STRATEGIES FOR PROGRESSING UNDERSTANDING OF CHARACTERISTICS OF TECHNOLOGY

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Abstract
This paper reports on the trial of a teaching resource developed to support student learning in the characteristics of technology component of the Nature of Technology strand in the New Zealand Curriculum (Ministry of Education, 2007). The trial was part of Stage Three of the Technological Knowledge and Nature of Technology: Implications for teaching and learning research project. Earlier findings from this research had shown that students found it difficult to identify, describe and evaluate both the drivers and impacts of developments in technology and therefore often did not exhibit understandings related to characteristics of technology above level 2 of the NZC. A resource was developed to help stimulate discussion around characteristics of technology that would support learning and provide opportunity to identify student understanding up to and including level 3 and 4 of the characteristics of technology component. Follow up material was also developed to 'push' students to level 5 and beyond. The resource was trialed by five teachers - two intermediate and three secondary teachers. This paper describes the resource and how it was used in each class, the resulting impact on student learning and the implications of the trial with regards to teaching this component.

Developing the Characteristics of Technology (CoT) Teaching Resource

An analytical model developed by Hallstrom and Gyberg from Sweden was used to develop the CoT teaching resource. The model focuses on the role an analysis of the history of technology can have on understanding how and why technological developments (including both the practice and outcomes of technology) change. The model describes the 'actors and factors' that influence technological change. It also provides different "levels of meaning" to "critically reflect upon the evolution of technology" (Hallstrom & Gyberg, 2009, p.5).

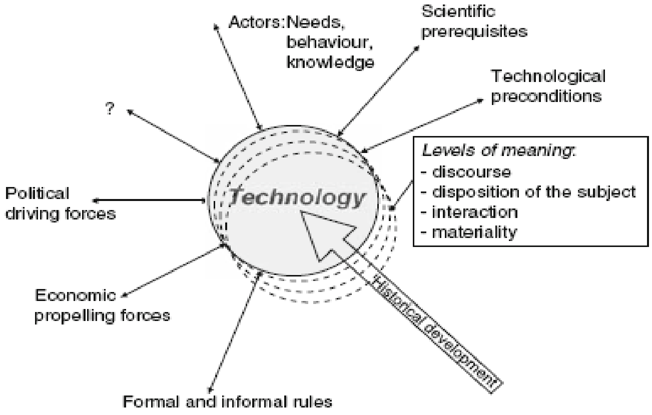
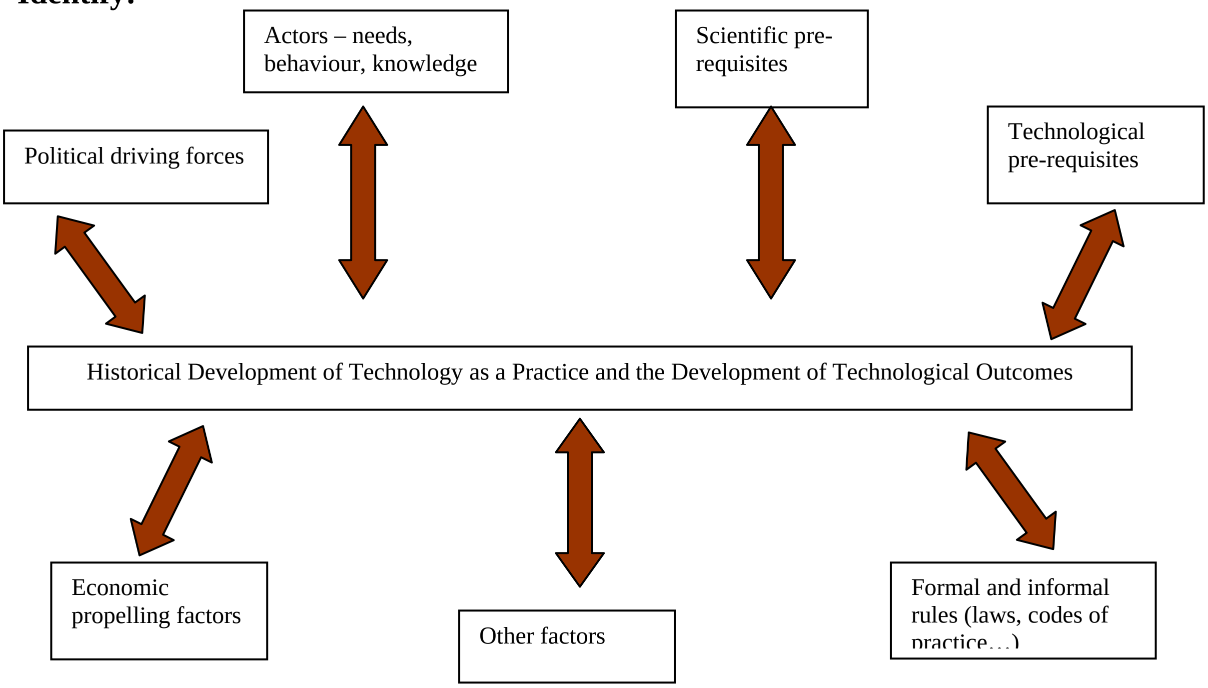


Fig. 1 A model of techno-historical interplay

We took this model and developed a resource consisting of an Actor and Factors template and a series of lenses to consolidate and/or identify student understanding of CoT at Level 2 and 3 and 'push' students beyond Level 4.

Initially the resource focuses on students identifying and describing ‘actors’ and ‘factors’ that might be contributing to some technological development. Identifying and describing requires easier processing strategies than explaining and evaluating. Identifying and describing is the focus of the strategies needed at Level 1 – 3 in the learning area of technology (Compton and Compton, 2010a). A template and questions were developed for teachers and students to use – see Figure 2.

Identify:



Choose one actor/factor from the list you have made under each heading and describe how this actor or factor has influenced the development of the example chosen.

Describe how practices or outcomes from your chosen example have impacted on one actor/factor from the list you have made under each heading.

Figure 2: ‘Actors and Factors’ Template

How the students responded to this template would be dependant on the level the students were working at. This part of the resource was therefore developed to serve diagnostic purposes as well as providing a focus for teaching when students were working between Level 1 and 4. As part of the development of this resource, an analysis of the ‘Indicators of Progression’ for ‘Characteristics of Technology’ was undertaken using the *Levels of Meaning*, as described by Gyberg & Lee and Hallstrom & Gyberg. We renamed these as *Lenses* to avoid confusion with curriculum levels. We also renamed three of the lenses to make them more intuitive for teachers and students. For example:

- ***Disposition of Subject*** became ***‘Disposition’***
- ***Interaction*** became ***‘Interplay’***
- ***Practice as deposited discourse*** became ‘***Rules of the Game’***

The names ***Discourse*** and ***Materiality*** were retained. (See Appendix A for an explanation of each lens)

This analysis revealed a predisposition towards particular lenses to support learning at different levels of the curriculum. It was hoped that teachers could use these lenses to explore and critically reflect on the complex interaction of the 'actors and factors' previously described, using the lens or lenses most appropriate to the curriculum level the students were working within. The lenses are of greater use, we think, when teachers and students are working from Levels 4 to 8. This is because the focus on particular lenses is more distinct from Level 4 onwards and students are required to use deeper processing strategies to understand the complexity the lenses provide. Questions and tasks could then be set that require students to use a range of strategic processing strategies that allow for deeper exploration and analysis. These questions would be carefully formulated for each level as related to the lens/lenses being used and a particular context. That is:

- Level 5 –**Disposition** and **Rules of the Game**
- Level 6 – **Interplay** and **Discourse**
- Level 7 – **Discourse**
- Level 8 – **Materiality**

(See Appendix B for examples of possible questions for each level set in the context of renewable energy sourse).

Method of Trialing the CoT Tool

The tool was trialled with five teachers (Two intermediate teachers working with mixed Years 7 and 8 students and three secondary teachers, one working with a Year 10 class and two working with Year 12 classes). We explained the tool to all teachers and discussed how it could be used with different age groups. We asked each teacher to use the 'Actors and Factors' template as a diagnostic aid to determine 'readiness' for pushing above Level 4. This involved providing the students with appropriate case study material to work with as they completed the template.

The teachers, in conjunction with us, then planned an intervention to run over one or two lessons. If the students demonstrated a readiness to move beyond Level 4, the lens or lenses to be used would be explained and the students would be asked to explore the interaction between the actors and factors. A task would then be set that required the students to use the designated lens/lenses to analyse and discuss the material.

Findings

The Year 7 and 8 students worked with the 'Actors and Factor' template as a diagnostic tool as part of a whole class activity. Discussions during this activity showed the majority of the students were working across Level 1 and 2. Attempts to continue to use the template as a teaching tool consistently caused problems for the students. For example, they found 'political driving forces, technological prerequisites and the personal dispositions of actors (people involved in the developments) difficult to identify. They also often mixed up what were scientific prerequisites and what were technological prerequisites. As a teaching tool therefore, the template was found to be too complex for these students. A new template was therefore developed where the focus was taken right back to the development of a timeline for how a single technological development had occurred over time, with technological outcomes developed included to represent significant shifts. Questions were then developed to begin to unpick why these changes had occurred in terms of people (users and developers), materials and techniques, and social and environmental issues influencing or impacted on. When students were asked to compare and contract two examples along their timeline, they were better able to answer these questions, and therefore beginning to consolidate their Level 2 understanding and in some cases progress this to beginning Level 3 by the end of the trial.

The teacher of the Year 10 class changed the headings in the template to what he thought would be easier for his students to understand. However, there appeared to be no benefit gained by doing this. In fact the students' ability to identify what was required appeared to be reduced with the resulting responses being more simplistic and focused on the understanding they had of concepts required for brief development rather than developing an understanding of the drivers of technological development. The follow up lessons in this class successfully used the template as a teaching tool to develop and consolidate Level 2 and 3 concepts in CoT. That is, identifying relevant drivers as per the template and exploring how, and most importantly *why*, the actors and factors influenced technological change. The teachers of the Years 7 and 8 and Year 10 classes used examples of developments from a range of contexts. These included the development of different types of clothing, tents, shoes and protective gear.

The teachers of both Year 12 classes used the template as a diagnostic tool initially and then used the results to plan additional focused learning experiences. One teacher commented, "The 'Actors and Factors' sheet was good in the respect that it gave me a solid starting point and highlighted areas that I would not have thought about". Once again terminology had to be explained but both teachers stated that "once explained the students were ok". The Year 12 students were more able to distinguish correctly between the scientific and technological prerequisites. Most were also able to identify political driving forces. Once again, the students found identifying the personal disposition of those involved in technological developments difficult. The students' focus on the needs of people, rather than their dispositions, may reflect the strong focus on this within technological practice in most school programmes.

In one Year 12 class, the student responses to the template indicated they were working within Level 3. The teacher therefore decided to repeat the activity in another context and teach specifically about the 'Interplay' or relationships between people and technological outcomes (Level 4) as a way to both consolidate and extend his students understanding.

All four of the classes discussed above were working at Level 3 or below and all these students found the two-way arrows of the template confusing. They found it difficult to recognise the interdependent relationship between technological development and society in all the factors on the template.

In the remaining Year 12 class the student responses to the template indicated they were working consistently above Level 3 – with many students howing sound Level 4 CoT understanding. These students did not find the two-way nature of the arrows confusing, but rather comfortably discussed the interdependent relationships. Therefore, with this class, it was decided to trial two of the lenses ('Disposition' and 'Rules of the Game'). These lenses were used by the teacher to try and progress student understanding into Level 5.

In the context of 'Streetwear', which was the focus of the Year 12 programme, the teacher required the students to do further research. She set the following tasks for her students:

- Focusing on the **people** you have identified as Actors and Factors:
  What personal experiences, beliefs and/or 'habits of mind' may have influenced how they perceived or contributed to the development of streetwear?
- Focusing on the different knowledge that contributed to the development of streetwear:
  Which examples of this knowledge could be described as codified technological knowledge?
  Why does knowledge become codified?
  Explain the role of codified knowledge.
- Think about new technologies related to streetwear. Choose an innovative fashion designer and describe how people's perception, knowledge and skills might have contributed to the development of the designer's clothes.

The responses of all these Year 12 students demonstrated an increased understanding of how the personal disposition of the people involved in the development of fashion influenced the development of both the outcomes and practice they were involved in. All students were able to synthesise what they had learnt through their discussions and research about personal disposition, collaboration and the contributing knowledge, to discuss the role of innovation and creativity. However, all the students had difficulty explaining why knowledge becomes codified.

Discussion and Conclusion

While the Actors and Factors template was helpful as an initial diagnostic tool in all classes, it was found to be too complex as a teaching tool for students working below Level 3 (both the year 7/8 classes).

For those students working between Levels 3- 4 (year 10 class, and both year 12 classes initially), the term 'actors' continued to be a confusing element of the template. However, when this terminology was changed to 'users' and 'developers' students were better able to complete the template. It was also noted that the other titles tended to direct student into only thinking of the impact on the technology, rather than the impact of the technology. This again was successfully addressed by changing the titles to encompass the two way interaction and splitting the table accordingly into influences and impact. For example, Political Driving Forces became Political Factors – split into 'political influences' on the technology and 'political impacts' of the technology. Physical environment or 'natural world' factors also appeared consistently in the 'other factors' section and it was decided this should appear as an additional title. The third main change to this template to increase its usefulness was to ensure the technology focus was narrowed down – at least initially. For example, 'Historical Development of Technology as a Practice and the Development of Technological Outcomes' became 'Historical Development of a particular Technological Development'. In all cases, the original template, and its modifications were presented to students to use in hard copy. We believe the template could be more effective as an electronic document, and therefore a more interactive tool. See Appendix C for the revised template.

The year 7 and 8 students working at Level 2 (or below) of the NZC found distinguishing between scientific and technological perquisites difficult. More teaching is required to help students identify the nature of scientific concepts and how they relate to, but are different to, technological developments. We believe a focus on Characteristics of Technological Outcomes (CoTO) will help with this. In particular 'how things work'. Understanding how technological outcomes work relies not only on being able to describe observable attributes but also on identifying phenomena that underpin the functioning of technological outcomes. These phenomena are usually scientific concepts.

Arthur (2009, p.51) states that all technological outcomes "capture and put to use" natural phenomenon. These phenomena or "natural effects" exist as part of the physical world and as such are independent of humans and technology" (Ibid., p.49). 'Harnessed' phenomena can be referred to as principles. Technologists use these principles to figure out how to design an outcome to 'work' as it is required to work. For example,

Phenomenon	→ Harnessed or captured and put to use →	Principle	→ yields →	Outcome
Natural effects independent of human/technology (i.e. has no *use* attached to them)		The idea of use of phenomenon for some purpose (or several phenomena)		
e.g. The steady oscillation of quartz (Arthur, 2009)	→	Quartz can be used for time keeping	→	Watch

Identifying the natural phenomena, as explained by the discipline of science, could help students working at Level 2 and 3 to distinguish between the scientific prerequisites and the technological prerequisites. (The level of science understanding needed should correspond to what students should understand at the appropriate level in the learning area of science.)

One of the Year 12 classes in this research was able to discuss the disposition of the people involved in a technological development. The other four classes found this difficult. Teaching about disposition requires teachers to extend beyond the ideas captured in the Technological Practice strand. Often these ideas are limited to needs of stakeholders and do not explore the drivers associated with the people (actors) involved in technological developments in a temporal context (historical, present and future). How technological developments are influenced by how and why people think and act, as well as the effects of technological developments on how and why people think and act, are the foci of this driver. This two-way interplay is important. The introduction of the ideas about codified knowledge at Level 5 also seemed to cause some difficulties for the Year 12 students. Teachers should note that in the 'Learning Progression Diagrams' (Compton and Compton, 2010b) understanding about the role of codified knowledge and how and why knowledge becomes codified, relies on students identifying what useful knowledge underpins particular technological developments. Codification is simply the organization and standardisation of specifications around materials and methods of operating within practice that technologists, and other professions, use to save time and make sure outcomes are fit for purpose.

This research had limits in terms of both the number of classes that we worked with and that the CoT tool was only used to extend student understanding to Level 5 with one class. However, the resource overall, and modifications made when using it, did seem to be a successful approach to both focus teacher attention to relevant concepts to be taught and extend student thinking beyond the level they were previously working within.

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Appendix A: Explanation of Lenses

Lenses through which to View and Examine Technological Development - Examples

(With reference to Gyberg & Lee, 2009 and Hallstrom & Gyberg, 2009)

Disposition: This lens focuses on our personal interpretation of experiences and ways of relating to technology and how we might share the experience of these events (Hallstrom & Gyberg, 2009). We react to technologies in differing ways influenced by our personal past experiences and the expectations we have which, in turn, are influenced by the societies we live in and the beliefs we have.

Example: An analysis of the disposition of individuals involved in technological developments not only includes the potential users of the technological outcomes but also the creators – that is the technologists themselves. What drove Bill Gates, William Alexander Bell? What skills, understandings, opinions and personal experiences shaped their practice and what they designed and developed? This lens also focuses on the needs and personal disposition (understanding, skills, opinions, values etc.) of probable or potential users, as these are extremely important for the development of successful technologies.

Rules of the Game: This lens focuses on the specialised knowledge, language and codes that define the content and nature of technological practice as it is 'situated' in time, place and intent. The knowledge, language and codes establish the rules which give the technological practice its "potential, stability and limitations" and "a practice that also creates its own ways and means" (Gyberg & Lee 2009, p.4).

Example: Technological developments involve competing priorities, compromise and innovative strategies to find solutions to particular design, social and/or environmental challenges across the made, social and natural worlds. To reason and act on what can and should be done requires rules to be established and followed. These rules sometimes exist because of already established ways to act (codes of practice around materials, ethics etc.) but also may have to be negotiated and adapted to create new rules. Gene technologies often provide a context that requires competing views to be explored to find new ways forward. The forming of any new material or technique to be used in the development of an outcome will require new codes of practices to establish tolerances and acceptability factors.

Interplay: This lens focuses on the interdependent relationship between people and technology. This interplay shapes technological development and technological interventions that mediate our surroundings (Hallstrom & Gyberg, 2009). This lens focuses on the two way interplay between people in the development of technology and between resulting technologies and people.

People (as both situated users and creators) ⟷ Technology (as mediation tools and repositories of knowledge/culture)

Example: Technological developments involve people exchanging knowledge, skills and practices. This exchange, often from different disciplines, will rely on established practices of interaction and will also create new conditions for these interactions to occur. For example, collaboration between medical specialists, material development technologists, digital imaging specialists and biomechanics has resulted in the development of significant medical technologies that have contributed to advances in diagnoses, communicative modelling and prosthetic intervention. The use of technological outcomes themselves can also be viewed and analysed by focusing on interactions between people and the made world. For example, advances in communication technologies mean that people can work at anytime without having to be in 'the office'.

Discourse: This lens focuses on "what people think, know and say about technology and the made, social and natural worlds" (Hallstrom & Gyberg, 2009, p.6). Examining the talk and thoughts of the people (creators, users, stakeholders and wider communities) helps us understand how people create meaning about technology. Technological developments in the world can be understood by exploring the ways and means of communication and the shared thinking of the time and place that a technological development occurs. The discourse lens helps delve into more complex understandings in the previous three lenses.

Example: The growing technological development in alternative power generation can be analysed by exploring the discourse circulating in societies about the future of the planet, understandings people have about sustainability, the need for protection against dependence on other countries and ideas people have about personal self-reliance etc.

Materiality: This lens focuses on the 'tangible' effects of using materials (matter and energy) when developing and realising technological outcomes. The materiality of technology "mediates" (Gyberg & Lee 2009, p.5) or transforms the world in real ways. Technologies force us to react in certain ways. We have to negotiate our way around them; we cannot ignore their presence as part of the made world. Technology 'affects, limits and facilitates' (Hallstrom & Gyberg, 2009) how we live our lives. Technology has an immediate effect on the social, made and natural worlds because of its material nature.

Example: The materiality of technology means it results in 'real' effects in the world. The development of contraceptive pills and devices change how bodies react chemically and physically. Hydro dams effect environments. Artificial body parts influence lifespan, physical performance and how people think about what it is to be human.

Appendix B: Possible Questions (Context - Renewable Energy Sources)

Questions or tasks designed to apply particular lens to *Explore* and *Analyse*

Level 5: Disposition and Rules of the Game

1. Focusing on the people you have identified as 'Actors and Factors': What personal experiences, beliefs and /or 'habits of mind' may have influenced how they perceived or contributed to the development of renewable energy sources?
2. Focusing on the different knowledge that contributed to the development of renewable energy sources: Which examples of this knowledge could be described as codified technological knowledge? Why does knowledge become codified? Explain the role of codified technological knowledge.

Level 6: Interplay

1. Look at all the 'Actors and Factors' you have identified. Explain how the different knowledge, beliefs and practices of the people involved would have impacted on the development, manufacture, and use of outcomes related to the generation of electricity from wind, solar and water sources in the past?
2. Explain the importance of interdisciplinary collaboration during the development of these outcomes
3. How do you think the collaboration may have enhanced or inhibited the development of the outcomes, and the public understanding these?

Level 7: Discourse

Explain what people think, know and say about renewable energy and its impact on the made, social and natural world. Discuss how the development of renewable energy sources and the manufacturing of different energy generating outcomes would have required competing factors to be examined and innovative solutions to be found. Your discussion should include how socio-cultural factors about technology and the environment influence technological practices, acceptance of past technologies and the development of alternative technological outcomes.

Level 8: Materiality

Describe how the tangible effects of the material nature of energy generating outcomes may have impacted on the lives of the people using these technological outcomes. Discussion should include the transformative effects on the social, made and natural worlds that an outcome has because of its materiality.

Questions or tasks designed to use particular lens to *Create Meaning* through synthesis and evaluation

Level 5: Disposition and Rules of the Game

1. Think about new technologies related to energy generation. Choose an innovative technological outcome and describe how people's perceptions, experiences, knowledge and skills might have contributed to the development of the outcome.
2. Evaluate potential risks and suggest possible safety mechanisms to deal with new technological knowledge associated with selected innovative solutions.

Level 6: Interplay

1. Evaluate the potential effects of interdisciplinary collaboration within an identified technological practice undertaken to explore alternative energy generation options.
2. How might the nature of interdisciplinary collaboration influence how people and/or communities accept alternative technological solutions?

Level 7: Discourse

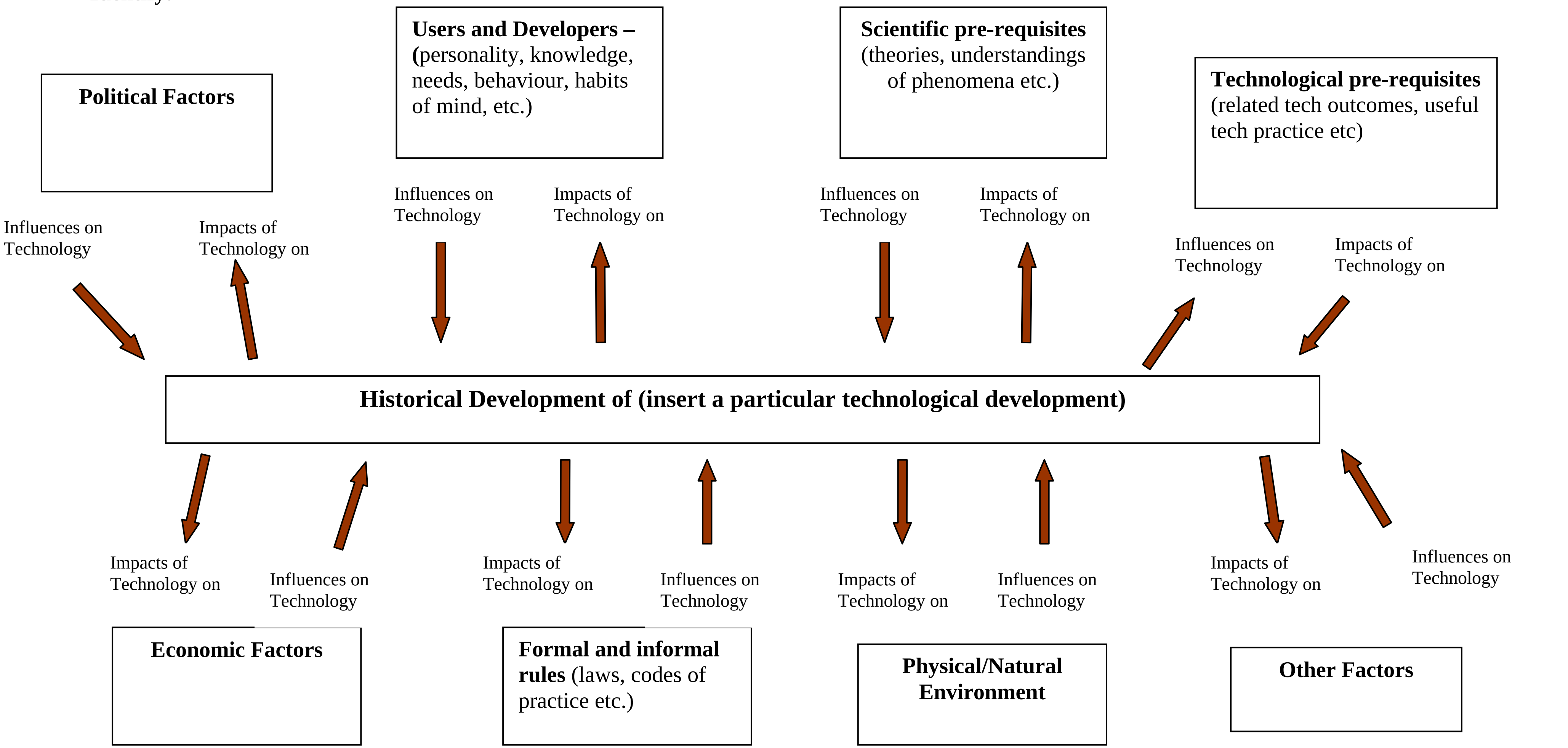
Evaluate the effectiveness of the discursive processes that contribute to decision making and the building of knowledge and practice within the field of renewable energy technology. Your discussion should be able to be used to justify the benefits of proceeding or not proceeding with particular design ideas. The benefits to technological practice and socio-cultural environment in which the technological outcome is located should be taken into account.

Level 8: Materiality

Use examples of current and possible future energy generating technological outcomes and their relationship to the made, social and natural world to explain why material objects can have such an influence on the lives of people and the environment. Discuss the responsibilities that technologists have to demonstrate your understanding of technology as 'intervention by design'.

Appendix C: Revised 'Actors and Factor' Template

Identify:



Choose one actor (user or developer) or factor from the list you have made under each heading and describe how this actor or factor has influenced the development of the example chosen.
Describe how practices or outcomes from your chosen example have impacted on one actor/factor from the list you have made under each heading.