

How we tell our engineering stories

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STRUCTURED ABSTRACT

CONTEXT

Engineering involves professionals and clients from diverse cultural and economic backgrounds and experiences. Professional engineering educators aim to make teaching materials engaging to help students make sense of knowledge from academic research, general theory and their own practice. Some of these aspects are hard to convey especially those from areas currently outside student experiences, including making decision in problem solving, and working in cross-cultural contexts. We use narratives to introduce students to new and challenging concepts, and in this paper discuss how and why such strategies engage students regardless of whether they have prior experience or knowledge. We demonstrate how we do so through an exploration of two frameworks: the Cynefin domains of knowledge; and teaching cross-cultural contexts through Indigenous storytelling. Narrative is already a key knowledge sharing strategy for Aboriginal people (Kennedy, 2016), and narratives enable explicit linking of theory and practice in practical and memorable ways while also making learning enjoyable.

PURPOSE

The narrative process extends conventional teaching methods and is well suited to the metacognitive domain. We illustrate how its use assists students to make sense of knowledge they are encountering and to acquire learning in an in-depth and personal manner, and how to structure such presentations.

APPROACH

The paper uses a recursive process employing a narrative form to explain how this teaching process works for improving student understanding of knowledge and knowledge management. Green and Brook (2000) introduced the theory of "transportation into a narrative world" based on immersion into a story as a mechanism of narrative influence. Green & Donahue (2011) then reported on the power of such narrative to change beliefs, including the effects of fictional or false stories on real-world attitudes. We apply their work in the Cynefin domains and show how different problem-solving processes may be enacted in each domain of knowledge. We then use Indigenous community story telling modes to illustrate how narratives can be developed to integrate theory with practical understanding in these narratives.

RESULTS

Experiencing such narratives provides accessible understanding of engineering theory and demonstrates how use of relevant narratives exemplifies both educational and engineering theory. The stories provide examples of the ability of narrative to explain and engage with students in complex learning domains. These narratives have been used in UTS Engineering in tacit knowledge sharing in class for over a year now and the method is receiving increasing support from staff and students.

CONCLUSIONS

An interactive method of teaching narrative engages students' in creating visual imagery of components of a scenario. Using different voices, when creating the narrative, allows a variety of perspectives, and interactively engaging the student voice in class provides nuances suitable to students' present perspectives and hence more likely to extend their awareness. The Indigenous narrative techniques were designed for such learning and the Cynefin model is a useful tool to distinguish stories into different domains of knowledge to provide a coherent learning example.

KEYWORDS

Indigenous storytelling, Cynefin model of problem solving, narrative methods

Introduction

A narrative learning approach is one that makes sense of experiential learning via a narrative medium. Although narrative teaching methods have been promoted in educational research, it is not yet widely used, and therefore it is useful to provide a framework to guide educators wishing to use such methods. Clark & Rossiter (2008) describe how narrative learning theory builds on efforts to localise learning in the real world. This links to theories and practice of experiential learning and constructivism and supports use of situated learning when relevant engineering situations are remote from the teaching context. This suggests that narrative provides a cultural perspective to learning and changes in thinking (Green & Donahue, 2011). It is this sensemaking process that we illustrate, using case studies of very different knowledge sharing forms to exemplify how to convey different knowledge in narrative form.

Background

The narratives used in the case studies presented are drawn from classes provided by each author to assist students of Engineering and IT to engage in knowledge sharing practice. We approach the issue from two different perspectives: from a Cynefin viewpoint of different knowledge management approaches, and from an Indigenous perspective of linking knowledge systems. Each approach is compared to the other, illustrating the versatility of narrative. While the approach of each style is for different knowledge concepts, the development of student knowledge is similar. The narrative focus allows students to negotiate complex domains avoiding feeling incompetent. This prevents emotions that inhibit students' learning motivation and their interest in benefiting from complex learning activities.

Cynefin Domains of Knowledge

"The Cynefin model proposes that knowledge is encountered in three modes across five domains. The knowledge modes are either 'Ordered' (systematic and structured), 'Unordered' (complex, without pre-determined form) or 'Disordered' (without form or knowable structure). Within these modes the Domains in the Ordered mode are 'Obvious' and 'Complicated' and 'Complex' and 'Chaos' in the Unordered mode, while 'Disorder' stands alone. Each Domain represents a way in which knowledge is received and responded to. Individual capacity for awareness of contextual factors will inevitably have an impact on responsiveness to conditions in which we find ourselves. (edited from: Shalbfafan and Leigh 2017)

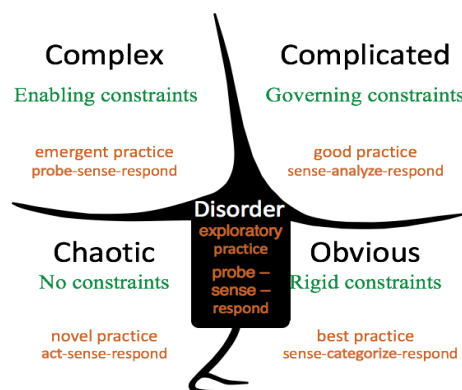


Figure 1 - Cynefin domains of knowledge

The quote above may be indecipherable to anyone with little experience of knowledge management as a discipline or field of research. Nor will it make a lot of sense to anyone who is entrained in habits and modes of the 'Ordered' domain and are therefore unaware of knowledge as malleable, flexible and ever-changing sets of data and information. The difficulty with such a portion of text is that it does not provide any guidelines on using the information it offers. However, such concepts of metaknowledge are becoming ever more important for engineers to engage with and understand complex problems. Thus, the question

becomes how to make its concepts and messages accessible to those who prefer 'hard data' and may feel quite lost in the 'wilderness' of inexplicable soft skills?

To meet that challenge, the Cynefin story sequence reported here has been developed to engage young engineers and lead them through the model using narrative to hold their attention and engage their imagination. The story sequence begins with familiar ideas and moves through to Un-order before closing in on Disorder to introduce a learning process incorporating knowledge management and engineering principles in almost equal measure.

Aboriginal Knowledges Sharing Narratives

There is a great depth and complexity of Aboriginal knowledges whereas western knowledge is highly compartmentalized. We suggest an effective way to convey this complexity, is to adopt the same teaching methods as used by Aboriginal people which is storytelling and performing processes, drawing on narrative to model the strategy and convey the kinds of information held by traditional knowledge holders.

Aboriginal Engineering practices and associated knowledge relevant to IT is better conveyed by including Aboriginal speakers whose sharing of knowledge provides an experience of the world view held by Aboriginal people around specific themes (Kennedy et al. 2016). Incorporating Indigenous knowledge into the curriculum includes networking with speakers who can cover material related to, and extending beyond, standard university subjects (Indigenous Engineering 2018).

However, it is also important for all educators to understand what and how knowledge is taught in different cultures, and the significance of the different approaches. In particular much engineering research will be managed in specific cultural settings where narrative research can be used to advantage, if there is an understanding of how this narration works.

Aboriginal narratives are not a linear description of events and can be highly representational of abstract concepts. They provide a sense framework where the initial version told to a young child as a dreamtime story is a moral tale that supplies simple answers to the sort of aspects of their environment that children question, such as 'How the Kangaroo got its tail'. These initial stories will already include landscape features and significant events in the cycle of the environment and the landscape.

Another important aspect of the use of narrative in Aboriginal contexts, is that these are communal stories, where many people of the one kinship relation will be equally responsible for teaching the story to others. Hence the stories are designed with points where different people can insert their own story to elaborate on specific knowledge aspects.

Aboriginal narratives begin simply and gain depth as the story teller assesses the listener's capacity to absorb and understand the more complex elements of the story. There are four levels to these stories (Sveiby & Skulthorp, 2006): the basic moral story is more for novices; the relational details are for more experienced people; the practical details are comprehended better when people are familiar with the landscape; the spiritual knowledge is not available to those without prior understanding.

These narratives start in the ordered domain. The Obvious domain is similar to the first levels of Aboriginal story telling. Aboriginal story telling at the third level will deal more with the Complicated domain where the knowledge sharing is to convey the patterns of knowledge known to experts. The spiritual level alone provides the understanding gained from probing a Complex world and developing emergent rules of behaviour.

The Cynefin Narrative in Practice

David Snowden was one of the researchers who developed the original concept of the Cynefin Domains and was developed to help people manage their knowledge more effec-

tively by understanding the domain they are working in (Snowden 2018). Introducing the concept to young engineering students, requires relating this to their experiences. Narratives are used to engage the audience with different knowledge domains in a concrete and practical context to assist their understanding. Such learning can facilitate different patterns of engagement and knowledge transformation.

Order - familiar and expert

This story begins with the students. Their arrival in the room and setting into place is the beginning point. They are asked to think about what they noticed as they entered the room. There is nothing different, which is the point they are about to see. The sheer familiarity of the space is brought home to them through the heuristic which characterises the 'Obvious' domain within the Ordered mode of knowledge. This heuristic is sense-categorise-respond and the storyteller shows them how they used it to arrive at their destination and settle in without much conscious thought, much as other familiar habits help us to move easily through routine tasks. This is best practice being smooth and effortless and built on practice and habit.

The second part of the story concerns their current study towards becoming engineering experts. By now they are aware of the work ahead and their presence in the room indicates commitment to achieving expertise. They are aware (if only tacitly) of the heuristic that will be their regular guide: sense-analyse-respond. These steps take them away from mere categorising and reacting, towards looking deeply into data and information for expert decisions within well-established parameters based on sound decision making. This is good practice. These two parts of the longer story are easier to convey given their alignment with the current context and students' interests and concerns.

Un-order - Complexity and Chaos

The story takes a sharp turn from here. It proposes that there is a kind of order in things that is not neat and tidy and may be regarded as scary and best avoided. These are the domains of Complexity and Chaos. This part of the story requires different perspectives on time, adaptive strategies and acceptance that decisions are only relevant to the context in which they are made, and cannot be applied, without alteration, to any other set of conditions.

As this is an unfamiliar notion, a longer story of events outside students' usual experiences serves to make the point. One often-told 'story' of a real event emphasises those very different perspectives listed previously and includes a nod to serendipity. In the Complexity domain the heuristic is 'probe-sense-respond' since there can be many probes, and varying lengths of time will elapse between emergence of the problem and the moment of decision. Each probe may require time for 'sense-making' of the information, and many probes may be run at once or sequentially, with results analysed together, or separately, to establish the option that is 'most likely to succeed on this occasion'.

This characterised the crisis encountered in 2008 at Amberley Air Force Base, when a wing wheel dropped off an F111 fighter plane during take-off, leaving the plane, its pilot and navigator with no known way to return safely to earth. During the hours it took to devise a potentially viable solution, the F111 simulator was re-engineered to test out all conceivable options. A few things were quickly apparent as probing for solutions evolved. First, the pilots' ejector seats would be a last resort if nothing else could be devised, and second, any attempt to 'land' the plane on two wheels would not work. This had been the first probe trialled in the simulator but would result in the plane flipping.

A thousand kilometres away in Sydney, the expert who had written the code for the simulator was brought in to help. There was no time to fly him to Amberley, so it was fortuitous that he was at home and that on his desk was an emulator of everything in the simulator - including one most serendipitous set of code. This programmed the simulator to land on an aircraft

carrier using the plane's 'tail hook'. It had been developed years earlier - because the simulator's designers and programmers 'just could'! The eventual decision was to land the plane 'wheels up' using the tail-hook and Amberley's arrestor cable. This had never previously been attempted. Simulator trials showed that, if the pilot followed his instructions exactly, the plane would land on its belly, sliding along the ground until stopped by the combined work of the tail-hook and the arrestor cable.

As various news reports showed (7 News 2008) there was a frighteningly small space between the plane and the ground as the hook connected and the plane came to a thundering stop. At that moment all those involved knew they had succeeded in doing something unique. They also knew that this had been a singular problem, requiring a unique solution.

The F111 story simultaneously celebrates the success of engineers (software, and mechanical) in a challenging environment and helps to emphasise that certainty is not always possible. The story illustrates how complexity cannot be dealt with by normal responses and demonstrates that expertise is not always enough unless combined with a willingness to experiment in the moment and let go of known precepts about how to behave in a crisis. (Leigh 2013)

Chaos - when there is nowhere else to go

Another pilot's actions illustrate the Chaos Domain. This is a very short story. Captain Chesley Sullenberger took off from La Guardia airport in New York and three minutes later, after a bird strike stopped both his engines, successfully ditched his Airbus A320 in the Hudson River. The actions of the crew ensured that everyone aboard survived, exemplifying a successful outcome of the Chaos Domain heuristic of 'act-sense-respond'. At times, conditions are such that doing something/anything is all that is possible. There is no time for thoughtful reflection or analytical probing. The two pilots drew on years of training and experience to achieve the "Hudson Miracle" - and the event itself was over in 28 minutes. Engineers need to understand that taking action is sometimes the only option.

Disorder - a place of loneliness and fear

Developing the capacity to use the Cynefin heuristics for assessing which Domain is framing our immediate context, enables avoidance of Disorder - a state of mind wherein all is fear and confusion. In the story of Cynefin this is the dark and murky area. Human beings do not much like being 'out of control' and falling into a mindset of 'Disorder' can happen when there is insufficient information, or a degree of unpreparedness that suggests the only option is 'retreat' to the safety of the Obvious Domain. If this is emerging as the state of mind the best possible advice is 'gather information-*decide which Domain-Move on*' (Stoop 2016). For engineers, this part of the story may be difficult to absorb, as it defies the urge to seek safety in the familiar and obvious. It is evident that a sense of discomfort and unease is a warning sign of approaching Complexity or Chaos, however, retreating into a false sense of security in the Complicated or Obvious Domains may be the very worst option: as illustrated by the following story illustrating how conditions may move rapidly from one Cynefin Knowledge Management domain to another.

Work began as usual one morning on the building site of a university building. Early in the day there was a sudden and unexpected switch from the Ordered/Simple domain to an Unordered/Chaotic one, when a fire began in the control cabin of a luffing jib tower crane. The fire began slowly then escalated into a major incident. The crane driver initially used available firefighting equipment to quell the fire. When this did not work, he knew he had a very short time to make the crane, the building site and nearby traffic routes, safe. That he did so is a tribute to his capacity to recognise the shift in his condition from Obvious to Chaotic, and act accordingly.

Immediately after the fire, the construction site plunged into the Complex domain, probing for ways to dismantle a severely damaged crane stranded above a crowded construction site,

while maintaining safety standards, allowing some flow of traffic and limited access to nearby buildings. It was some time before the site was returned to the Simple domain. Used in teaching contexts, this story is developed further through conversation and analysis of each phase of events, with students building models of how the various heuristics were applied throughout the day.

Aboriginal Narratives in Practice

The purpose of these narratives is quite different. In the Aboriginal narratives we use in teaching, the flow is between the Aboriginal knowledge and the non-Aboriginal knowledge systems. Here we use the knowledge system in one domain to make clearer the significance of issues in the other, introducing non-Aboriginal knowledge that is yet unknown to students through narrative. Using the Cynefin model we are moving across domains from an ancient Complicated system to a Complex system. We introduce Aboriginal knowledge relevant to specific learning objectives, such as the idea of storytelling as journey mapping, that is not a linear timeline, then use this analogy to engage a perception of the complex journey of collecting knowledge through their degree.

In class our story begins with acknowledgement of people and country with a personal story from the speaker. The personal story of relationship to the land, and (where relevant) what the local culture means to the speaker, is an important aspect and in this case, we use a scientific context. Students are introduced to the work of Roy Tobler (Tobler et al. 2017), an Aboriginal geneticist, whose research showed that Aboriginal people lived as separate groups in the same areas of land for about 45-50,000 years.

Then a specific theme for exploration is introduced. This example focuses on how different cultural perspectives or experiences might explain different values. Students are asked to think about an area of land they know, perhaps where they grew up, or go regularly on holiday. Through recalling all the features they know, and areas of special significance built from memories over many years, they are invited to imagine this as having occurred over generations for 50,000 years, with these stories passed down to them. They are asked to imagine what they might understand about that country, what their feelings for that area might be?

Next, they are asked to consider themselves as an Aboriginal engineer, an expert in crafting spears and boomerang or a firestick burner who looked after country; and imagine how would they would learn this knowledge and how they would pass it on, adding to the community or collective wealth of knowledge.

Linking the story to the learning topic, and going broader

Aboriginal culture has an oral tradition, wherein story telling is a way of ensuring that the knowledge learning process is both immersive, and memorable (Green and Brook, 2000). So, the next narrative step moves to a Dreamtime story told to children to start their learning about moral values and the country and animals around them. In the story the animals and people travel across land, encounter water holes here or eat from berry bushes over there and so the listeners learn how to survive in country.

Placing the students in the cultural context being described

The students are introduced to the way that stories are simplified versions of the full story to be expanded through listening while growing up. When travelling that country, family repeat the story with the information at each point along the track – “this is where the wallaby stopped to drink”, and so on.

The importance of the narrative is to provide a link among the different information elements in the story, in a way that can be remembered, as the story listener will later become the story teller. The landscape contains the features that help recall the story, locating memory in features of the environment, to ensure survival and caring for country. This method was used

by Cicero in his oration and is known as the method of loci (Sachs 2018) using cues located in the landscape to trigger the significant aspects of the narrative.

When an elder says: "Now let me tell you how the kangaroo got its tail" he does not believe that a long time ago there was a large animal running around and was speared, then bounded away with a tail. He is saying that he will be giving a part of the story of the Kangaroo as told in community. So, the listener's role is to recall what they know about the kangaroo and think how this new story adds to their knowledge, as when a teacher says "sit down, open your maths book" you prepare to learn maths.

In Aboriginal stories, as the child is growing up the story will grow to include such factors as where water is and where feed is good at specific times of year. The season or time of the story can often be understood through the conclusion to a story, when a main character will ascend to the stars, suggesting which star system is overhead at that time (Kutay, 2018).

Providing an example and relate to students' context

The students are invited to imagine going to a new region, where all their knowledge has no meaning, no place, and to understand that this is why people want to stay 'on country', where they know the stories. Firestick stories for example only apply to a particular area of country. These stories need to reference a real person and experience to validate the knowledge taught (Verran, 2007).

Victor Steffensen of the Tagalaka People of Cape York was trained by his elders to fire burn on his country (Bidwell et al., 2008). He travels around Australia teaching firestick burning, as this is vitally important for maintaining the plants of Australia and preventing wild fires. However, he cannot provide specific training on other peoples' country, as he does not know the features used in firestick burning. What are the weeds? How moist are the plants? What are the seasons? What are the animals to protect? How will they be affected? These are the questions he will ask of the people living on country. And from the answers, they build a collaborative understanding of how to burn this country. Thus, fire burning is a form of pattern matching. This parallels what students learn at University both as frameworks and processes, the skills they need to move between companies and skill areas.

Some more explanation is needed for this aspect of communal knowledge sharing when done in an oral tradition. An important factor is keeping the knowledge pure, avoiding gossip and rumour. Aboriginal oral traditions emphasise that the language speaks the truth when it talks of the land, what is happening, what is moral, and does not deviate. When people speak of a story they are clear who they are talking about, whose knowledge it is, and carefully attribute their knowledge. This factor helps to remind students to reference their sources.

Not everyone can tell a story, only those with a kinship relation, either through direct family for more recent stories, or the inheritance system for ancient tales. Students are similarly expected to understand, when reading or listening to others, to check the material, its source, and if it consistently fits with what has been learnt.

Moving back and forth between contexts to merge them

As we teach we interweave the Indigenous and Western perspectives to show the similarity but also to provide a strong narrative to tie the Western knowledge method together.

We explain how as children grow up, they hear new information that fits in at different locations in their learned story. They start to hear more about how to hunt animals, dig for grubs, pick the right tree for a didgeridoo. Similarly, university teaches with a development process, both on a need to know basis and focusing on increasing detail. This relies on building on prior experience and knowledge.

The Aboriginal knowledge around a theme or subject is extremely detailed knowledge, not easy to teach. It is Tacit Knowledge which is hard to write down or to tell anyone. It is the

knowledge the old fellah managing the press will tell you when there is a problem that they solved years ago, but as this rarely happens so he will not remember to tell you until the issue arises. It is knowledge that can only be conveyed in the time and place where it is relevant. So the story process introduces students to how they learn throughout their university life.

A cultural view - the point of the story

The final analogy is that of the Aboriginal Corroboree or Ceremony, which is orchestrated by the elders when people gather for protein harvests such as when the fish are running at Brewarrina. First the elders/lecturers, meet to set the performance themes which relate to specific conditions to be understood and shared (Verran, 2007). Then the performers or tutors plan the learning environment and play the roles related to their specific knowledges. It is the kangaroo elder, a specialist in that knowledge, who tells people when they can hunt the kangaroo and how many. It is they who play the part of the kangaroo in the ceremony. The depth of knowledge of such an elder is so great, in the Dreamtime story they say, “and then the man became kangaroo” (Kutay, 2017).

Conclusion

Students are introduced through narrative to this role of expertise gradually and systematically, through the Cynefin and Aboriginal cultural storytelling. They are reminded that they do not yet know where their story will go, but that they are building their story every day. We can show how they can let their study and social life at University fill in the gaps as they move towards their Degree. And they find their story changes and grows. This will become their identity as a professional and will carry them through life.

The Cynefin Domains of Knowledge is a model of knowledge that provides a clear and valid rationale for the way in which knowledge is laid out. It explains how Aboriginal knowledge works, by moving slowly and methodically from the Obvious or Simple versions through more Complex forms that are only accessible to those with all the prior knowledge, and therefore able to deal with unexpected and out of the ordinary conditions.

As students engage with Aboriginal lore and Cynefin models of knowledge management they move through levels of understanding about knowledge towards maturity as speakers of their own narrative.

References

- 7 News, S. (2008). Real Top Guns F-111 Belly Landing.
- Bidwell, N. Standley, P. George, T. and Steffensen. V. 2008. The Landscape's Apprentice : Lessons for Place-Centred Design from Grounding Documentary. In Proceedings of DIS 2008, 88–98. <https://doi.org/10.1145/1394445.1394455>
- Clark, M.C. & Rossiter, M. (2008). Narrative learning in Adulthood, New directions for adult and continuing education, 119: 61 - 70
- Green, M. C., & Brock, T. C. (2000). The role of transportation in the persuasiveness of public narratives. *Journal of Personality and Social Psychology*, 79, 701–721.
- Green M.C. and Donahue J.K. (2011) Persistence of Belief Change in the Face of Deception: The Effect of Factual Stories Revealed to Be False, *Media Psychology*, 14:3, 312-331, DOI: 10.1080/15213269.2011.598050
- Indigenous Engineering (2018) <http://indigenousengineering.org.au/category/topic-areas/>
- Kennedy, J. Goldfinch, T. Leigh, E. McCarthy, T. Prpic L. and Dawes L.(2016) A Beginners Guide to Incorporating Aboriginal Perspective into Engineering Curricula <http://indigenousengineering.org.au/wp-content/uploads/2016/07/eac-v4-small2.pdf>
- Kutay, C (2017) Tacit Knowledge Sharing <https://www.youtube.com/watch?v=pb8LZyFcbCc>

- Kutay, C (2018) Teaching an Australian Aboriginal Knowledge sharing process. In Faucher, Colette (Ed) *Advances in Culturally-Aware Intelligent Systems and in Cross-Cultural Psychological Studies*. Springer International Publishing pp. 63--96
- Leigh, E. (2013). *Wheels Up! Now Where Do We Go?* SimTecT 2013. Adelaide, Simulation Australia.
- Tobler, Ray, A. R., Julien Soubrier, Pere Bover, Bastien Llamas, Jonathan Tuke, Nigel Bean, Ali Abdullah-Highfold, Shane Agius, Amy O'Donoghue, Isabel O'Loughlin, Peter Sutton, Fran Zilio, Keryn Walshe, Alan N. Williams, Chris S. M. Turney, Matthew Williams, Stephen M. Richards, Robert J. Mitchell, Emma Kowal, John R. Stephen, Lesley Williams, Wolfgang Haak & Alan Cooper (2017). "Aboriginal mitogenomes reveal 50,000 years of regionalism in Australia." *Nature* volume 544(April 2017): 180–184.
- Snowden, D. (2018). "Complexity, citizen engagement in a Post-Social Media time." from <https://www.youtube.com/watch?v=JkJDyPh9phc>.
- Stoop, E. (2016). *Cynefin Domains of Knowledge*. https://commons.wikimedia.org/wiki/File:Cynefin_framework_by_Edwin_Stoop.jpg, Sketching Maniacs.
- Sveiby, K.-E. and T. Skuthorpe (2006). *Treading Lightly*. Sydney, Allen &Unwin
- Verran, Helen. (2007) "Knowledge Traditions of Aboriginal Australians: Questions and Answers arising in a Databasing Project" *Encyclopaedia of the History of Non-Western Science: Sciences, Technology and Medicine*. Berlin Heidelberg, New York: Springer,