their performance in the formative assessments (Jackson et al., 2020). In the natural selection unit, we suggest that, in addition to continuous formative assessments, students conduct a performance-based assessment task that demonstrates their learning. In a purely remote learning setting, students can

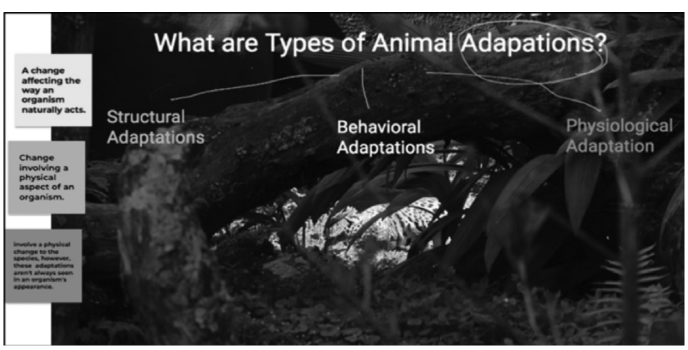

Figure 3. Jamboard by a teacher to introduce the concept adaptation types.

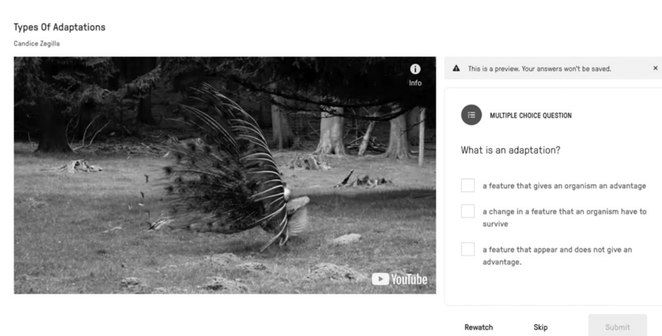

Figure 4. EdPuzzle video with questions.

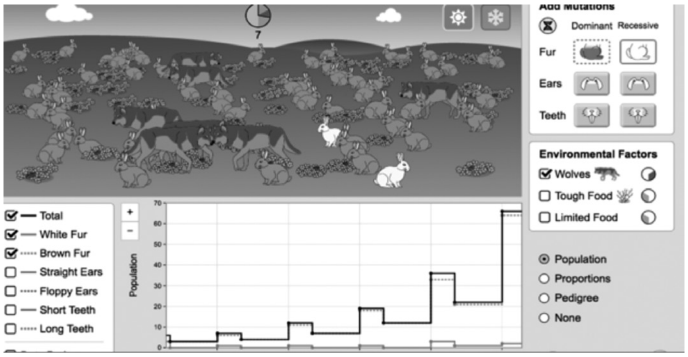

Figure 5. Simulation for examining effects of mutations.

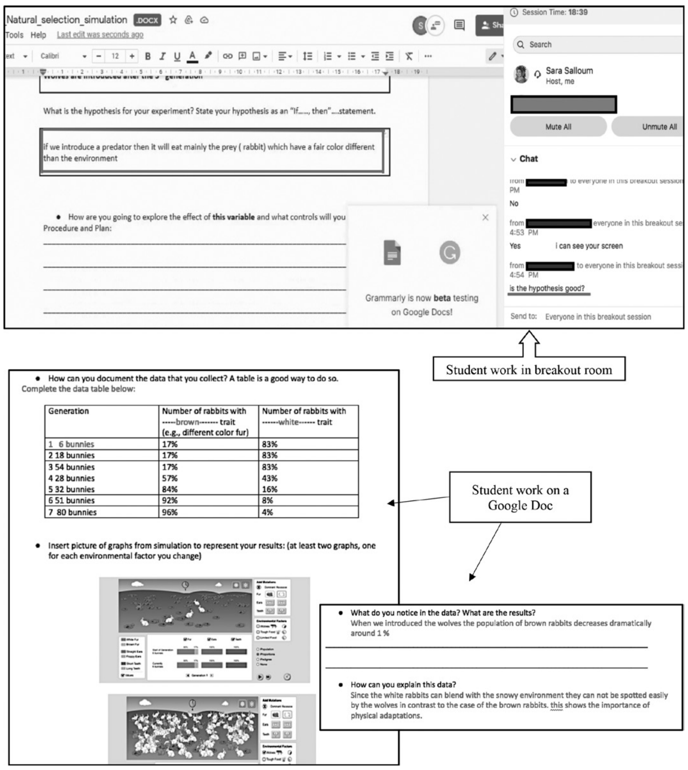

Figure 6. Students' work on a Google Doc in a breakout room.

create and present mini documentaries that connect real (or imaginary) animal adaptations to their survival in an environment of their choice; in a hybrid format, students can also build physical models of their animals.

○ Conclusion

Online and virtual learning has been adopted by several public schools in the United States, such as the Florida Virtual School (http://www.flvs.net) and Virginia Virtual Academy (https://vava.k12.com) long before the pandemic forced all schools to shift to online learning. A more common modality in K–12 before the pandemic was hybrid learning, which takes place partly online and partly in a supervised physical location using an integrated approach (Horn & Staker, 2014). The use of the traditional (pre-COVID) FCM scaffolds students' ownership of their learning while allowing time for hands-on activities and inquiry-based and project-based learning. However, combining the FCM with the 5E model helps us realize more effectively meaningful inquiry-based learning for higher levels of scientific literacy. Rather than listening to lectures, students are given opportunities to explore and reflect outside the face-to-face or synchronous online class sessions through accessible, free, and user-friendly tools. Although the FCM has been considered as a hybrid model, amid the disruption caused to our education system by COVID-19, alternative and innovative ways of blending learning ought to be considered for universal educational benefits, which include:

- Covering basic facts in interactive asynchronous online teaching to devote more time for student-centered IBL activities for higher levels of scientific literacy.
- Adapting to the new educational landscape, which necessitates hybrid forms of teaching and learning, especially ones that shift the role of the teacher to that of a mentor and facilitator.
- Reducing the lecture-based synchronous sessions and transforming them into an application of content introduced asynchronously, hence blending learning untraditionally.

○ Supplementary Material

These components are available with the online version of this article.

- Appendix 1: Note-Catcher for the 'Engage' Padlet Activity
- Appendix 2: Natural Selection Activity Handout (Phet simulation)

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