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Education and Outreach: Innovation in palaeontological research driven by students and non-specialists

by Marc Laflamme[*1] and Paul A. E. Piunno[1]

Introduction:

Scientific research is becoming increasingly interdisciplinary, drawing together experts from a range of fields to generate knowledge and address major problems. This is particularly true for palaeontology, which stands at the intersection of a wide array of disciplines including geology, biology, chemistry, materials science, statistics and biomechanics. Although scientific innovation is principally driven by trained scientists, research opportunities often present themselves to others — in palaeontology, this can tie into the strong public interest in famous extinct animals such as dinosaurs and mammoths. Indeed, palaeontology has an extensive history of important contributions by people without formal training, from Mary Anning's sensational fossil finds in the early nineteenth century, to a recent news story about a young boy from Prince Edward Island in Canada discovering a missing link in early reptile evolution. Harnessing the potential of students and amateurs for palaeontological research is crucial to ensuring growth in our discipline, and is important for those of us who are keen on developing better relationships between academia and the public.

Modern palaeontology is at the crossroads of interdisciplinary studies, and people in the different fields must communicate effectively for research to work well. A popular and successful way to manage interdisciplinary projects is the Agile method. This involves splitting large projects into smaller, more manageable, short-term components, and regularly checking in on what the project goal is, whether it has changed and how previous work has addressed that goal. Agile project management is ideally suited to academic research, where the end point is often loosely defined, and goals often change within the boundaries of the research initiative. We hope to demonstrate that the Agile method is also appropriate for student and non-specialist initiatives, especially in interdisciplinary fields such as palaeontology.

We are using the Agile method in our research and teaching laboratories at the University of Toronto Mississauga in Canada. We believe that research driven by students and non-specialists is an important part of hands-on active learning, where it helps to develop critical-thinking skills and teaches people to apply their knowledge to challenges in the wider world. In the rest of this article, we showcase student-driven initiatives that show how the Agile method is useful in palaeontology.

Importance of independent research for students and non-specialists:

Hands-on experience is a fundamental aspect of palaeontology. Getting involved in research has repeatedly been shown to foster lifelong learning in science, technology, engineering and mathematics (STEM), resulting in a more scientifically literate society. According to the final report of the Boyer Commission on Educating Undergraduates in the Research University, exposure to practical research initiatives promotes critical-thinking skills and retention of scientific information. Research projects teach people to work independently both in and outside the discipline, because they require effective time and project management. Researchers must develop and sustain their own initiative, responsibility and accountability, individually and in groups, and must be effective at decision-making and problem-solving. Research initiatives for students and non-specialists help to build an appreciation for uncertainty, ambiguity and the limits to knowledge. They show how personal experiences and biases can affect analyses and interpretations, helping members of the public to weigh in on scientific debate.

Traditional research initiatives promote independence and learning in isolation. However, working alone is now unusual, as stronger links are growing between disciplines. Interdisciplinary education is becoming ever more prominent in STEM, but every discipline speaks its own language, which can make effective communication challenging.

Interdisciplinary research therefore requires tools that help people to communicate and keep the project going across all groups, while allowing enough flexibility to help participants to get over difficulties. Project-management professionals are taught these techniques; however, such skills are not often taught in modern science.

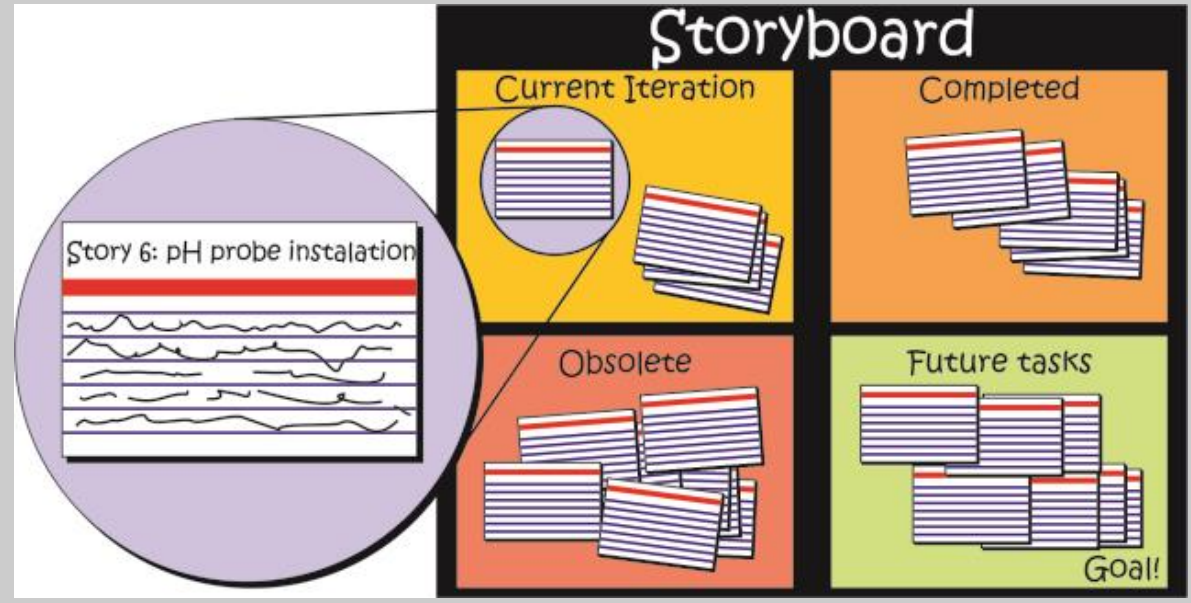

Figure 1 — An Agile project storyboard. Stories are organized in a sequence that depicts the anticipated pathway to the project goal. The version pictured shows work being pursued in the current work cycle (for example, this week). The order and applicability of the stories are reviewed regularly and changed as required to maintain the most direct and sensible pathway to the project goal.

The Agile method focuses on breaking up a daunting research project (see the storyboard in Fig. 1) into a series of small, manageable tasks (called stories). A key part of this method is the ability to quickly and effectively adapt to changing project requirements. These principles are ideally suited to large research projects with multiple investigators, and they let members with different levels of experience interact effectively and continuously. Continual reflection on aims and work done so far by every team member reduces the tendency to be discouraged by the amount of work required to complete the project. The approach also keeps people from being trapped in a research direction that may not prove useful.

The storyboard acts as a daily log of research progress, and allows all members of the research team to contribute and to respond to changes in project direction. Like a comic book, a project storyboard consists of several stories that each occupy a single panel. It maps out the daily sequence of tasks that are necessary to achieve the overall research goal. Stories describe specific project tasks, which each have components that can be completed in a day.

Taking the study of a new fossil as an example, the storyboard would map out the steps to produce the diagnosis, description and comparison that typically accompany a formal scientific description of a fossil. Each of these tasks would be an independent story. Each story is accompanied by a title simple enough for all members of the research team, from primary investigators to students and non-specialists, to understand. In our example, our first story would be “taxonomic literature”, which would consist of producing a list of important papers needed to describe the fossil. On a daily basis, the person assigned the task would create an annotated bibliography from every article read, and generate a short synopsis. The next story would involve gathering the relevant information from the literature search, for instance, producing known size ranges of previously studied specimens, or identifying key characters of the fossil that are important in designating species. This allows the new material to be effectively compared, and brings the entire team onto the same page. Daily assessment of the work places tangible boundaries on what data should be targeted next, from size ranges to the presence or absence of key characters. Future stories could involve illustrating the fossil material, analysing the data collected, or eventually describing each section in the systematic palaeontology. Each of these daily goals would be free to move and evolve as new data is collected, or as project goals are completed.

From a practical perspective, the Agile method limits project design to short-term tasks. No aspects of the final product are designed until it is certain that they are necessary. In this way, only the highest-priority tasks are addressed. Similarly, if it turns out that certain tasks are not essential, they can be rejected with little or no time having been spent on them unnecessarily. This approach is called a ‘lean’ development method. Ideally, research teams should meet every day for a quick review. Projects with interdisciplinary teams benefit most from this approach, because the simplicity of the daily project titles, combined with the visual simplicity of the storyboard, allows workers from all disciplines to understand the overall project goals and continue to contribute at all stages rather than limiting their input to specialized topics. Ultimately, the Agile method integrates all members of the research team, while splitting progress into manageable components in which all members remain engaged. The interested reader is encouraged to consult our suggestions for further reading at the end of this article for more details.

Advanced Interdisciplinary Research Laboratory (AIRLab) initiative:

We are currently setting up a team-based interdisciplinary undergraduate palaeontology project. Our students will be taught, and given the opportunity to use, Agile project management. We will begin by explaining the concept behind AIRLab, and then describe a specific student-driven project.

AIRLab is an upper-level student-driven project similar to an undergraduate research thesis, but it emphasizes team-based learning within a large project. A team of students, non-specialists and faculty members is assembled, ideally people with different, yet complementary specialities. The team is given a broad research challenge, and participants have complete freedom to select research directions and define their storyboard. Each week, the student team meets with supervisors, who act as sounding boards to help the team to consider all options, ultimately helping them to stay on the path to the final goal. Students manage and maintain their ever-changing storyboard, which records all project-related decisions, directions and outcomes. Students gain a sense of accomplishment as stories progress, and become aware of the speed at which they can complete stories. This will help them to estimate the time required to achieve important project milestones, and ultimately to complete the project.

As part of a future AIRLab palaeontology project, our research challenge (storyboard) will be to design and build economical, reproducible and functional chambers to investigate tissue decay under varying oxygen levels. These chambers must be equipped with instruments to gather precise data on changing chemical conditions as a result of decay. This project leads directly into investigations of the biases that influence exceptional fossil deposits — that is, sites that preserve soft-bodied organisms, rather than the typical fossil assemblages of bones, teeth and shells. These exceptional fossil sites, called *Lagerstätte* (see articles on Palaeontology Online by Jonathan Antcliffe (Ediacara biota; Fig. 2A) and Victoria McCoy; (Mazon Creek; Fig. 2C), are exceedingly rare. *Lagerstätten* such as the Burgess Shale in Canada (Fig. 2B) and Mazon Creek in Illinois (Fig. 2C) represent the richest source of anatomical information for extinct species and offer more complete views of diversity patterns in deep time than more typical sites. Interdisciplinary studies that examine the physical, chemical and biological factors that control the timing and process of fossil preservation (taphonomy) are a necessary first step in correctly identifying any trends in the fossil record. At first glance, building such instruments is daunting. However, with appropriate guidance and strict adherence to the Agile method, the student team will quickly learn to dissect the project into manageable components and assemble a storyboard. Once the instruments are constructed, tested and approved, decay can be monitored in real time and our studies of fossilization can begin.

Evaluating progress:

In research, the evaluation of progress is usually straightforward. The typical research goal will be a paper suitable for publication in a scientific journal; however, the scope and success of the project will dictate the output. As data is gathered, evaluated, interpreted and discussed, research directions will change and progress will involve active data-gathering. A successful storyboard will form the backbone of the manuscript, highlighting productive research avenues and outlining the steps towards successful completion. Each section of the manuscript will be laid out comprehensively, and each member of the team will be fully aware of every step taken. This alone will make most research projects easier and quicker.

Figure 1 — Exceptional fossilization of soft-tissues. (A) Ediacaran organism *Swartpuntia* from Namibia, (B) *Naraoia* (USNM 57687) from the Burgess Shale, and (C) *Esconites* from Mazon Creek. Scale bars are 1 cm.

Evaluating progress in education is more daunting. AIRLab emphasizes self-evaluation of personal growth and personal limits to knowledge. Project participants are asked to reflect and report on the following two questions in each regular review meeting:

- What is the goal of the project?
- What have I done to support the progress of the team?

This is particularly important in projects for which effective teamwork is required. Based on their ability to address these questions in each project meeting and the number of completed stories they have contributed to, the student can be given a grade that accurately reflects their contribution.

Concluding remarks:

As faculty members, we are often approached by students and amateurs about getting involved with research. For most, this is their first attempt at conducting research, so proper project design and management is often more important than the actual scientific question. We hope that we have showcased the benefits of strong project design and management using the Agile method. We think it is efficient and comprehensive, and we believe that it is ideally suited to interdisciplinary research in palaeontology. We have personally witnessed the benefits of incorporating research into an undergraduate education, and we have no doubt that society at large benefits when members of the public have experienced research initiatives first-hand.

Suggestions for further reading:

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