

# Structured Inquiry and Standardization

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**Abstract**—This paper focuses on management of technology education and research and specifically on standardization education. The paper argues for an interrelation between education and research. An illustrative case study is conducted of standardization education at Delft University of Technology. This case shows how different methods of education can eventually result in publishable research and how this research can subsequently be used as input for education. The paper concludes by discussing the advantages of adhering to the interrelation between education and research.

**Index Terms**—Standardization education, standardization research, inquiry-based learning, structured inquiry.

## I. INTRODUCTION

Academic teachers often use their research in the courses they offer. For example, teachers use prior publications such as journal papers or textbooks as course material. In this paper, this type of education is defined as ‘research-based education’; education that applies research. It is argued that research-based education can be structured so that it can result in new research. Ideally, this new research can subsequently be used as teaching material for future courses. The central question in this paper is: How can research-based education be developed in such a way that it will result in new knowledge that can be used for both research and education purposes?

The focus of this paper is on standardization education. Over the last decade, standardization education programs have increased considerably worldwide. This is evident by the many programs and courses that have been developed at all levels of education [1], especially in countries such as Japan South Korea, China and Indonesia [2]-[4]. In Europe, many universities address standardization as a research topic and teach it in their curricula, for example, in the Netherlands, France, and Germany [5]. The topic is also taught in the U.S., albeit to a limited degree[2], [6].

TABLE I: SIX CONTENT MODULES IN GENERIC STANDARDIZATION EDUCATION (ADOPTED FROM [1])

Module	Description
Module 1	Examples in everyday life
Module 2	Factual/fundamental contents
Module 3	Academic/theoretical aspects
Module 4	Case studies
Module 5	Skill-set related contents
Module 6	(How to use) specific standards

The remainder of this paper is structured as follows. First, we conduct a case study of two courses that address standardization which are offered at Delft University of Technology (TU Delft). The case study is used to ‘illustrate’ a topic ‘in a descriptive mode’ [7]. We provide information about course objectives, format, organization, and grading, and we analyse to what extent each course covers the generic modules of standardization education [1] (see Table I). Student evaluations are provided where possible. Next, using the insights from the case study, we discuss various methods in which research-based education on standardization can result in both new knowledge and input for education. We conclude by examining the advantages of these methods for students and teachers.

## II. TWO COURSES AT DELFT UNIVERSITY OF TECHNOLOGY THAT ADDRESS STANDARDIZATION

At Delft, education about standardization focuses on compatibility standards and particularly on factors for winning standards battles. The M.Sc. program of Management of Technology offers a general (award winning) ‘Technology and Strategy’ course in its first year and a ‘Standards Battles, Technology Patterns and Business Ecosystems’ course in its more specialized second year. The specific course builds upon and extends the knowledge taught in the general course. An important part of the ‘Technology and Strategy’ course focuses on identifying the reasons why certain industries adopt a dominant standard and why a particular firm’s technology is adopted as the dominant standard. Students examine the factors that affect the outcome of standards battles. The more specialized course focuses on standards battles, technology patterns and business ecosystems. Students study how the network of stakeholders supporting the competing standards changes during the technology life cycle and how this impacts dominance of the competing standards. Table II provides an overview of the basic characteristics of each course.

TABLE II: GENERAL CHARACTERISTICS OF THE COURSES

Module	‘Technology and Strategy’	‘Standards Battles, Technology Patterns and Business Ecosystems’
Level	M.Sc.	M.Sc.
Stage	1 <sup>st</sup> year	2 <sup>nd</sup> year
Study load	6 ECTS	6 ECTS
# students	75	10-20
Language	English	English

The aim of these two courses is to help students, as engineers, become savvier players and to prepare them for a successful business career in the area of standardization. Students can become standardization strategists in large companies such as Philips or they can apply their knowledge

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at consulting agencies or standard development organizations.

A. The ‘Technology and Strategy’ Course

The primary course objective related to the standardization part of the ‘Technology and Strategy’ course is to familiarize students with the key factors affecting standard dominance.

The course comprises six regular sessions, six teaching case sessions and one game session. Each regular session consists of interactive lectures. Students prepare for the lectures by studying the literature. In the teaching case sessions, students analyze and discuss specific cases that are linked to topics studied in the regular sessions. Examples of teaching cases include the battle between Blu-ray and HD-DVD and the battles fought in different generations of the gaming console industry. By analyzing and discussing these battles, students apply the theory learnt during the regular sessions to various practical situations.

Students are given assignments to prepare for the teaching cases and work in discussant groups. These prepare several topics for class-wide discussions. In class, the teacher introduces additional information and questions about the case and the sessions are interactional. Through these teaching methods, students further deepen their understanding of the topics and themes presented during the regular sessions. This course covers two elements of the six generic modules presented by Choi and De Vries [1]; module 3 and module 4.

During the game session, the “Back Bay Battery” Strategic Innovation Simulation is used to allow students to apply the theory of technology s-curves for technology improvement and diffusion. After the session, students can use the simulation five more times. Students with the highest ten scores will be awarded an extra point in the final exam. This is an incentive for students to play the game and to apply the theories covered in the course.

We distinguish between two grading components: (1) The unweighted average of the grades for the teaching cases and contribution to class discussions, which accounts for 20% of the final grade, and (2) A closed book exam with open questions, which accounts for 80% of the final grade. Both these grades should be at least 5.75 (sufficient) . Students can only sit the exam if they have achieved a sufficient grade for the teaching cases. The final grade is the weighted average of the grades for the teaching case assignments and the exam.

TABLE III: STUDENT EVALUATIONS FOR THE ‘TECHNOLOGY AND STRATEGY’ COURSE 2011-2012

Criteria	Student evaluation
Usefulness	Good
Connection to prior knowledge	Good
Level	Excellent
Teaching method	Good
Teaching	Good
Study material	Satisfactory/good
Organization	Good
Assessment	Good
General opinion	7+

The course consists of 168 hours. This includes four hours of lectures a week = total 28 hours (1 ECTS), 8 hours a week

for preparing lectures = total 53 hours (2 ECTS), 28 hours for preparing the case studies (1 ECTS), 53 hours preparing for the exam and the simulation game, and three hours for the final exam (2 ECTS)

The ‘Technology and Strategy’ course has good evaluation scores (see Table III). The course also received a teaching award which is based on the student evaluations for the 2010-2011 course. In total 78 students enrolled in the course and 58 took part in the evaluation.

B. The ‘Standards Battles, Technology Patterns and Business Ecosystems’ Course

The main course objective of this course is to understand the theoretical background of standards battles, technology patterns, and business ecosystems and the relations between these topics.

The course comprises six four-hour sessions. Six of these sessions include a mixture of lecturing and discussions. Students prepare for the lectures by studying the literature. Through class discussions, students further deepen their understanding of the topics and themes presented during the lectures. Also, a one-day game session is organized.

The first session is about the essentials of standardization and aims to create general awareness and enthusiasm for the topic of standardization. In the second session, various theoretical and empirical papers relating to the economics of standardization are discussed. A framework of factors of standard dominance is presented which is a result of research carried out by Van de Kaa [8]. To increase understanding of the factors for standard dominance, students apply the framework to various cases of standards battles [9]-[11]. In the third session, students play the simulation game ‘setting standards’ which allows students to take part in a formal standardization process. This course covers five of the six generic modules presented by Choi and De Vries [1]. The first session can best be classified under modules 1 and 2, the second session relates to modules 3 and 4, and the third session to module 5.

The other four sessions cover topics such as the technology life cycle and examine various academic papers that focus on how factors for standard dominance may change in different stages of the technology life cycle [12]. Students study the literature on inter-organizational networks, and analyze the academic literature on the impact of inter-organizational networks on standard dominance [13].

All students must complete an assignment which consists of three parts: (1) Standards battles, (2) Technology patterns, (3) Business ecosystems. In the first part, students analyze a standards battle of choice. They must present a case description consisting of a historical overview of the standards battle, and a case analysis of how and why the (dominant) standard achieved dominance. To make a good case description, students need to closely study the existing literature on the standards battle (some standards battles such as the battle for a VCR standard have been studied numerous times). They then make a list of factors that affect standard dominance using the framework of factors of standard dominance discussed in the second session. They indicate which factors were mentioned in each publication. Sometimes the literature on the standards battle may not

mention all factors found in the literature. This can mean that these factors did not apply to the case or that addition of one or more of these factors could provide a better explanation of the case. Therefore, additional research should show to what extent these factors actually played a role in the battle. Hence, the student conducts a secondary data analysis in the form of reports, practitioners' literature, external databases, etc. and writes a preliminary version of the case description and analysis. At this stage, the student has to carry out additional interviews with practitioners to fully reconstruct the case. A pre-set questionnaire is used when carrying out interviews. The interviews are transcribed and attached as an appendix. Quotes can be used to back up claims made in the report. In the analysis of the standards battle, students are asked to link all of their observations back to the literature (so a particular event that leads to dominance of one particular standard should not just be mentioned but also be explained by making use of the appropriate literature).

In the second part of the assignment (Technology patterns), students should answer the following question: 'What is the pattern of development and diffusion for the product in which the standard is implemented?' First, students should clearly define the product / technology. Second, students should provide a historical overview of the main events in the life cycle of the product. This results in a technology life cycle for the product in which the standard is implemented.

In the final part of the assignment (Business ecosystems), students analyse the inter-organizational network of actors developing and promoting each standard at every stage of the technology life cycle. Finally, students should answer the following question: 'How does the network of stakeholders supporting the competing standards change over time during the technology life cycle and how does this impact the dominance of competing standards?'

Students are asked to be particularly critical towards theory (theory can be right, but may not be applicable to their problem) and towards data (data can be more or less reliable, depending on the source).

Due to the small number of students involved, quantitative evidence of the quality of the course is not available for the 'Standards Battles, Technology Patterns and Business Ecosystems' course.

### III. DISCUSSION

The teaching approach in the 'Standards Battles, Technology Patterns and Business Ecosystems' course, can best be categorized as inquiry-based learning where principles of scientific research are applied in teaching [14]. In the case presented in this paper, students are treated as junior researchers, and they apply the principles of scientific research in education. They collect and synthesize data to deal with a specific problem. More specifically, this paper follows Tamir [15] and uses six stages: defining the problem (who will be the winner in a standards battle?), proposing hypotheses (interorganizational network influences standard dominance), doing the project/experiment, analyzing the data, interpreting the results, and drawing conclusions (the assignment). By following this approach, students learn how to conduct actual scientific research, one of the educational

side goals of this course.

The assignment report follows a pre-defined template set up by the teachers. Thus, a form of structured inquiry [16] is applied where students are given a research question and data collection plan. This makes it possible to analyze and compare the empirical data that students have gathered.

The empirical data gathered by students may be used for research. For example, two students gathered data on the case of HD DVD versus Blu-ray and Windows versus Mac PC operating systems. These data have been used as empirical data in a paper which examines the changes in structure and composition of business networks supporting these standards in the different phases of the technology life cycle. In the paper, it is suggested that strategic decisions of firms were key to winning and losing these battles and should therefore not be overlooked. The paper has been presented at several conferences and has been published as a book chapter. The paper is a typical example of how education about standardization can lead to insights for research on standardization. Furthermore, the paper is currently part of the required reading list of the 'Standards Battles, Technology Patterns and Business Ecosystems' course for the 2012-2013 academic year.

Also, some students have written their master's thesis on the topic of the course, applying the empirical data gathered in the course. To date, three students that completed the 'Standards Battles, Technology Patterns and Business Ecosystems' course have written a master's thesis on standards battles. For example, one student is currently finishing his master's thesis on 'Re-evaluating the VCR Standards Battle'. The classical battle between VHS (as supported by JVC), Betamax (supported by Sony) and V2000 (Philips and others) is a well-documented battle [17]-[24] about the emergence of a dominant standard in the VCR market in the 1970s and 1980s. Although Betamax was widely recognized as superior compared to VHS, the latter standard eventually won the standards battle. In this research project, the objective is to re-evaluate this battle using a framework for standard dominance [8] that is more complete compared to existing frameworks suggested in the literature [12], [25], [26]. The second objective is to test the framework and to examine whether it provides a better 'toolbox' to analyze standards battles than other models / literature. The project started with an extensive literature study to analyze papers that focus on the standards battle, and to investigate whether the factors mentioned in the framework played a role in this battle and if so how they affected the outcome of the battle. Maybe the literature on the VCR battle did not mention all factors found by Van de Kaa et al. [8]. This can mean that these factors did not apply to the case or that the addition of one or more of these factors could provide a better explanation of the case. Therefore, additional research should show to what extent these factors actually played a role in the battle. This has been done by interviewing both academics who studied the case and practitioners who were involved in the case. In interviews with key authors, the factors mentioned in the framework were discussed and it was assessed whether the author came to new insights in the case after applying the model. The research carried out by the student has resulted in several research papers which the

student authors. This student may continue to pursue a PhD.

Other examples include a student that graduated in 2011 and wrote a thesis entitled ‘Interrelation of Factors for Standard Dominance in Standard Battles in the consumer electronics and IT industries’ and another student that graduated in 2011 (grade 8 out of 10 ) wrote a thesis entitled ‘Factors influencing photovoltaic adoption and selection’. This thesis was written in the form of a paper and is currently under preparation for an ISI rated journal.

These examples provide illustrative evidence that research-based education can be developed in such a way that it will result in new knowledge that can successfully be used for research and / or education purposes. This effect mostly occurs in the second year of the master’s program during specialization and master thesis writing, probably because at this stage, students are more motivated as they take elective courses. During the first year of the master’s program, all courses are mandatory.

#### IV. CONCLUSION

The two courses discussed in this paper are distinctive because they apply state of the art research on standardization [8], [27]-[30], and the teaching materials are constantly updated. In other words, the education is very much research driven. Due to a variety of teaching methods such as interactive lectures, teaching cases, and a simulation game, students apply knowledge in different ways, greatly contributing to their understanding of the specifics of standardization.

Also, the education results in novel input for research through empirical material gathered in the courses and in the master theses. Finally, this research is used in subsequent versions of the courses. So, it is shown that inquiry based learning can result in new knowledge that can subsequently be used in later education. In other words, there is a two-way relationship between education on the one hand and research on the other, as illustrated in Fig. 1. Organizing courses according to this principle will increase the academic level of the courses offered as students learn while they perform research.

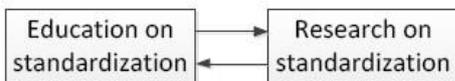


Fig. 1. A two-way relationship between education and research.

Educationalists are recommended to adhere to the two-way relationship between education and research as presented in Fig. 1. There are two advantages. First, students find this type of education more interesting and stimulating as it allows them to apply the teaching material to real life practical situations (see Table IV). Second, teachers can use the research carried out by the students.

TABLE IV: REACTIONS OF FOUR STUDENTS IN THE 2011-2012 EVALUATIONS OF THE ‘TECHNOLOGY AND STRATEGY’ COURSE

Reaction of student
I liked the assignment.
Good relation between theory and practical examples.
The assignment we did was interesting and stimulating.
Thorough analysis, by which you can apply theory in practice.

#### REFERENCES

- [1] D. G. Choi and H. J. De Vries, "Standardization as emerging content in technology education at all levels of education," *International Journal of Technology and Design Education*, vol. 21, pp. 111-135, 2011.
- [2] D. E. Purcell, "Standards education revival in US needed if it is to remain competitive in global markets," *NEMA electroindustry*, vol. 11, pp. 10-11, 2006.
- [3] D. O. R. Komala, "The Mechanism of Developing Standards Education Program in Indonesia," in *Proc. ICES conference 2012*, Bali, Indonesia, 2012.
- [4] S. Mingshun, "The Higher Education of Standardization in China Jiliang University (CJLU)," in *Proc. ICES conference*, Delft, The Netherlands, 2007.
- [5] T. M. Egedi, "The State of Standards Education in Europe," in *Proc. ICES conference*, Tokyo, Japan, 2009.
- [6] D. E. Purcell, "Presentation on United States Academic Standards Education Courses to NIST/ICES International Standards Education Workshop," in *Proc. ICES conference*, Gaithersburg, Maryland USA 2008.
- [7] R. K. Yin, *Case study research, design and methods*, Newbury Park, CA: Sage, 2003.
- [8] G. Van de Kaa, J. Van den Ende, H. J. De Vries, and E. Van Heck, "Factors for winning interface format battles: a review and synthesis of the literature," *Technological Forecasting & Social Change*, vol. 78, pp. 1397-1411, 2011.
- [9] S. R. Gallagher and S. H. Park, "Innovation and competition in standard-based industries: a historical analysis of the U.S. home video game market," *IEEE T. Eng. Manage.*, vol. 49, pp. 67-82, 2002.
- [10] M. A. Schilling, "Technological leapfrogging: lessons from the U.S. video game console industry," *California Management Review*, vol. 45, pp. 6-32, 2003.
- [11] C. Shapiro and H. R. Varian, "The art of standards wars," *California Management Review*, vol. 41, pp. 8-32, 1999.
- [12] F. F. Suarez, "Battles for technological dominance: an integrative framework," *Research Policy*, vol. 33, pp. 271-286, 2004.
- [13] A. E. Leiponen, "Competing through cooperation: the organization of standard setting in wireless telecommunications," *Management Science*, vol. 54, pp. 1904-1919, 2008.
- [14] F. Moti, L. Ilana, and E. David, "Implementing the Project-Based Learning Approach in an Academic Engineering Course," *International Journal of Technology and Design Education*, vol. 13, pp. 273-288, 2003.
- [15] P. Tamir, "Considering the Role of Invitations to Inquiry in Science Teaching and in Teacher Education," *Journal of Science Teacher Education*, vol. 1, pp. 41-45, 1990.
- [16] H. Banchi and R. Bell, "The Many Levels of Inquiry," *Science and Children*, vol. 46, pp. 26-29, 2008.
- [17] M. A. Cusumano, Y. Mylonadis, and R. S. Rosenbloom, "Strategic maneuvering and mass-market dynamics: the triumph of VHS over Beta," *Bus. Hist. Rev.*, vol. 66, pp. 51-94, 1992.
- [18] X. Dai, *Corporate Strategy, Public Policy and New Technologies: Philips and the European Consumer Electronics Industry*, Exeter: BFC Wheatons Ltd, 1996.
- [19] N. Economides, "Network Externalities, Complementarities, and Invitations to Enter," *Eur. J. Pol. Econ.*, vol. 12, pp. 211-233, 1996.
- [20] B. C. Klopfenstein, "Forecasting Consumer Adoption of Information Technology and Services - Lessons from Home Video Forecasting," *J. Am. Soc. Inform. Sci.*, vol. 40, pp. 17-26, 1989.
- [21] John, "Listening to the Voice of the Market," *Int. Market. Rev.*, vol. 11, pp. 47-59, 1994.
- [22] C. A. Bartlett and S. Ghosal, "Organizing for World Wide Effectiveness: the Transnational Solution," *California Management Review*, vol. 31, pp. 54-74, 1988.
- [23] T. Cottrell and G. Sick, "First-Mover (Dis)advantage and Real Options," *J. Appl. Corp. Fin.*, vol. 14, pp. 41-51, 2001.
- [24] H. Ohashi, "Anticipatory effects of voluntary export restraints: a study of home video cassette recorders market," *J. Int. Econ.*, vol. 57, pp. 83-105, 2002.
- [25] J. Lee, D. E. O'Neal, M. W. Pruett, and H. Thoams, "Planning for dominance: a strategic perspective on the emergence of a dominant design," *R&D Manage.*, vol. 25, pp. 3-15, 1995.
- [26] M. A. Schilling, "Technological lockout: an integrative model of the economic and strategic factors driving technology success and failure," *Academy of Management Review*, vol. 23, pp. 267-284, 1998.
- [27] S. R. Gallagher, "The battle of the blue laser DVDs: The significance of corporate strategy in standards battles," *Technovation*, vol. 32, pp. 90-98, 2012.

- [28] M. A. Cusumano, "Technology Strategy and Management: Platform Wars Come to Social Media," *Communications of the ACM*, vol. 54, pp. 31-33, 2011.
- [29] P.-H. Soh, "Network Patterns and Competitive Advantage before the Emergence of a Dominant Design," *Strategic Management Journal*, vol. 31, pp. 438-461, 2010.
- [30] C. C. J. M. Millar, P. H. Millar, and C. J. Choi, "Technology standards and increasing returns: Microsoft versus Nokia and Linux," *Int. J. Technol. Manage.*, vol. 49, pp. 357-369, 2010.

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