'Standards' on the bench
Do standards for technological literacy render an adequate image of technology?

Ghaemi Nia, M.M.; de Vries, Marc J.

DOI
10.3926/jotse.207

Publication date
2016

Document Version
Final published version

Published in
Journal of Technology and Science Education

Journal of Technology and Science Education

'STANDARDS' ON THE BENCH: DO STANDARDS FOR TECHNOLOGICAL LITERACY RENDER AN ADEQUATE IMAGE OF TECHNOLOGY?

Mahdi G. Nia, Marc J. de Vries

Delft University of Technology

The Netherlands

m.m.ghaeminia@tudelft.nl, m.j.devries@tudelft.nl

Received November 2015

Accepted January 2016

Abstract

The technological literacy of students has recently become one of the primary goals of education in countries such as the USA, England, New Zealand, Australia, and so forth. However the question here is whether these educations – their long-term policy documents as well as the standards they provide in particular – address sufficient learning about the nature of technology. This seems to be an important concern that through taking advantage of the philosophy of technology (the arena which affords a bountiful ground of various reflections on the nature of technology) is intended to be discussed throughout this study. In the first place, the paper presents a relevant framework based upon Mitcham's (1994) four-aspect account of technology, i.e., technology as objects, knowledge, activities, and volition. Then it categorizes the main relevant concepts and concerns put forward by many other philosophers of technology into this framework; this will yield a concrete model (tool) to analyze any intended standard such as the above mentioned ones. Afterwards, to show how this model works, the well-known case of the USA – Standards for Technological Literacy (ITEA, 2007) – will be used as an example for inspection; the results will disclose the points where the current American case needs to be modified.

Keywords – Technological literacy, Standards for technological literacy, Philosophy of technology, The nature of technology, Concepts of technology.

----

1 INTRODUCTION

It is not so long ago that the issue of *technological literacy* was given a substantial place in education; various researchers all over the world have taken it into serious consideration and, consequently, numerous attempts have been initiated to design the educational contents of teaching about technology over the previous 30 years (see, e.g., International Technology Education Series, 2011-2015; De Vries, 1997, 2005a; Rossouw, Hacker & De Vries, 2010; Dakers, 2005; Head & Dakers, 2005, and also the 'Standards' or 'long-term policy documents' such as Australian Education Council, 1994; Department of Education of South Africa, 2002; ITEA, 2007; Ministry of Education of New Zealand, 2007).

Even so, do these educational contents– specifically their resulting technological literacy Standards– render a comprehensive image of the *nature of technology* to students, who are expected to have more sophisticated interactions with it now and in the future? The answer can hardly be positive! For one thing, the concept of 'modelling' – as an essential part of most engineering activities – is claimed by the scholars such as De Vries (2013) that, as discussed later on, does not receive a desirable attention throughout the current Standards; this can be thought of only as one instance among others. Such a fact motivates us to seek a way to analyze these Standards, or other same types of long-term policy documents, to see the state of other relevant concepts

On-line ISSN 2013-6374 – Print-ISSN 2014-5349 DL: B-2000-2012 – http://dx.doi.org/10.3926/jotse.207

within them as well and, even beyond that, to realize that to what extent these documents deliver an adequate understanding about the nature of technology. This endeavour will actually attempt to enhance the overall approach of such documents towards various and notable aspects of technology, as the current Standards are in general praiseworthy guidelines for organizing the relevant (and lower-level practical) curricula of technology education; they are not and should not be expected to be, themselves, detailed curricula bounded to strict rules or materials of teaching about technology.

Before moving any further, it is worthwhile also to make the approach of this inspection even clearer by giving emphasis to a fact, that is, the concept of 'technological literacy' is a broad view embracing more than just the 'image of' or 'understanding about' the nature of technology touched upon in this paper; it indeed includes the other aspects of technology as well, such as 'ways of thinking and acting' and 'capabilities' in relation to technology (National Academy of Engineering, National Research Council, Pearson & Young, 2002) which have not been addressed by this paper; they can be considered separately.

That said, in order to get a wiser view on how to deal with this concern, we would firstly like to have a chronological flashback to approximately the 1980s when an international movement was initiated in the area of learning about technology: the mission of this movement was actually to underpin a new path shifting such learning, from its customary *craft-oriented* attitude, to a broader approach which would consider 'technological literacy' as the essential basis in this regard (De Vries, 2013).

This movement was in fact a significant next step in the field of technology-oriented reflections, which occurred less than a half century after the advent of its predecessor, i.e., philosophical attempts to deliberate on the nature and various aspects of technology (Dakers, 2005; De Vries, 2000, 2006). Stated more clearly, the philosophy of technology in this point has initiated valuable resources for providing a conceptual basis for technological literacy reflections.

The primary approach of this movement by the late 1990s was mostly towards establishing an extensive discipline for technology education – that which eventually induced very beneficial contents, subjects, and even further philosophical reflections in this regard around topics such as the following:

- The necessity for technology education
- Conceptualization of technology education literature
- Transition from craft- and skills-oriented school approaches to the new one of a broader perspective on technology
- The significance of revising education curricula
- The importance of realizing science and technology as somewhat dissimilar disciplines
- Examining different actual and/or possible interactions between science and technology
- Normativity of technology education
- Necessary skills for technology teachers
- New approaches toward technological artefacts and systems studies
- Investigating technological designing processes and their various aspects

However, these attempts gradually gave rise to a more specific step, as well, concerned with the literacy of students in this respect and, from this point on, the mission of underpinning a sound discipline in technology education for students was taken into consideration (Jones, Buntting & De Vries, 2013).

Performing such a mission in a suitable manner is no doubt a process which can be, and obviously should be, improved through continuous evaluation – to assess, as far as it relates to our study, the appropriateness of the image of and understanding about the nature of technology that is rendered by these educational curricula and Standards. Nevertheless, such an evaluation has not yet been implemented, and there exist some critical questions in this regard put forward by different scholars. Jones et al. (2013), for instance, enquire as to the main characteristics that constitute the nature of technology and the very concepts that should be, but are still not properly, taught and learnt in this respect; the researchers indeed put stress on the insufficiency of appropriate academic investigation into the manner that meets the needs of educational systems from this perspective.

It seems to us that these (types of) concerns could be tackled through taking advantage of the philosophy of technology; the discipline which, as will be discussed further on in this paper, can once again provide a conceptual contribution as to the nature and various properties of 'technology' and what students are supposed to learn in this regard, from different points of view. This is the very mission undertaken by this study: comparing that articulated by the philosophers of technology with that proposed by an extensively-documented educational standard of the USA, i.e. *Standards for Technological literacy: content for the study of technology* (ITEA, 2007), as an exemplar long-term policy document of technological literacy. This yields a fruitful method to evaluate, in the same way, the adequacy of the Standards designed for teaching about technology and to propose the modifications needed to be considered in this regard.

This paper proceeds as indicated below and begins with an essential explanation of' why and how' this contribution has approached the philosophy of technology; this will end with a model categorizing most of the relevant concepts, proposed within the philosophical reflections on technology, to be used in technology education materials and standards (Section 2). Afterwards, in order to show how this developed model work, it will be thoroughly applied to the above-mentioned American case; this will yield an insight regarding the efficiency of that case, at least from our philosophy-flavoured perspective (Section 3). Finally, the last two sections draw the main points together and provide a conclusion to discuss, and open up some innovative approaches for further studies (Sections 4 and 5).

2 PHILOSOPHY OF TECHNOLOGY; WHY AND HOW?

Philosophy of technology as an antecedent field of technological reflections, as mentioned earlier, can afford a fertile ground of perspectives, content, and analyses to enrich and strengthen the tree of technological literacy studies. This is not a new claim at all, and one can easily find some supportive ideas in this relation in these earlier studies, such as the following:

- Seeking an effective way of shaping concepts of technology for students, De Vries and Tamir (1997) state that, philosophy of technology is a discipline that has much to offer for technology education. Insights into the real nature of technology and its relationship with science and society can help technology educators build a subject that helps pupils get a good concept of technology and to learn to understand and use concepts in technology' (p. 3).
- Delving into the different aspects of teaching about technology, De Vries (2005b) speaks of two important issues to be taken seriously into account: (1) what is a correct concept of technology, and (2) what educational settings need to be created in order to shift – and in point of fact, improve – pupils' actual concept of technology towards a correct concept in the experts' viewpoint. Nonetheless, contrary to many other school subjects,' he continues, 'there is [yet] no clear academic equivalent of technology education, from which a good conceptual basis can be derived …' (p. 149); he believes that the philosophy of technology can afford such an appropriate basis.
- The philosophy of technology in the view of Jones et al. (2013) contains' a rich source of inspiration that can be used to guide the development of technology education' (p. 194).

These are only some ideas among others that, although they speak of the significant potential of philosophical reflections to yield a more concrete conceptualization of what is needed to be learned about technology, have not yet led to a well-articulated scheme in this regard; this both inspires us and rationalizes our approach to strive to develop such a practical method.

However, prior to moving any further, it is worthwhile and essential to mention that our attempt has been initiated based on a satisfying account of *technological literacy*, in the first place; though one has difficulty finding a well-articulated definition for this concept, this mainly has to do with being more acquainted with the intrinsic nature of technology and its interrelationship with different individual and social aspects of human life (see, e.g., ITEA, 2007; and Jones et al., 2013). Consequently, this account will deal with a broad area of concepts and concerns that need to be taken into contemplation for teaching about technology.

The first step of this study was dedicated to compiling a list of such concepts and concerns. In order to do so, we conducted a survey into the former relevant research, and the article of Rossouw et al. (2010) seemed an insightful work in this step; benefiting from the ideas of various experts with philosophical, historical (together with educational) perspectives to technology, this study had composed an innovative list of concepts and contexts necessary for education regarding the nature of technology, as a contribution to the aims of technological literacy. Yet, though a valuable contribution, there were two problematic issues in that method:

- the provided list had originated from an *experimental*, not a philosophical, analysis, and therefore it could not be guaranteed to be comprehensive, and consequently,

- it was difficult to ascertain any categorization or classification related to the nature of technology, as addressed by the philosophers, within it.

Thus, this list needed in our opinion to be completed and somehow changed so that it more effectively serves our goal.

Afterwards, the next step was devoted to conducting an extensive review of certain well-known books or references regarding the philosophy of technology, principal among which were:

- Thinking through technology (Mitcham, 1994)
- Readings in the philosophy of technology (Kaplan, 2004)
- Philosophy of technology: An Introduction (Dusek, 2006)
- A companion to the philosophy of technology (Olsen, Pedersen & Hendricks, 2009)
- New waves in philosophy of technology (Olsen, Selinger & Riis, 2009)
- Philosophy of technology and engineering sciences (Meijers, 2009)
- A philosophy of technology (Vermaas, Kroes, Van De Poel, Franssen & Houkes, 2011)

This provided us with a more extensive list of relevant concepts that received the attention of philosophers of technology. However, we still needed an appropriate tool to be able to efficiently categorize this lengthy list. Then, as a complementary stage, we followed in accordance with Mitcham's theory (1994), previously recommended by scholars such as De Vries (1997) and Frederik, Sonneveld and De Vries (2011) to be considered in technology education. This theory was even resorted to, though only to a small extent, in the same way earlier by Compton (2007), as a philosophy-based criterion to assess and ensure the approach of The New Zealand Curriculum to teaching about technology. That is not to say that Mitcham's theory was the best; rather, it was one adequate method, among other possibilities, which fits our need here to classify the concepts.

Mitcham has distinguished four ways of defining technology: technology as *object, knowledge, activity, and volition*. In a later work, he explicates the background of his theory as:

> *In the most general sense, technology is 'the making and using of artifacts,' but we should look at four deeper aspects of this phenomenon. First, this making and using can be parsed into the objects that we make and use, such as machines and tools. This is 'technology as object.' Second, if we focus on the knowledge and skills involved in this making and using activity, that's 'technology as knowledge.' Third, there is the activity in which technical knowledge produces artifacts and the related action of using them: this constitutes 'technology as action or activity.' Fourth, there is another often overlooked dimension of 'technology as volition' — the will that brings knowledge to bear on the physical world to design products, processes, and systems. This technological will, through its manifestations, influences the shape of culture and prolongs itself at the same time.* (Mitcham, 2001)

Finally, the last step was dedicated to applying Mitcham's theory to the aggregated concepts, which yielded Table 1, i.e., a framework that could be employed as our desired tool to analyze the intended case(s) in a systematic way. It is worth mentioning that Mitcham's own extensive explanation of different sides of technology, in his well-known book of *Thinking through Technology* (1994), has been predominantly used here in developing Table 1 (see, for more detail, pp. 161-191 for 'technology as object'; pp. 192-208, for 'technology as knowledge'; pp. 209-246, for 'technology as activity', and pp. 247-266, for 'technology as volition').

Aspects of technology			
Technology as object	*Technology as knowledge*	*Technology as activity*	*Technology as volition*
• Artefacts (as objects) *•Systems* *•A (specific) Design*	*• Representation of knowledge & skills* *•Normativity* *•Interrelation of science & technology* *•'Know-that' & 'know-how'* *•Creativity*	*•Designing* *•Evaluation* *•Modelling* *•Innovation* *•Invention* *•Needs, wants & demands* *•Use plan*	*•Artefacts (as volition)* *•Value-sensitive design* *•Ethics, values, & moralities* *•Aesthetics* *•Social construction of technology* *•Sociotechnical systems* *•Different contexts of technology* *•Technology & metaphysics* *•Technology & politics* *•Technology & society* *•Technology & culture* *•Technology & economy* *•Technology & environment* *•Technology, future, & humanity*

Table 1. The Main Framework of the Paper: concepts of technology from different aspectual perspectives

That said, it is also worthwhile to emphasize here that this framework is not claimed at all to be a perfect one; rather, it can be seen as an initial version that can be improved, specifically in terms of its entailed concepts, in later works. Bearing this in mind, let us move to the next section to demonstrate the manner in which it works and how it enables us to realize the extent to which the intended 'Standards' – here, that of the USA – satisfy our approach to learning about technology's nature.

3 CASE STUDY: THE USA'S STANDARDS FOR TECHNOLOGICAL LITERACY

Among the existing Standards of technological literacy in the education systems of certain countries, the American case of *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2007) can be regarded as the most extensive and elaborated document, serving as a vision as to 'what students should know and be able to do in order to be technologically literate' (p. vii.).

This document (referred to henceforth as STL) has been sensibly organized to bridge the gap between students' life- and work-styles that are ever-increasingly dependent on technology and their understanding in this regard. By focusing on training K-12 students, STL has identified 20 principal standards necessary for them to learn about appropriately (Table 2); each standard in itself also entails certain benchmarks that present more practical and expounded instructtions (ITEA, 2007, p.15).

Another structural characteristic of STL is its specific classification of students: they are trained according to their grade level regarding their diverse but related contingent needs, interests, and abilities whether physical or mental. In this respect, it suggests a form of grade-based categorization that begins with K-2 and continues through 3-5, 6-8, and 9-12, each accompanied by some further sub-categorizations (for more detail, see ITEA, 2007, p. 14).

All this encouraged us to investigate such a structured long-term policy document to see to what extent it addresses our philosophical account regarding the concepts and concerns required to be learned about the nature of technology. Nevertheless, this was not as easy as it initially appeared because STL is actually not a curriculum directly related to the contents of educational materials nor is it detailed. Rather, being a very extensive *attainment target*, it entails a set of Standards for teachers in order to develop their relevant desired curricula, and this raised the challenging necessity of attempting to derive a distinct interpretation of the actual intention of some of its standards or benchmarks in terms of the concepts needed to be educated. For one thing, our results from the first inspection of STL were amazingly not entirely the same as those of the second, and this persuaded us to try again, this time bearing in mind these inconsistencies, to get to a more reliable result, as spelled out in Table 3.

3.1 An Overall Review of STL

As indicated in Tables 2 and 3, the standards have been categorized in a specific form, comprising five chapters –say five *angles of view to technology*– namely, *the nature of technology*, *technology and society*, *design*, *abilities for a technological world*, and the *designed world* (those which should be taught about, according to the aforementioned grade-based classification of students).

Chapters	***Standards***
3- Students will develop an understanding of The Nature of Technology. This includes acquiring knowledge of:	*1: The characteristics and scope of technology.*
	2: The core concepts of technology.
	3: The relationships among technologies and the connections between technology and other fields.
4- Students will develop an understanding of Technology and Society. This includes learning about:	*4: The cultural, social, economic, and political effects of technology.*
	5: The effects of technology on the environment.
	6: The role of society in the development and use of technology.
	7: The influence of technology on history.
5- Students will develop an understanding of Design. This includes knowing about:	*8: The attributes of design.*
	9: Engineering design.
	10: The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
6- Students will develop Abilities for a Technological World. This includes becoming able to:	*11: Apply the design process.*
	12:Use and maintain technological products and systems
	13: Assess the impact of products and systems.
7-Students will develop an understanding of The Designed World. This includes selecting and using:	*14: Medical technologies.*
	15: Agricultural and related biotechnologies
	16: Energy and power technologies.
	17: Information and communication technologies.
	18: Transportation technologies.
	19: Manufacturing technologies.
	20: Construction technologies.

Table 2. Listing of Standards for Technological Literacy in STL

This type of categorization, though it might seem acceptable at first sight, is the subject of dispute and, as deliberated upon later on, while taking some of the concepts of Table 1 into proper consideration, it disregards some others or at least does not appropriately touch upon them. This may have roots in the fact that STL is the outcome of usual experience-based educational reflections: which typically, as stated by De Vries (2013), emerge from the customary craft-oriented approaches. The following subsections present a more detailed discussion in this regard.

3.2 'Technology as Object'

Beginning with this aspect, one can easily observe that the notion of *artefact*, as the most immediately apparent side of technology, has been suitably taken into consideration at the very opening of STL, where Standard 1 and its included benchmarks attempt to deliver an appropriate introduction about artefacts and artefactual features and also to enable students – who are typically accustomed to identify only the high-tech artefacts as technological (see De Vries, 2005a, pp. 107-112) – to adjust their conceptual bias toward the actual essence of technical artefacts.

Speaking more philosophically, the concept of the *dual nature* of artefacts too has actually been to some extent considered among the Standards: they consider both the *physical* and *intentional* nature of artefacts, though not using the same terms, respectively through taking both the 'object' and 'volition' sides of them into account (see, e.g., benchmarks 1-3, and 13).

Nevertheless, STL scarcely provides a satisfying explanation as to the concept of 'a *(specific) design*' of artefacts – particularly as to how such 'a design' relates the physical structure of an artefact to its function (or intention). In other words, even though this document attempts to provide some preliminary understanding about 'a design' through standards such as the 12th, such an inspection has not much to do with that of 'the dual nature' perspective – considering the specific design of artefacts as an essential element for the 'physical' and 'intentional' natures to interrelate and interact with each other.

The concept of *systems*, finally, has been properly looked at from different directions, mainly in (1) the 2nd and 3rd standards, where students are supposed to know more about the systemic nature of technology, and (2) the 12th, where they learn to some extent how to use and maintain technological products and systems in more appropriate and accurate ways.

3.3 'Technology as Knowledge'

Let us begin this section firstly by investigating STL's deliberation on different aspects of the *interrelation of Science & Technology*, in terms of characterizing various dimensions of technological knowledge in relation to the scientific dimension, expounding their distinctions, and delineating the interactions between them. These subjects have been fairly well discussed throughout this document; it yields a number of general descriptions of knowledge in science and technology (Standard 3), talks about some relevant historical evidences in this regard (Standard 7), and in the meanwhile even scrutinizes notions such as the knowledge of design (Chapter 5) and *creativity* (Standards 1 and 8) to elucidate the 'non-scientific' side of technological knowledge.

Chapter 3: Nature of Technology	
1: The Characteristics and Scope of Technology	*artefact (as objects) - artefact (as volition) - creativity - invention & innovation - needs & wants - social construction of technology - system*
2: The Core Concepts of Technology	*designing - evaluation - management - modelling - sociotechnical systems - system*
3: Relationships Among Technologies and the Connections Between Technology and Other Fields	*invention & innovation - system - technology & science*
Chapter 4: Technology and Society	
4: The Cultural, Social, Economic, and Political Effects of Technology	*technology & culture - technology & economics - technology & environment - technology & ethics – technology & politics - technology & society*
5: The Effects of Technology on Environment	*designing - invention & innovation - management - modelling - technology & economics - technology & environment*
6: The Role of Society in the Development and Use of Technology	*invention & innovation - needs & wants – social construction of technology*
7: The Influence of Technology on History	*artefacts (as volition) - designing - invention & innovation - social construction of technology - technology & culture - technology & economics - technology & politics - technology & science - technology & society*
Chapter 5: Design	
8: The Attributes of Design	*creativity - designing - evaluation - invention & innovation - modelling - value sensitive design*
9: Engineering Design	*creativity - designing - evaluation - modelling*
10: The Role of Troubleshooting, Research and Development, Invention and Innovation, and Experimentation in Problem Solving	*designing - invention & innovation*
Chapter 6: Abilities for a Technological World	
11: [being able to] Apply Design Process	*designing - evaluation - invention & innovation - modelling - value sensitive design*
12: [being able to] Use and Maintain Technological Products and Systems	*a design - system - use plan*
13: [being able to] Assess the impact of Products and Systems	*artefacts (as volition) - technology Assessment - technology & culture - technology & society - value sensitive design*
Chapter 7: The Designed World	
This chapter mainly focuses on various 'technological contexts'.	

Table 3. The concepts and concerns related to the nature of technology, in STL

Nevertheless, there are still some missing points in this relation that deserve to be taken up more within STL. For instance, the know-how aspect of technological knowledge, as well as the manner in which it proceeds further hand-in-hand with the *know-that* aspect (see, e.g., Vermaas et al., 2011, pp. 63-64), is recommended to be considered far more than the minor reflection seen in its current speculation.

Technological knowledge has other substantial specific characteristics as well that have not been seriously taken into account in STL. This type of knowledge, for instance, may be manifested by different qualities across various artefacts directly *representing the level of their designers and/or engineers' knowledge and skills*, in terms of providing *effective* ways and tools to satisfy the intended functions (see, e.g., Vermaas et al., 2011, Chapter 4).

Normativity is the next considerable feature of technological knowledge that has not been seriously touched upon within STL; only a little implicit attention has been paid to the role of different needs, expectations, ethical views, and the like in this regard. This is while this concept has been reflected upon in many respects by philosophers of technology such as De Vries (2005a), Franssen (2009), and Frederik et al. (2011). They argue about why and how our contextual beliefs, views, goals, and actions are strictly to do with our evaluations and judgments and lead to specific types of technological knowledge and design, the reflections of which can provide significant and practical insights for students about the real character of technological knowledge.

3.4 'Technology as Activity/Process'

This perspective on technology has a very different situation in STL, compared to those of *technology as objects* or as *knowledge*. That is to say, the problem of the case has not to do with covering the related concepts; all of them, as seen later on, have been considered to varying degrees, through this document. Rather, the concern this time is that two prominent concepts among them – namely, *evaluation* and *modelling* – have not been examined in a manner that satisfies our philosophy-originated expectations. Let us present a profounder inspection of the state of all these concepts, in STL.

Beginning with *designing*, encompassing most other notions placed in the technological 'activities' cell (of Table 1), this broad process has expectedly drawn significant attention here: one chapter (Standards 8-10) has entirely focused on various aspects of 'designing' and its sub-notions (this could be also as certained to some extent within Standard 2).

Turning to the concepts of (human) *needs*, *wants* and *demands*– as the main drivers of designing various artefacts – they too have been discussed in the course of standards such as the 1st and the 6th. Meanwhile, the critical role of the different types of invention and innovation in the designing process has been touched upon through the chapters 3 to 6.

However, regarding *evaluation* (or *assessment*), STL mostly determines it as what normally occurs in different steps by diverse 'designers'; they, for instance, perform continuous assessments on their ideas, sketches, models, and prototypes, based on various feedback, in order to meet the desired function and quality: the aspect which has been referred to specifically in Standards 2, 8, 9, and 11. Nevertheless, 'evaluation' has another side as well that have not been extensively addressed in STL, that is, the side of the very aforementioned 'feedbacks' that in fact have root in customers' assessment of artefacts. They do so in order to realize the extent of fitness for what they have paid for with what they actually need, in terms of the (quality of the) function of the intended artefact(s), or to recognize the impact of (a specific) technology on their individual and social life.

As to the notion of *the use* plan, it can be seen to be discussed too, at least as much as is expected of an attainment target, through Standard 12.

Finally, *modelling* can be thought of as the most problematic concept of this subsection and, viewed from the philosophical perspective of this article, it seems that students do not acquire a comprehensive understanding about different dimensions of the nature of modelling, in this way.

All the same, this notion may initially appear to have received suitable attention in STL, through considerations such as follows:

- General discussions regarding models as tools that can be employed in the design processes (Standard 8);
- Modelling for conducting communication, representation, and evaluation about the designed solution(s) (Standards 5, 9, and 11);

- Modelling for testing and receiving feedback in order to complete the final adjustments or improvements (Standards 9 and 11);
- Modelling for prototyping (Standards 8, 9, and 11);
- Modelling as a visual (two- or three-dimensional) tool to benefit the comparison and selection of the best solution(s) (Standard 11);
- Different types of modelling: graphical, mathematical, and physical (Standard 11).

Nevertheless, these do not seem to suffice the needs of students, who must become technologically literate; they need, as stressed by De Vries (2013), to learn more explicitly and more elaborately about the essence of models and the process of modelling–in the sense of what the nature of 'modelling' is, what various functions of 'models' are, how they come into use, etc. Indeed, these are the inquiries addressed in some way or another by the philosophers of technology who have realized more dimensions and categories of models in engineering practices. For instance, Boon and Knuuttila (2009) open up a compact, broad, but classified description for the goal of putting models to use in engineering sciences, that is '… to understand, predict or optimize the behavior of devices or the properties of diverse materials, whether actual or possible' (p. 693); they also emphasize the remarkable distinction between the models developed in 'engineering sciences' and those produced in 'engineering in practice'. Another valuable dimension elaborated on in this paper is the *epistemic aspect* of models: perceived by authors as not only 'representational' but also 'epistemic' tools –partially independent from theory and data– which assist engineers in enhancing their education by constructing and manipulating them and, sometimes, in realizing an unexpected innovative concept or area of research. Furthermore, philosophers such as De Vries (2013) also believe that students, in another aspect, must acquire a proper insight into the diverse typologies that classify models from different perspectives. He suggests a compact instance as to how models could be categorized, and recognized, based on their *types* and *functions*. All these are only some, among many other, philosophical considerations which have led us to realize the considerable gap between what *modelling* actually is –in its nature and practice– and how it has been considered in STL; the latter has only taken up modelling in a very limited manner confined to revealing certain representational functions of models (namely evaluation, test, prototyping, receiving feedback, and so on) accompanied by demonstrating a very simple classification in this regard.

3.5 'Technology as Volition'

This aspect of STL, as seen further on in this paper, has only partly to do with the philosophical considerations about technology; that is to say, while embracing to some extent a number of concepts addressed in Table 1, there are certain others which have not yet been suitably taken into account. In addition, a substantial conflict within STL, too, can be also recognized when examining it in this respect.

To begin with, *artefacts as human volition*, which refers to the social nature of objects (Vermaas et al., 2011, pp. 18-20), has been taken into consideration primarily in Standards 1 and 13. This makes sense because in order to be technologically more literate, in this sense, students should in tandem acquire

- valuable knowledge about the social nature of artefacts (discussed under the subject of 'The Characteristics and Scope of Technology' in Standard 1) as well as
- a proper level of abilities to live in a technological world (considered through the theme of becoming able to 'Assess the Impact of Products and Systems' in Standard 13).

These two sides of reflection are, moreover, in collaboration with inspecting how the design of artefacts (or systems) ties in to various volitional *values of human beings* – touched upon under the term of value sensitive design – which has been considered in Standards 11 and 13.

There are some explicitly society-based aspects of technological volition as well, concerned with the relationship between technology and the various sides of a human being's social life and taken up, in the philosophy of technology, with notions such as *social construction of technology*, *technology and politics*, *technology and economics*, and *technology and culture*; such aspects have been specifically deliberated on within Chapter 4.

Turning to the other concepts, it can be perceived that STL has paid particular attention (Chapter 7, Standards 14 to 20) to developing students' understanding of and helping them to be able to select and use various contexts of technologies including medical, agricultural and related *bio-, energy and power, information and* *communication, transportation, manufacturing, and construction* technologies. As a matter of fact, this long-term policy document seems to provide a plentiful contribution in this sense as well.

Now let us take a look at STL's approach to *ethics*, *values*, and *moralities*, the concepts of which are undoubtedly the most prominent subjects of discussion in the contemporary philosophy of technology. These have been addressed in the 4th chapter; they make students become more literate, in this sense, on different levels of designing, making, and using technical artefacts (or systems), which is well-intentioned in its own right. However, a significant conflict exists, in STL, with the philosophical reflections in this regard that needs to be clarified, as the latter mostly argues against the *neutrality thesis* (which considers technology as a *neutral entity* completely dependent on a human decision to be weighed). Recent philosophers typically believe that (some) technical artefacts or systems do entail certain characteristics which create specific values and impose them on human life; there are some notable reasons resorted to in this regard, such as follows:

- The inherent side-effects, whether intentional or unintentional, of some technologies like harmful chemical plants or electromagnetic devices;
- The inherent value or disvalue put in the specific design and the main goal of using some technologies; speed bumps, for instance, entail the value of increasing people safety;
- The undeniable structure of sociotechnical systems, such as the civil aviation organisms, which cannot be excluded from the active role of its inside (human) actors as essential functioning parts – and not users – of that technological systems.

  (See, for more detail, Vermaas et al., 2011, pp. 16-18)

This value-laden account of (some) technologies, absolutely, contrasts with the perception upon which STL was developed (as clearly asserted from its very beginning):

> *Students should come to see each technology neither good nor bad in itself, but one whose costs and benefits should be weighed to decide if it is worth developing* (pp. 5).

This perspective is also emphasized by Standard 4 where this benchmark appears:

> *Technology, by itself, is neither good nor bad, but decisions about the use of products and systems can result in desirable or undesirable consequences* (pp. 60).

This problem is not at all a slight or negligible one, and it indeed deals with students' foundational account of technology. Therefore, such a perspective is better to be amended according to the non-*neutrality* insight into technology; otherwise, students will most likely encounter genuine conflicts between what they learn, in this sense, and what they will later experience in practice.

There are also some concepts – such as *aesthetics*– supposed to be taken into more consideration in this document. It has indeed been argued by philosophers like De Vries (2005a) that the 'aesthetical' aspect of technology needs to be seriously considered within the plans of teaching about technology; as the aesthetical values play prominent roles particularly in two important engineering fields: *architecture* and *industrial design*, that have coupled technology and art.

Last but not least, it appears as though STL has approached technology from the 'now' perspective through which students learn how to live better lives in their current customary sociotechnical world. However, it is difficult to find, for example, a significant benchmark discussing or tracing how different views on *metaphysics* have led (the 'past' outlook), do lead, or may lead (the 'future' outlook) to various types of interactions with technology and different lifestyles. The history of human life is full of substantial and attractive instances capable of guiding the minds of students to an improved understanding of technological evolutions and their relationship with various world views. It would then be interesting for them to know, for example:

- How specific beliefs of the ancient Egyptians led to the design and construction of the Pyramids;
- How Persians' perception of God influenced their particular architecture mainly rooted in the Safavid era;
- Why the modern account of science and technology has underpinned a new path of technological development such as inventing the steam-engine motor, and the like, particularly in the West, and how it has led to post-modern technologies which are extensively based on IT and virtual space.

In this sense, students are really supposed to think more about the 'future'– in terms of tracking the current pathway of technology advancements and thinking of the future possible characteristics of technology and, consequently, the human life- and work-style, as well as contemplating which contexts of technology tend to gain a more impactful role and which will gradually diminish or be replaced by other fields of technological breakthroughs. They will learn much better in this manner how to enhance their abilities and knowledge in order to undertake more effective roles in shaping their own desirable future.

4 CONCLUSIONS

Summarizing the above mentioned points can afford an overall picture as to how this paper has taken advantage of the philosophy to contribute to improving the current Standards of technology education.

Through articulating the relevant concepts in an innovative way based upon Mitcham's characterization of various aspects of technology, this study could come up with a reasonable method to be used to address the proposed research question, which is concerned with delivering sufficient knowledge about the nature of technology to students. Then, applying the developed framework to STL, as an exemplar case, revealed that this long-term policy document, though a very useful contribution of certain strong points, could still undergo a number of modifications in order to yield a more comprehensive insight into the nature and various properties of technology, the claim which can be briefly recapitulated as Table 4 and briefly outlined as follows:

- The particular attention of this Standard to 'the nature of technology' and 'design', respectively through the two distinct chapters of 3 and 5,affords a suitable account of technology as both 'object' and 'activity'; nevertheless, it still needs to pay more profound attention to 'the specific design' of artefacts, as what interrelates their physical and intentional natures, which has been scarcely discussed in an explicit way, as well as to the essence of 'modelling' and 'evaluation' which, though touched upon more or less, have not been talked over, at least, as compared to that described by philosophers of technology.

Aspect of Technology	***Concept***	***State of consideration****		
		Adequately considered	***Moderately considered***	***Scarcely considered***
Technology as object	*Artefacts (as objects)*	√		
	Systems	√		
	Specific design			√
Technology as knowledge	*Representation of knowledge and skills*			√
	Normativity (of technological knowledge)			√
	Interrelation of science & technology	√		
	'Know-that' and 'know-how'			√
	Creativity	√		
Technology as activity/process	*Designing*	√		
	Evaluation		√	
	Modelling		√	
	Innovation	√		
	Invention	√		
	Needs, wants and demands	√		
	Use plan	√		
Technology as volition	*Artefacts (as volition)*	√		
	Value sensitive design	√		
	Ethics, values and moralities		√	
	Aesthetics			√
	Social construction of technology	√		
	Sociotechnical systems	√		
	Different contexts of technology	√		
	Technology and metaphysics			√
	Technology and the future			√
	Technology and politics, society, culture, economy, and/or environment	√		

****According to the deliberated state of each concept, in Section 5, three levels of considering them have been defined in this table: those which have been adequately considered and seem sufficient; those which have been moderately considered, in that they have been touched upon but not as much as needed, or even in a misleading way, comparing to the literature of the philosophy of technology; and those which have been barely considered, that is, the concepts missing or, at least, not clearly discussed in explicit terms.*

Table 4. A brief sketch of the significant technological concepts' state of consideration in STL

- As to the 'knowledge' aspect of technology, there are certain essential concepts that it is hard to find any clear discussion of throughout STL, and it is therefore suggested that they are incorporated into upcoming revisions; students are proposed to become more acquainted with 'the normative nature' of technological knowledge and also distinguish its 'know-how' aspect from the 'know-that'; they also need to be capable of realizing how technological phenomena indicate diverse types and levels of knowledge and skills that support them.
- Chapter 4 associates the societal dimension of technology, which is later accompanied by an extensive discussion of its various contexts in Chapter 7; together these provide a satisfying deliberation of technology's 'volitional' aspect for students. Yet certain subjects seem missing, namely, those which relate the notions of 'aesthetics', 'metaphysics', and 'the future of human beings' to the essence of technology. Moreover, as far as the subjects of ethics, values and moralities are concerned, STL's 'neutral' view toward technology is highly recommended to be revised and replaced by the 'non-neutral' perspective.

We would like to end the paper with some suggestions for further studies; since its initiated approach has been based upon a concrete ground of philosophical reflections on technology, it can be therefore applied to evaluate other Standards and even other types of curricula or materials of technological literacy as well. For one thing, the New Zealand Curriculum (Ministry of Education of New Zealand, 2007) and its Technology Curriculum Support (Ministry of Education of New Zealand, 2010) have claimed to pursue Mitcham's account of different aspects of technology; this claim can be examined using this method. Alternatively, one can analyze to what extent the craft-based and design-oriented approach of England's long-term policy document, i.e. National curriculum in England: design and technology programmes of study (Department of Education of the UK, 2013), delivers a comprehensive understanding of technology in practice. Also, such an investigation can be accordingly extended to even analysing and modifying the relevant schoolbooks, where the above-mentioned general instructions have been given more deliberation.

REFERENCES

Australian Education Council (1994). *A statement on technology for Australian schools, a joint project of the states, territories and the commonwealth of Australia initiated by the Australian Education Council*. Victoria: Curriculum Corporation.

Boon, M., & Knuuttila, T. (2009). *Models as epistemic tools in engineering sciences. Philosophy of technology and engineering sciences* (pp. 693-726). Oxford: Elsevier B.V. http://dx.doi.org/10.1016/B978-0-444-51667-1.50030-6

Compton, V. (2007). The role of technology education in supporting a democratic literacy. *In Keynote presentation published in conference proceedings of Technology Education New Zealand, 6th biennial conference* (pp. 8-14). Auckland, New Zealand: TENZ.

Dakers, J. (2005). Technology education as solo activity or socially constructed learning. *International Journal of Technology and Design Education*, 15, 73-89. http://dx.doi.org/10.1007/s10798-004-6196-1

De Vries, M.J. (1997). Science, technology and society: A methodological perspective. *International Journal of Technology and Design Education*, 7, 21-32. http://dx.doi.org/10.1023/A:1008821322208

De Vries, M.J. (2000). Technology education: Towards a new school subject. In B. Moon, S. Brown, & M. Ben-Peretz (Eds.), *The Routledge international companion to education* (pp. 910-920). London: Routledge.

De Vries, M.J. (2005a). *Teaching about technology: An introduction to the philosophy of technology for non-philosophers*. Dordrecht: Springer.

De Vries, M.J. (2005b). The nature of technological knowledge: Philosophical reflections and educational consequences. *International Journal of Technology and Design Education*, 15, 149-154. http://dx.doi.org/10.1007/s10798-005-8276-2

De Vries, M.J. (2006). Two decades of technology education in retrospect. In M.J. De Vries, & I. Mottier (Eds.), *International handbook of technology education. Reviewing the past twenty years* (pp. 3-10). Rotterdam: Sense Publishers.

De Vries, M.J. (2013). Modeling in technology and engineering education. In P.J. Williams, & D. Gedera (Eds.), Technology education for the future: A play on sustainability. *Proceedings of the PATT27 conference* (pp 122-127). Hamilton: Technology Environmental Science and Mathematics Education Research Centre, University of Waikato.

De Vries, M.J. & Tamir, A. (1997). Shaping concepts of technology: What concepts and how to shape them. *International Journal of Technology and Design Education*, 7, 3-10. http://dx.doi.org/10.1023/A:1008869205370

Department of Education of South Africa. (2002). *Revised national curriculum statement grades R-9 (schools); technology*. Pretoria, South Africa.

Department of Education of the UK (2013). *National curriculum in England: Design and technology programmes of study Design and technology*. Available online at: https://www.gov.uk/government/publications/national-curriculum-in-england-design-and-technology-programmes-of-study

Dusek, V. (2006). *Philosophy of technology: An introduction*. MA: Blackwell Publishing Ltd.

Franssen, M. (2009). *Artifacts and normativity. Philosophy of technology and engineering sciences* (pp. 923-952). Amsterdam: Elsevier B.V. http://dx.doi.org/10.1016/B978-0-444-51667-1.50038-0

Frederik, I., Sonneveld, W., & De Vries, M.J. (2011). Teaching and learning the nature of technical artifacts. *International Journal of Technology and Design Education*, 21, 277-290. http://dx.doi.org/10.1007/s10798-010-9119-3

Head, G. & Dakers, J. (2005). Vérillon's trio and Wenger's community: Learning in technology education. *International Journal of Technology and Design Education*, 15, 33-46. http://dx.doi.org/10.1007/s10798-004-6194-3

ITEA (2007). *Standards for technological literacy: Contents for the study of technology*. Reston, USA.

Jones, A., Buntting, C., & De Vries, M.J. (2013). The developing field of technology education: A review to look forward. *International Journal of Technology and Design Education*, 23, 191-212. http://dx.doi.org/10.1007/s10798-011-9174-4

Kaplan, D.M. (2004). *Readings in the philosophy of technology*. Lanham: Rowman& Littlefield Publishers, Inc.

Meijers, A. (2009). *Philosophy of technology and engineering sciences*. Amsterdam: Elsevier B.V.

Ministry of Education of New Zealand (2007). *The New Zealand curriculum*. Wellington, New Zealand.

Ministry of Education of New Zealand (2010). *Technology curriculum support*. Wellington, New Zealand.

Mitcham, C. (1994). *Thinking through technology*. Chicago: The University of Chicago Press.

Mitcham, C. (2001). *Philosophizing about technology: Why should we bother?*. Available online at: http://ethix.org/2001/06/01/philosophizing-about-technology-why-should-we-bother

National Academy of Engineering, National Research Council, Pearson, G., & Young, A. (2002). *Technically speaking: Why all Americans need to know more about technology*. Washington, D.C.: National Academy Press.

Olsen, J.K.B., Pedersen, S.A., & Hendricks, V.F. (2009). *A companion to the philosophy of technology*. Chichester: Blackwell Publishing Ltd. http://dx.doi.org/10.1002/9781444310795

Olsen, J.K.B, Selinger, E., & Riis, S. (2009). *New waves in philosophy of technology*. Basingstoke: Macmillan Publishers Ltd.

Rossouw, A., Hacker, M., & De Vries, M.J. (2010). Concepts and contexts in engineering and technology education: An international and interdisciplinary Delphi study. *International Journal of Technology and Design Education*, 21, 409-424. http://dx.doi.org/10.1007/s10798-010-9129-1

Vermaas, P., Kroes, P., Van De Poel, I., Franssen, M., & Houkes, W. (2011). *A philosophy of technology*. Milton Keynes: Morgan & Claypool Publishers.

Citation: Nia, M.G., & de Vries, M.J. (2016). 'Standards' on the bench: Do standards for technological literacy render an adequate image of technology?. *Journal of Technology and Science Education (JOTSE), 6(1), 5-18.* http://dx.doi.org/10.3926/jotse.207

On-line ISSN: 2013-6374 – Print ISSN: 2014-5349 – DL: B-2000-2012

AUTHOR BIOGRAPHY

Mahdi G. Nia

Mahdi G. Nia is a PhD researcher of Technology Education for Engineers at Delft University of Technology, the Netherlands. His background is in Electrical Engineering (BSc.) and MBA in Strategic Planning. He is interested in the subject of what future engineers need to learn about technology, and he has attempted to reflect on this subject from various perspectives, in the course of his PhD research. He is also a member of Iran Society of Engineering Education, a prominent institution underpinned by some well-known faculty members with the mission of developing the quality of engineering education in that country.

Marc J. de Vries

Dr. Marc J. de Vries is an affiliate professor of Christian Philosophy (of technology) at Delft University of Technology, the Netherlands. He also has a chair in Science Education at the same institute. At Eindhoven University of Technology, the Netherlands, he serves as an assistant professor in philosophy of science and technology. His background is in physics (MSc). He is the editor-in-chief of the International Journal of Technology and Design Education, published an introductory book on the philosophy of technology for educators ("Teaching About Technology"), wrote a monograph on the history of the Philips Research organization and is a member of the editorial board of the Philosophia Reformata international journal. He co-authored the book The Matrix Code, on science fiction movies and Christian philosophy.

Published by OmniaScience (www.omniascience.com)

Journal of Technology and Science Education, 2016 (www.jotse.org)