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Transformational Events

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Transformational Events is a new pedagogic pattern that explains how innovations (and other transformations) happened. The pattern is three temporal stages: an interval of increasingly unsatisfactory ad hoc solutions to a persistent problem (the "mess"), an offer of an invention or of a new way of thinking, and a period of widespread adoption and settlement. The pattern has been used by historians to document how innovations happened. The authors used it in addition to help students learn to spot modern "messes" and use them as springboards to generate innovations of their own.

1. Introduction

Pedagogic patterns are schema for teaching and learning. They are inspired by the architectural patterns of Alexander (1979). Alexander claimed that the most beautiful and satisfying buildings result when architects align relationships among architectural objects (patterns) with the driving concerns of the building's users (forces). Teaching patterns expedite learning by arranging known concepts in patterns that reveal the new concept and by aligning the new concept with driving concerns of the students. Bergin (2003) offers numerous examples of patterns for the effective teaching of Computer Science.

We will examine here a new pedagogic pattern, "transformational event." This pattern is associated with every innovation, including scientific, technological, and cultural transformations. We will show several prior uses of this pattern and will report on own operational experience with it in courses on transformation and innovation. This pattern is the basis of a powerful way to explain and motivate scientific and technological innovation. It can also be used as a superstructure for teaching the skill of innovation.

An important aspect of patterns is that they resolve conflicting forces. The transformational event pattern is the foundation of three key skills of innovators, namely, the abilities to tell when the time is ripe for a transformation, to make a compelling proposal for change, and to bring about its adoption in the concerned community. The innovator is the agent who channels opposing, disharmonious forces (before the event) into alignment (after the event).

We use the word innovation in its operational meaning that a community has adopted a new practice (Denning, 2004). Practices are habitual, routine actions; so adopting a new one means changing a habit of deed or thought. Such changes are not

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easy. Innovators and leaders are evaluated by their skill in generating them. The transformational events pattern is a high-level description of innovation process.

2. Background

We teach computer science at the Naval Postgraduate School in Monterey, California. NPS offers MS and PhD degrees to military officers in engineering, science, business, and political science. We have 1700 students from all five US military services and from Homeland Security. One-quarter of the students are from 56 foreign countries that have military education treaties with the USA.

The US Department of Defense (DoD) believes that warfare and defense all occur within distributed networks of communication. It wants to transform the way its fighting and security forces think and act in this new world. DoD mandates that NPS graduates be leaders and innovators, capable of participating in and generating a "culture of innovation." In the CS department, we fulfill this mandate by offering study in innovation and a master's thesis project that demands innovation. We designed three courses:

1. *Great Principles of Computing*, which is a roadmap for the field that indicates where the most important innovations came from.
2. *Cornerstones in Computing*, which dissects these innovations and shows how the innovators produced the transformational moments and then worked for wide acceptance and application of their discoveries.
3. *Technology and Transformation*, which helps the students find thesis projects with transformation potential and learn the skill of innovation.

The pedagogic pattern "transformational events" is the organizing theme of the cornerstones course and the teaching of the innovation skill.

3. Basic Pattern

The pattern behind innovations and changes of social perception within a community has three parts (see Appendix A):

1. *Period of increasing ferment*. A period during which a persistent problem is addressed with ad hoc solutions. The solutions are incoherent, contradictory, and incompatible. There is considerable dissatisfaction with the state of affairs, marked by frustration, anxiety, suffering, and conflict. People refer to the situation as a "mess."
2. *Transformational moment*. Someone proposes a new framework for thinking or a new way to do things.
3. *Period of adoption and settling*. The new framework resolves the original problem whenever it is tried. The ad hoc systems disappear and are replaced with integrated solutions. The anxiety, frustration, suffering, and conflicts are replaced with satisfaction and settlement.

This pattern has been used in at least four settings by well-known authors. One of the most famous was Kuhn (1979). Kuhn used this pattern to explain major scientific revolutions. He said that a scientific theory would hold sway for a long time until a growing number of anomalies and paradoxes could no longer be ignored. Someone would then propose a new framework, removing the anomalies and resolving the paradoxes. The new framework would be adopted into the thinking and social practice of scientists.

Drucker (1985) employed this pattern to describe the work of entrepreneurs. He maintained that the hardest part of producing transformational change was to find the right opportunity and propose a compelling offer. He devoted half his book to a study of seven areas where opportunities can be found.

Burke (1995) discussed eight profound innovations in Western scientific thought during the past two millennia. Each change transformed not only social practice, but also the way that people saw themselves in relation to the universe. Burke said that his method to reveal the nature and extent of the social change was to document how people lived and worked in the 50-year period preceding the invention, then to describe the invention and the circumstances that generated it, and then to document how people lived and worked in the 50 – 100 year period following the invention.

One of Burke's examples was the invention of the printing press by Gutenberg around 1450. The stories for the period preceding 1450 reveal a society in which almost no one could write, very few could read, and most knowledge was transmitted through oral traditions. Toward 1450, demand for written records was rising, especially among merchants; but trade was stymied because manual transcription was the only method of copying. Gutenberg's moveable-type press was a breakthrough, providing a mechanical way to make many copies cheaply. In the hundred or so years following the invention, literacy became common, literatures in many subjects formed, news sheets started, and people relied on printed works rather than oral traditions for proof. Burke said over a 200-year period, Europe moved from an oral tradition in an illiterate society to a written tradition in a literate society.

Evans (2004) employed this pattern to tell the stories of 70 American innovators, emphasizing that the third stage (adoption) resulted not from good fortune, but from the tireless persistence of the innovator. In the individual stories, Evans reveals the social practices of the affected community before and after the innovator's work, showing profound changes. In many of these stories, the idea or technology behind the adopted new practice was the work of another inventor. Evans focused on the adoption rather than the invention, saying "invention without adoption is merely a pastime."

Denning and Dunham (2006) describe the innovator's skill as seven foundational practices. The first two practices concern the discovery of an opportunity; they define the innovator's key actions prior to the transformational moment. The third is the offer to generate a new community practice that exploits the opportunity; it is the transformational moment. The fourth through seventh practices concern the adoption and sustainment of the new practice; they define the innovator's key actions in bringing about adoption. The transformational event pattern underlies the innovator's skill.

As described above, the pattern appears to be an interesting pedagogical tool for describing a social process. In fact, it is more than this: we use it for teaching. The cornerstones and transformation courses move students through the three stages: we let them experience the mess, we lead them to insight and invention, and then we let them settle into a period of unification and stabilization. Thus the pattern is useful for learning new actions as well as describing past actions.

For all these reasons, we propose that "transformational events" be accepted as a pedagogic pattern.

4. How we Used the Pattern

We organized our one-quarter course, "Cornerstones of Computer Science," directly around this pattern. We devoted each of the 11 weeks in the course for one of the great principles of computing.

- In a lecture presentation, we revealed the situation in computer science prior to the discovery of that week's principle. We gave vivid stories, many from our own experiences, of the situation in the field prior to the discovery. We sought to show that most people in the field perceived a problem area as a "mess" of costly ad hoc solutions that prevented progress.
- We assigned the reading of one or more seminal papers from the computing literature. The papers were considered seminal because they offered new principles that dissolved the "mess". We asked the students to evaluate each paper by writing a report answering 8 questions designed to reveal various aspects of the transformational pattern (see Appendix B).
- We asked a student team to present the seminal paper, along with a biography of the author, and to discuss how the principle transformed social practice in computer science down to the present day.

The standard computer science curriculum is heavily weighted toward programming and analysis of algorithms; it obscures the experimental side. We decided to use the pattern itself to reveal the richness and depth of the experimental side of the field. The first few topics in the cornerstones course concern programs and algorithms as the objects of study (algorithms analysis, complexity of computation, limits of computing machines, artful practice of programming). These transformations behind these topics involve mathematical approaches. When we switch to systems topics (networks, performance evaluation, storage management, graphics, and databases), the students fall into a muddle because their tools for analyzing algorithms do not help them understand systems issues. At the height of their muddle, we propose a distinction between programs and computations as objects of study, and between mathematical logic and experiment as the corresponding tools for understanding.

This distinction is a transformational moment for them. Thereafter they study the systems papers with vigor and insight. By the end of the course they are able to identify over a dozen current "messes"—modern problem areas ripe for transformation—and to pose questions whose resolution might mitigate them. Our students not only observe how past innovators had experienced the pattern, but they also experienced it for themselves.

5. The Pattern as a Generator

The pattern is obviously useful as a way to describe the history of an innovation: a way to organize the stories of the messes, the relevant scientific and engineering discoveries, and the integrated systems that followed, but there is a danger. If the pattern is used to reduce transformation to a mere sequence of facts in a narrative, many students are likely to be bored and to become detached.

We avoided the danger by using the pattern to understand how to *generate* transformations. With Bergin (2003, 2005) we focused on how the pattern changed the learning experience of the student. We captured our students' interests and taught them some basic skills of transformation.

To do this, we placed a lot of emphasis on understanding the seminal author's own experience of the "mess." The students really liked this. One of our first seminal authors was Donald Knuth. We asked the students to use Web tools and other sources to find out as much as they could about his personality, ways of interacting with his students, ways of problem solving, and his obsessions with both mathematical clarity and art. They found Knuth to be a fascinating character. They learned how he saw the world and what he did after his seminal work to facilitate the transformation that followed. We offered our own personal experiences from that era to help them further understand the nature of the mess that Knuth found himself in. Our students examined how Knuth identified with a solution, took his stands, and experienced the risks of defining uncharted directions. They came to understand how programming looked to Knuth at the time, as distinct from how programming looks to us today. In other words, they came to understand the problem *context* as Knuth experienced it. In the subsequent weeks, our students dug with equal vigor into the backgrounds of the other authors, their experiences of their messes, and the risks they took. The messes and the innovators came alive for them.

Another interesting outcome was that several students discovered that their chosen thesis topics were not satisfactory to them. One, who was still early enough in the program, modified his thesis topic in order to focus on a current mess and view his research as a possible way to transform it. Another, who could not change her topic, modified her thesis to document a current mess and bring out ways that her studies might help.

Thus the Transformational Events pattern is not merely a descriptive aid for historical information about innovations and transformations; it is a way of teaching some basic skills of innovation and transformation.

6. Outcomes

The use of this pedagogic pattern had two major benefits, one for the students and the other for the faculty.

The students markedly increased their abilities to identify current "messes" and see them as opportunities for innovations and transformations. Moreover, they increased their abilities to tell motivating stories about the need for a transformation and the potential benefits of a proposed innovation. As we noted, these are two key steps in the innovation process. The transformational events pattern enabled us to achieve one of our mandated educational outcomes.

On the faculty side, we were able to communicate gap in the computer science curriculum between mathematical studies of algorithms and empirical studies of systems. Other faculty undertook revisions of some courses to balance between mathematical and systems views of computer science. The faculty also decided to move the cornerstones course to an earlier position in the syllabus to help students settle more confidently into their thesis topics.

7. Conclusion

The transformational event pattern is a highly motivating way to understand transformational change and teach some basic skills of innovation. It is a solid backbone for stories about how innovators changed the world.

The pattern underlies the seven foundation practices that make up the innovator's skill and can teach some of them.

The pattern is also a good way to organize a cornerstones course. Simply reading seminal papers can be boring to many students, especially when the papers are outside their immediate areas of interest. When used to examine the context of a mess, the pattern makes these studies interesting. It reveals human foibles, emotions, and concerns; it reveals the depth of social change and thinking wrought by many innovations; and it reveals the economic incentives that enable innovators to succeed.

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Appendix A. Transformational Event Pattern

Name

Transformational Event

Thumbnail

Transformational events occur as part of innovation processes. The event itself is usually a proposal to change practice by adopting a new idea, process, or artifact. Before the event, people used a variety of ad hoc means to cope with a problem, none satisfactory. After the event, people adopt the proposal and gradually replace their ad hoc methods with the new one and the problem disappears.

The Pattern

A significant innovation or fundamental change of perception occurs in three stages:

- *Period of increasing ferment*. Growing dissatisfaction in a community over conflicting, ad hoc solutions to an important problem.
- *Transformational moment*. A proposal for a new approach.
- *Period of adoption and settling*. The proposal initiates new practices and integrates them with other community practices.

Occasionally, there is no obvious period of ferment; the proposal comes as a surprise. The period of adoption and settling is still there.

Examples

Kuhn (1979) used the pattern to explain how new scientific theories come into existence. He coined the term "paradigm change" for these transformations.

Drucker (1985) used the pattern to describe the work of entrepreneurs and to explain how they discover opportunities for transformations.

Burke (1995) used the pattern to study eight transformative events in Western thought about science, engineering, nature, and the universe.

Evans (2004) used the pattern to explain the significance of new social practices brought about by innovators.

Denning & Dunham (2006) describe the process of transformation as seven foundational practices of innovators. The entire process is based on the transformational event pattern, with the "transformational moment" being the "offer" practice halfway partway the entire process.

Audience/Context

The pattern is encountered in various contexts, usually when studying technology innovations, the progress of science, and the how-to of innovation. The seminal papers of computing, often studied in capstone courses or as part of other courses, were transformational moments. Those who wish to generate innovation can use the pattern to guide them to situations where the time is "ripe" for a transformation event, whereupon they can provide the transformative proposal and work toward adoption.

Forces

The period preceding a transformation event is characterized by a mishmash of conflicting, ad hoc solutions to an important problem in the concerned community. No solution is general. There is considerable discontent with the state of the art and a general impression that "things are a mess." The proposer of the transformational moment acts as an agent of force alignment by offering a uniform way to solve the problem.

Sometimes it appears that the proposer simply offers a new possibility that is not intended to solve any particular problem. For example, the Web was an unknown concept to many people, whose first contact with it was the Mosaic browser. On seeing Mosaic, they quickly saw all sorts of new ways they could share and obtain information. However, if we carefully examine such cases, we find that the new possibility actually allows people to discontinue certain practices in favor of new, more productive ones. The realignment of forces can occur even without the perception of a "problem" prior to the transformational event.

The history of computing is filled with technology transformations. Many students aspire to produce their own. Most discover to their dismay that great ideas do not automatically "win" and produce transformations. The innovator has to show the intended audience how things will get better for them after they adopt and has to overcome habit, inertia, apathy, and resistance on the way to adoption. The innovator thus becomes the agent that channels opposing, disharmonious forces (before the event) into alignment (after the event).

Solution

When adopted as a pedagogic pattern in a "capstones of computing" course, it works as follows. We ask the students to read a seminal paper and to answer in writing a list of probing and provocative questions about the paper (see Appendix B). We lead a discussion about the situation that existed prior to the paper, bringing out the community sense of frustration at the inability to solve a problem. We then trace the ways in which the proposal was tested and adopted and led to integrated systems free of the original problem. This pattern works equally well to understand transformation in both mathematical and systems areas of computing. We conclude the course with a discussion about current problem areas that display the same sense of frustration and messiness, demonstrating that times are ripe for new transformations.

When adopted as a pedagogic pattern in a "technology and transformation" course, it works as follows. We study the stories of several major innovators and ask about the actions they took to generate their results. Soon a pattern of seven basic practices is discerned. The first two steps concern the discovery of a new idea. The third step is proposing a new practice based on the new idea. The fourth through seventh step concern the adoption of the new idea in the target community. The crucial third step—the offer—is the transformational moment of innovation. The objective is to teach the students how to guide their own innovation processes from start to finish. They can generate transformational moments.

Related Patterns

Our capstone course made use of Joseph Bergin's "spiral" to get at the dual nature of Computer Science: symbolic (logic and mathematical) and system (computational performance and design fitness). In the first week of the course we used Bergin's "toy box" to introduce a template for evaluating seminal papers.

Appendix B. Template for Evaluating a Transformational Paper

1. What is the author's main claim?
2. How did the author frame the question?
3. What was the author's motivation or intent?
4. What grounding did the author offer to support the claim?
5. What was the paper's context at the time it was written?
6. What actions did the paper implicitly or explicitly call for? Were any of them taken?
7. Did the paper close its issues or did it open new possibilities?
8. How is the paper connected to contemporary issues in Computer Science?