EXPLANATORY PAPER

The Nature of Technology Strand: Characteristics of Technological Outcomes

ABSTRACT

The purpose of this explanatory paper is to clarify and define what a technological outcome is, and how it is characterised and described. It presents the component descriptor, the key ideas underpinning it, and illustrative examples of these from technology. This paper also suggests possible learning experiences.

COMPONENT DESCRIPTOR

Technological outcomes are products and systems developed through technological practice for a specific purpose. A technological outcome is evaluated in terms of its fitness for purpose. Technological outcomes can be described by their physical and functional nature. A technological outcome can only be interpreted when the social and historical context of its development and use are known. The term proper function is used to describe the function that the technologist intended the technological outcome to have and/or its socially accepted common use. If a technological outcome does not carry out its proper function successfully it is described as a malfunction. Alternative functions are successful functions that have been evolved by end-users. Technological outcomes work together with non-technological entities and systems in the development of socio-technological environments.

KEY IDEAS

Technological outcomes are defined as fully realised products and systems, created by people for an identified purpose through technological practice. Once the technological outcome is placed *in situ*, no further design input is required for the outcome to function. Being fully realised means technological outcomes are more than a concept or plan for something to be developed - they actually exist and function as designed in the made world. Function in this sense includes all aspects that underpin the fitness for purpose of the technological outcome – including aesthetic aspects. Taking this definition into account, technological outcomes can be distinguished from natural objects (such as trees and rocks, etc.), and works of art, and other outcomes of human activity (such as language, knowledge, social structures, organisational systems, etc.).

Within this definition, technological outcomes can be further categorised into two types – technological products and technological systems. However, the relationship between the categories of technological products and systems can be complex. In many ways, it depends on the way you look at a technological outcome as to whether you would describe it as a technological product or a technological system. For example, a cell phone could be described as a technological system, which is made up of interconnected components, working together to achieve a task. Alternatively, a cell phone may be described as a technological product, where the focus is no longer on the interconnected components, but on the materials used in the product.

A key feature of technological products and systems is that they are intimately connected to other entities (including natural objects and people) and systems (including political, social, cultural systems, etc.). That is, technological outcomes help to form socio-technological environments as the made world combines with the natural and social world. Socio-technological environments include such things as communication networks, hospitals, transport systems, waste disposal, recreational parks, factories, power plants, etc. For example, the cellular communication environment incorporates a range of technological products and systems (cell phones, towers, data-logging computers, transmitting circuits, receiver circuits, and so on), alongside non technological systems (such as legal, political, financial, energy, etc.) and entities (such as people, geographical features, etc.).

A technological outcome is characterised as having a dual nature. That is a *physical nature* – what it looks like and/or is comprised of, and a *functional nature* – what it can do. Understanding the relationship between the physical and functional natures of technological outcomes provides a good starting point for understanding the technological outcome as a whole.

Understanding this relationship is crucial when undertaking technological practice to develop a technological product or system for a specific purpose. This understanding allows technologists to recognise that several potential options exist for an outcome's physical and specific functional nature. For example, should you wish to design a technological outcome that would function as a drinking vessel, you may explore a range of shapes (coffee mug *versus* long stem wine glass) and/or materials (ceramic *versus* glass). What will determine the physical nature in the end, will be the decisions made as to what would provide the drinking vessel with the best fitness for purpose. This will be defined by such things as the liquid to be held, the needs/desires of the intended users, and the environment in which the vessel will end up being situated, alongside the materials, components, and equipment available for it production or manufacture. Similarly, should you wish to design a technological outcome using particular materials or components, you may explore the performance possibilities this would provide in order to identify possible functions the outcome could be designed to achieve. Therefore, the functional nature requirements will set boundaries around the suitability of proposed physical nature options, and the physical nature options will set boundaries around what functional nature is feasible for a technological outcome at any time.

The relationship between the physical and functional nature of any technological outcome can provide a useful analytical tool for guiding decisions regarding the fitness for purpose of a technological outcome during its development. It also provides an effective analytical tool for interpreting existing technological outcomes as well as providing a basis for understanding past and contemporary influences on its development such as being able to establish what knowledge, skill, equipment, and materials were available. Understanding the physical and functional nature of a technological outcome also provides insight into possible future implications and subsequent adaptations or innovations for the outcome's development. The physical nature of a technological outcome can provide critical clues as to the possible function of a technological outcome when this is not known.

When undertaking the analysis of existing technological outcomes, *design elements* provide another useful analytical tool useful for interpreting outcomes and their design decisions. Design elements related to the physical nature of outcomes (sometimes referred to as the form of an outcome) include such things as colour, movement, pattern and rhythm, proportion, balance, harmony and contrast, and style. Design elements related to the functional nature of outcomes include such things as strength and durability, safety and stability, efficiency, reliability, nutritional value, user-friendliness, and ergonomic fit. These elements can be used to understand how physical and functional factors were prioritised in the design and development of an outcome in order for that outcome to be considered fit for purpose. Design elements are prioritised in different ways as determined by such things as a designer's intent for the outcome, understandings of materials, the socio-cultural location the outcome is to be situated, professional and personal beliefs, etc. These elements also provide guidance when deciding what factors should be considered during the development of technological outcomes.

Technological outcomes can also be described and understood in relation to their intended and actual function. The term proper function is used to describe the function that the technologist intended the technological outcome to have and/or its socially accepted common use. The intended function is what drove the development of the physical and functional nature, as described above, and what allowed the technological outcome to be evaluated as fit for purpose.

The concept of alternative function is also important when understanding technological outcomes. Alternative functions evolve from the successful use of the technological outcome in a way that was not originally intended by the technologist. Not only do users regularly employ technological outcomes for alternative functions, they may modify the physical nature in order to optimise its performance in terms of this new function. They may also put pressure on technologists to redesign the original technological outcome to meet the additional functional needs they have identified. This demonstrates one way in which end-users, technological outcomes, and technologists interact with each other. When an alternative function comes to be the socially accepted normal function of the outcome, this becomes the new proper function of the outcome.

Malfunction is a descriptive term for a technological outcome that does not carry out its proper function successfully. This is referred to as a single event failure, and is usually easy to distinguish from any gradual reduction in function caused by general wear-and-tear effects on a technological outcome over time. Malfunction is also very different to what can be described as designed failure, where a product, or component of a system, is intentionally designed to stop working after a certain number of uses. The ethics of designing the life-time

of a technological outcome must take account of complex factors such as market forces, maintaining jobs, consideration of future material developments, changing fashions, social norms, and public opinion. Exploration of examples of malfunction, gradual reduction in functioning from ongoing use, or designed failure of technological outcomes, provides an interesting focus for understanding the complex interface between design, materials, end-users, established instructions, and operational parameters, and the environments in which technological outcomes are situated. Operational parameters refer to the boundaries and/or conditions within which the outcome has been designed to function.

ILLUSTRATIVE EXAMPLES FROM TECHNOLOGY

The malfunctioning of the O-rings in the Space Shuttle Challenger in 1986 provides a dramatic context to explore issues around the physical and functional nature of technological outcomes, and the way in which technological products make up an interconnected technological system. Understanding how products interact within a wider system, when designed to meet specific environmental parameters is crucial to successful function. In this case, while the O-rings were fit for purpose within specific environmental parameters, they malfunctioned when these were exceeded. The impact this accident had on the general public, scientists and technologists (at a personal career level and collective community level), NASA, and the American Government are easily accessible for exploration and would provide a rich source to encourage debate.

Sites such as the FAS Space Policy Project and the Challenger Disaster – a NASA tragedy are just two of many informative sources available.

The role of end-users in developing alternative functions and stimulating innovative redesigning is well captured in many New Zealand examples of technological outcomes. Finding new functions for existing materials and/or developing new materials to enhance performance are also strong features of successful technological industries in New Zealand. A range of examples (such as wind turbines, film technologies, car batteries, and electric fence technology) can be used as a focus to explore the dual nature (physical and functional) of technological outcomes. Sources such as IPENZ's e.nz magazine, numerous internet sites, and current items in news media can all be used to provide New Zealand-based resources with varying depths of information.

POSSIBLE LEARNING EXPERIENCES

The learning experiences suggested below have been provided to support teachers as they develop their understandings of the Characteristics of Technological Outcomes component of the Nature of Technology strand, and how this could be reflected in student achievement at various levels. There is no expectation that these would form the basis of any specific unit of work in technology. The learning experiences have been written in such a way as to support student learning across a range of levels. This stance reflects the majority of classrooms where it is expected that students will demonstrate a range of levels of achievement.

Junior Primary (NE-Year 4)

Small groups of students could be provided with a range of familiar objects (for example, concrete block, rock, pen, Weet-Bix, apple, plant, potato, potato chips, stick, walking stick, etc.) and asked to select which of these they consider to be technological outcomes – giving reasons for their selections. Some of the objects could be the same for each group to see if different groups categorise the same object differently.

Students discuss their reasons for selecting objects as being technological outcomes as a class, and the teacher draws out a shared definition of a technological outcome from these discussions. Students could be asked to select a technological outcome and describe this to the class while the rest of the students close their eyes. The remaining students then try to guess what the outcome is. The teacher models questions that get the students thinking about describing *both* the physical and functional nature of the outcome.

The teacher could then provide students with two sets of technological outcomes. One set could be technological outcomes that have been developed for a similar purpose and environment but from different historical eras (for example, chalk, quill, pencil, pen, and handheld computer tablet). The other set could include technological outcomes that have been developed for a similar purpose and in a similar era, but for different environments

(for example, make-up brush, toothbrush, hairbrush, nail brush, hearth broom, and yard broom). Ask students to describe the physical and functional nature of each of the technological outcomes and make links to how and why the outcomes within each set differ.

Students achieving at level 1 could be expected to:

- identify technological outcomes;
- identify possible users of identified technological outcomes;
- describe a technological outcome in terms of what it looks like; and
- describe a technological outcome in terms of what it does.

Students achieving at level 2 could be expected to:

- identify technological outcomes and explain how they differ to other objects;
- identify a technological outcome and describe the relationship between its physical and functional attributes; and
- describe the physical and functional attributes of a technological outcome, with the description implying who possible users may be.

Senior Primary/Intermediate (Years 5-8)

Students could explore two related examples of technological products and technological systems; for example, a billy and an electric jug, and a non-sprung wooden clothes peg and a plastic spring clothes peg. Students could identify and explain why the examples could be called products or systems. Students describe the way in which the physical attributes of their technological outcome allows it to carry out the function it has been designed for, and suggest how fit for purpose each outcome appears to be. Students could discuss how changing the environmental condition or the age of the users might impact on how successfully the outcome could be used.

The teacher could provide the students with a partially developed brief that includes a conceptual statement and the performance specifications for a technological outcome. Depending on the prior knowledge and experience of the students, these may be related to the earlier examples, (for example, a peg for keeping food fresh once opened) or completely unrelated. In pairs, students explore a range of design ideas and evaluate these against the requirements provided in the brief as to how the technological outcome should function. Students could also discuss other functions that a modified version of the design could be used for by different people in different situations. A whole class discussion could focus on differences and similarities in the design ideas and link these to the relationship between the physical and functional nature of technological outcomes.

Students achieving at level 2 could be expected to:

- explain why technological products and systems can be described as technological outcomes; and
- describe the physical nature of a technological product and explain how this allows the outcome to function in a certain way.

describe the physical nature of a technological system and explain how this allows the outcome to function in a certain way

Students achieving at level 3 could be expected to:

- develop designs of a range of technological outcomes that could provide a given function and describe their physical nature; and
- evaluate designs and explain which they consider could be described as a “good” or “bad” design.

Students achieving at level 4 could be expected to:

- identify the proper function of selected technological outcomes and suggest possible alternative uses; and
- explain what might happen to the outcome, the user, and/or the environment if selected technological outcomes were used to do things they were not designed for.

Junior secondary (Years 9-10)

Students could explore an historical event to explore why a technological outcome malfunctioned. For example, the Challenger disaster could be explored to develop student understandings about how proper function relies on the outcome being used in the context it was designed for, and changing this context can result in outcome malfunction.

Students could then explore the technological outcome they are currently developing (for example, a stool) in terms of its ability to function in a range of contexts (for example, used on different types of surfaces – such as wooden floors, carpet, concrete, and grass) and potential ways of being used; for example, being stood on, swung on, and/or supporting more than one person.

Students could discuss ways in which they could maximise the outcome's reliability and/or efficiency across multiple contexts. Particular attention should be paid to the implications of decision making that establishes acceptable operational parameters, and what evidence and reasoning students need in order to justify design decisions with regards to the physical and functional nature of their technological outcome.

Students achieving at level 3 could be expected to:

- describe the physical nature of a technological outcome they are developing and describe how it could function and why it would be suitable for particular users; and
- explain how changes to the physical nature of their outcome could enhance its fitness for purpose.

Students achieving at level 4 could be expected to:

- describe the proper function of the selected technological outcome;
- explain how the technological outcome might be able to be used by end-users for purposes other than what it was originally designed for; and
- discuss the likely impact of using technological outcomes in alternative ways.

Students achieving at level 5 could be expected to:

- explain how explorations of their own outcome in various contexts allowed them to gain a deeper understanding of how they could modify their design to reduce user misuse and/or inappropriate environmental location;
- explain the concept of malfunction, and use the selected technological outcome to illustrate the difference between malfunction and failure due to wear and tear; and
- explain why the technological outcome malfunctioned and identify changes in its design should you be developing the outcome today.

Senior Secondary (Years 11-13)

Students select an incident where a socially significant technological outcome has malfunctioned, (for example, the Cave Creek platform collapse) and examine the reasons provided for the failure. Students explore, in particular, what physical and functional design elements appeared to be prioritised and how this was justified at the time of development and after the malfunction.

Implications of the event are explored in terms of subsequent technological outcome development and the development of, or modification to, codes of practice to minimise future risks. Lessons learnt from all events investigated in the class are summarised and linked to how technological outcomes and technological knowledge is enhanced through exploring the reasons for the failure.

Students identify an existing technological outcome in their local environment and analyse it in terms of its wider socio-cultural and historical context. Suggestions for how this outcome could be modified to enhance it in some way could be explored and a feasibility study carried out to form the basis of a proposal for future developments. This could provide the basis for the student to undertake their own technological practice in the future.

Students achieving at level 4 could be expected to:

- describe the proper function of the technological outcome that failed;
- explain how the failure of a technological outcome occurred, and how this related to the relationship between its physical and functional nature; and
- explain what changes to the physical attributes of the technological outcome could have been made to better suit the intended user/s or physical environment.

Students achieving at level 5 could be expected to:

- explain the concept of malfunction and use the selected technological outcome to illustrate the importance of context on judging an outcome as fit for purpose;
- explain why a technological outcome malfunctioned;
- undertake a contemporary evaluation of the fitness for purpose of the technological outcome based on experiences and/or knowledge available now; and
- explain how the risk of a selected technological outcome malfunctioning could be reduced.

Students achieving at level 6 could be expected to:

- discuss how the technological outcome that failed was part of a socio-technological environment and how the interactions between the technological outcome, people, and social and physical environments impacted on the failure;
- describe the socio-technological environment that surrounds the selected technological outcome and identify relationships between other technological product and technological systems; and
- discuss the impacts and implications of the way technological outcomes, people, and social and physical environments interact in a selected socio-technological environment.

Students achieving at level 7 could be expected to:

- explain how decisions about the physical and functional nature of a technological outcome that failed reflects the prioritization of certain design elements over others;
- discuss how the failure of the technological outcome impacted on subsequent decisions for related technological developments and/or operational guidelines;
- analyse the selected technological outcome in terms of how design elements have been prioritised; and
- establish an argument for the retention or redesign of the selected technological outcome.

Students achieving at level 8 could be expected to:

- critique the development of a technological outcome that failed in terms of decisions made about its fitness for purpose prior to and post its failure in situ and discuss how consideration of broader issues may have influenced the decision making; and
- provide a feasibility study for the future development of a selected technological outcome that could be improved to increase its fitness for purpose in the broadest sense; the argument should reflect a sound understanding of historical, cultural, social, and geographical influences and impacts.