The educators’ telescope to the future of technology

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Abstract - e live in a world of accelerating changes, where technology plays an important role as an enabler. oo ing ahead means being prepared for these changes. reparedness may be *reactive* – reacting to the situation at the moment something happens *proactive* – being prepared in advance for a situation that may happen or *preactive* – being able in advance to affect something that may happen in the future and how it happens. *Forecasting* the future helps us to be prepared for new situations. t is based on ma ing predictions that are derived from understanding past and present data. nown data is organi ed in the form of trends and further e trapolated to cover the future. rom the technical point of view, there are a variety of approaches for forecasting algorithmic, simulation, statistical analysis etc. The methods used may be *quantitative* future data is seen as a function of past data or *qualitative* sub ective, based on the opinion or udgment of the target group used in the analysis . Technology is an essential part of education, both in supporting effective learning and as a content of teaching itself. As a result, every educator needs s ills to analy e the future of relevant technologies. n this paper, we introduce a framewor that can be used in analysis of the importance of technological changes in education and as a part of curricula. The approach is based on trend analysis and classification of the relevant technologies to ta e into account the time span of their effects in society. The question we answer in this paper is “How can an educator analyze the consequences of technological changes in their work?”.

I. INTRODUCTION

Technological forecasting deals with the characteristics of technology. It is also used to survive in the future, in the long term and from the strategic point of view (being *preactive*, or at least *proactive*; to recognize the opportunities and risks; to recognize the weaknesses and to be able to benefit from the strengths). The forecasts provide insight into future opportunities and the processes applying them. The methods of technological forecasting are commonly known and available for all that are interested in them. The approaches may be *uantitative* (exact) or *ualitative* (heuristic); the methods cover a wide variety of alternatives representing algorithmic, simulation based, statistical analysis based techniques, or systematic ways to collect data to represent the opinion or judgment of the target group. Making one’s own (usually focused) forecasts is done in a closed manner (by companies, organizations, individuals) but a lot of such knowledge is publicly available from open sources. The latter are in most cases freely available and applicable for different purposes.

Although technological changes seem to be problematic, there is a lot of *regularity* built into the changes. In the short term, changes base on the innovations known today. Even in the middle to long term, the changes base on the expected evolution of the currently known innovations. Forecasts rarely reach further than 15-20 years ahead.

The study methods used in technological forecasting are usually based on known trends of the past and their continuum to the future. The aim of this paper is to provide a framework that helps educators to analyze the technological changes surrounding them and to help them to be prepared in the future changes, in their course contents, curricula structure and relevance, learning methods and the tools used. The framework is based on commonly known models that are integrated to provide several viewpoints to the phenomena related to changes in the technology landscape. The key elements of our framework cover the principles of the *innovation process* and *technology adoption*, the concept of *technology life cycles*, and the importance of the technologies in the society, including the expected *adoption delay* of them.

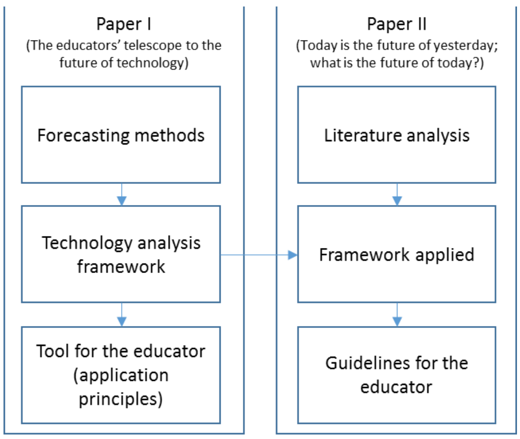

Figure 1. Structure of the problem solving – two interconnected papers

We approach this study topic with two papers (Figure 1). We selected this split approach to separate method development and its application from each other. This approach provides a means for a slightly deeper discussion on the study method than only one paper allows, and more space to the discussion on the technological changes and their importance. In spite of this "paired characteristic", both are also self-standing research papers.

The *research uestion* handled in this paper (Paper 1 in Fig. 1) is " *ow can an educator analy e the conse uences of technological changes in their wor* " To answer this question we will introduce our analysis framework. In Paper II (Fig. 1; [10], the framework is applied for analyzing the changes caused by Information and Communication Technology (ICT) related innovations.

This paper is structured in the following way. Section 2 links the paper to the theoretical foundations of it and in our earlier studies. In Section 3 we discuss the analysis tools on a general level. Sections 4-6 cover the components of our model: importance and effectiveness classification (4), life cycle model (5), and hype cycle (6). Section 7 integrates the model components in the form of the *Technology Change Analysis and Categori ation TCAC* Framework and its application process. Section 8 summarizes the paper.

II. Background of the Study and Related Studies

In this paper we will focus on the *life cycle* of an innovation. In technology research, there is an analogy between life cycle models and the *diffusion models* that describe the adoption of a new technology. [11; 12; 4] Whereas a *life cycle model* focuses on the maturity of a technology, the *diffusion approach* is focused on its adoption among *potential users*. In both cases the distribution curve follows the same *shaped figure*.

The life cycle model analysis presented in this paper has its roots in the early 1990s in [4]. The concept of the " *euristic Diffusion odel*" as a technology analysis method approaches the problems of technological changes from the aspect of *phenomena understanding* rather than exact mathematical modeling. Since that, the authors have published several research papers having different focus in this topic. The recent years, studies have focused on the *analysis of technology driven changes in society and the usiness environment*, the papers related to this work are the basis of the current pair of papers. The first step in this "foundation building" is the paper [5] which introduced the main principles of *trend ased analysis* and *interpretation of the trends*. The paper ends with a discussion covering a wide variety of trend analyses (based on public data sources), without any synthesis.

The focus of the paper [6] was on the use of *pen Data* and the role of *open ecosystems* in the current society. It also handled *open ecosystem related trends*, culminating in the first (very preliminary) version of the Technological TCAC Framework; we call it the " *CT Change Analysis and Categori ation CAC* " framework; Paper II [10]. It applies the theory of *reeman ere* [1] to the findings of ICT related change factors. The same theme was continued in papers [6; 7] focusing on *open data related changes* in society, and further in the paper [8] focusing on *data driven ecosystems*, the role of social networking, security related problems, and scalable business models (*hyperscala ility*). Both of these papers cover new improved versions of the ICAC.

One more version, still based on minor iterative and incremental changes to the earlier version, was published in a conference presentation [9]; the topic was related to the *value of data and its privacy ownership.* An interesting observation arose when preparing the talk – the trend discontinuity of some major trends, i.e. the fact that the importance level of some phenomena may change fast; something that seems to be an important driver of future changes suddenly takes on the role of embedded and indirect technology driver. The crystallized analysis method used in the analysis, TCAC, is introduced in this paper, and its application in ICT related changes, the final ICAC version, is presented in Paper II [10].

Technological forecasting is a topic of long term and wide research interest. It covers both innovation related topic areas and modelling of diffusion. One of the "bibles" related to forecasting methods is the book of J.P. Martino [13]. His work in advances in technological forecasting is available in his paper [14]. In the area of diffusion models and innovation adaption remarkable work is done by Rogers (adoption) and Majahan (adoption of innovations, innovation life cycles) [11; 12]. Because our aim is to introduce our analysis framework, we have excluded wider systematic review of earlier studies. However, most relevant references are listed in the following sections of this paper embedded in each topic context. The topics cover classification of the importance of innovations [1], trends, diffusion and adoption [11; 12; 4; 5] and Gartners Hype Cycle of embryonic technologies [2].

III. Components of the Analysis Framework

Forecasting helps us to be prepared in the future. In most cases, predictions are based on analyzing past and present data and extrapolating the existing trend to the future. However, there is a problem and a paradox: in spite of understanding the past, the future does not follow the trend. The time span is also important. It is not so difficult to see into the near future, but seeing far ahead is no easy task. As a result, published analyses usually cover "important trends of the next year" as near future analysis. These are usually based on the reviews of expert opinions more than on the use of systematic fact-based analysis approaches. Consequently, the results are not uniform, and look at the same phenomenon from different viewpoints. The fact is, however, that when one makes technology prognoses, nothing radical can happen in the next ten years if the analysis environment remains stable, especially in the technology context. All we apply in ten years from now has more or less already been invented.

hy then ma e these predictions? The answer is: most of us can neither see the near future, nor recognize the importance of the technologies already in our use. Something that we feel important (from our subjective point of view) may be of very little importance on the global scale, and vice versa. The technology analysis makes us focus our thinking on the right things – it answers the question " *hat ind of progress should we ta e into account*?"

An additional question is " hat is the importance of each technology?" There is no clear way to weigh the real *importance* and *effectiveness* of a certain technology neither in the near future and especially not in the long term. Our *TCAC framewor* gives at least a partial answer to this question. The following sections contain some "tools" – ways to analyze future changes, to help the reader in the analysis. It covers the following viewpoints: (1) classification of the innovation importance (Section 4), (2) trend and life cycle model principles – the S-shape (Section 5), and (3) the hype cycle of pre-embryonic technologies (Section 6). The final framework (Section 7) is built of these components.

IV. CLASSIFICATION OF INNOVATIONS

The classification of innovations answers the question " *hat is the importance of each technology*?" Our work applies the idea presented by Freeman & Perez [1]. According to them,

- *ncremental changes* appear continuously in existing products and services (continuing the existing trend);
- *adical changes* appear when new research findings are applied in products to transfer their properties or performance to a new step or cycle (movement to a new trend);
- *Changes in technological systems* are caused by combinations of several incremental and radical innovations in societal and organizational systems;
- *Changes in paradigms* are revolutionary and lead to pervasive effects throughout the target system under discussion (in our case the information society).

The external importance and effectiveness of tehcnologies grows from top to bottom.

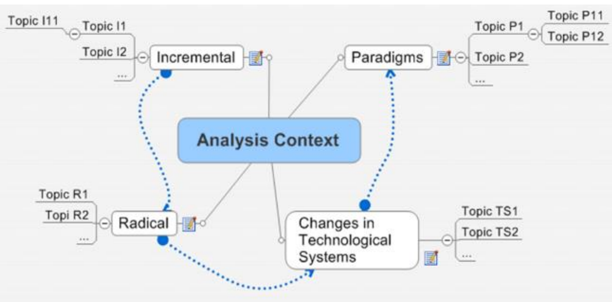

Figure 2. Technology category analysis illustrated

Classifying the importance of technologies according to this classification is not easy. We follow the principles introduced by Freeman and Perez in [1] and in more detailed by Jaakkola in [4]:

- *ncremental changes* accelerate the existing change on the existing trend;
- In the case of *radical changes* the trend continues, but at a certain moment there is an *upward shift* (break in the trend) caused by the innovation.
- *Changes in technological systems* are combinations of several technological innovations providing means for changes in societal systems, *daily ways of operating and usiness models*; the key aspect is increasing *competitiveness* and fast growth of *productivity* for early adopters.
- *Changes in paradigms* indicate *permanent changes* in societal systems, daily ways of operating and business models replacing the old ones.

There are several ways to illustrate the categorization. In our framework we have selected a mind map (Fig. 2) to illustrate the categorization and to group the topic areas belonging to each category. The arrows between the categories indicate the transfer of technologies from categories of lower importance to ones of higher importance.

V. TRENDS, LIFE CYCLE ANALYSIS AND DIFFUSION

A trend shows the changes in the target phenomenon as a function of time. In *technology analysis* the trend represents the *life cycle of an innovation* from embryonic phase towards maturation. It follows the S-shape curve, illustrating simultaneously both the maturity and the adoption of the technology. Fig. 3 represents the generalized life cycle / diffusion model.

The analogy between life cycles and the adoption process can be explained by the human decision-making process. According to Rogers [12], the *adoption diffusion of a product technology* among potential adopters can be divided into four classes: *innovators* (2.5%), *early adopters* (13.5%), *early ma ority* (34%), *late ma ority* (34%), and *laggards* (16%); see lower text box in Fig. 3. The cumulative adoption curve follows logistic distribution, most commonly analyzed by the mathematical model developed by Bass (Bass's diffusion model, see e.g. the paper [11]). The adoption decision is based on the uncertainty related to the technology: the more mature it is, the more experience-based information is available of it; this accelerates the (imitation based) adoption of it towards the full penetration (full user potential reached). Because of that the use of technology indicates its maturity (depth of the use, importance to the users; only a mature technology is widely spread among the potential users).

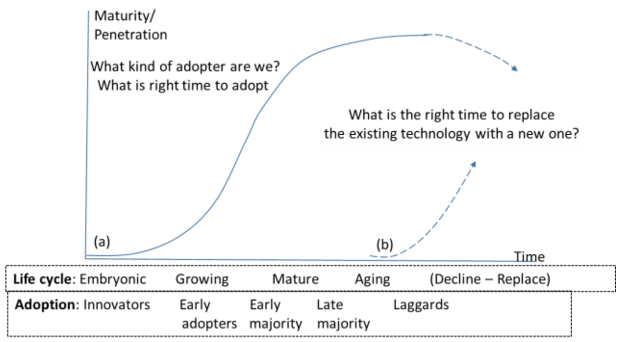

Figure 3. Technology life cycle / diffusion model

When we look at the same phenomenon from the technology maturity (life cycle) point of view, its stability increases along the life cycle. The life cycle can be divided into four phases (upper text box in Fig. 3): *m ryonic* (not stabilized), (accelerated) *growing*, mature (slowing growth), and *aging* (old technology). Finally, it is followed by the *decline* phase, in which the technology is replaced by a new one or by a new generation of the existing one. Analysts can use the life cycle model to support their decision making with two questions: *hat is the right time to adopt it hat is the right time to replace it* The embryonic phase is usually a period of uncertainty – we do not yet exactly know its future and the technology is not yet fully stabilized; several competing alternatives exist. This part is described usually by a *hype cycle* (discussed below), providing the means for more detailed analysis covering the transfer from the *pre em ryonic* (hype) to embryonic phase.

In life cycle analysis, the curve can also be interpreted as a consumption curve of the *innovation power* of a technology. The innovation potential is consumed along the life cycle and fully used at the end of the aging phase. It also describes the existence of *competitive edge* and productivity benefits to its users: the innovation power (ability to provide competitive edge to its users) will be big at the beginning of the lifespan, but also the uncertainty level and the risk of the failure are high.

VI. HYPE CYCLE

The hype cycle (also called hype slope) is an illustration of technology promises. It was introduced by Gartner Group, which is one of the best-known long-term actors in the area of technology studies and analysis. It illustrates the very first part of the life cycle of a technology (*pre em ryonic phase* in Figure 3) and answers the questions: *hen do new technologies ma e old promises ow do you discern the hype from what s commercially via le hen will such claims pay off if at all* Gartner annually publishes a variety of hype cycles in different technology sectors. These provide an insight into managing the decision to deploy selected technologies to meet specific business goals.

Gartner introduces the hype cycle as a research methodology for *pre em ryonic technologies* [2]. The structure is illustrated in Figure 4.

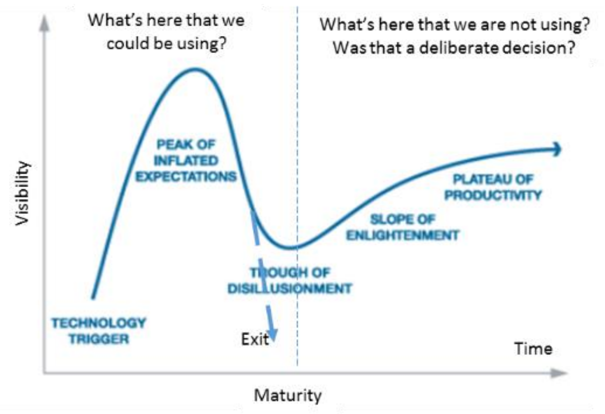

Figure 4. The hype cycle – interpreting technology hype

Each Hype Cycle drills down into the five key phases of a technology's life cycle (following the definitions of Gartner [2]):

- *Technology Trigger*: A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist and commercial viability is unproven.
- *ea of nflated pectations*: Early publicity produces a number of success stories — often accompanied by scores of failures. Some companies take action; many do not.
- *Trough of Disillusionment*: Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters.
- *lope of nlightenment*: More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious.
- *lateau of roductivity*: Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off.
- *it* (added to the original source by the authors) occurs if ultimately the technology has not been able to prove its validity for commercial and mass use – to be ready to transfer towards the embryonic phase of the life cycle.

The Gartner Hype Cycle illustrates the maturity and adoption of technologies and applications in graphical form. It also shows how they are potentially relevant to solving real business problems and exploiting new opportunities. For decision makers, it is an analysis tool about the promise of an emerging technology; for risk takers, it opens the door to the frontier of new technologies, and for the decision-maker who appreciates safety, it will lead to a decision not to use the possibilities of the technology at this stage. It also supports preparedness for the appearance of new technology – being proactive and preparing the organization for future changes (being preactive).

VII. FROM COMPONENTS TO THE MODEL

Figure 5 summarizes the components of our approach and provides a process model to produce the TCAC. The final result of the analysis process introduced in Fig. 5 is the classification structure of the relevant factors of the analysis context. In our pair of papers, the context is ICT-related technological changes (ICAC). The analysis steps are the following:

1. The starting point is *data collected* on the study context (in our case ICT-related technological changes; Paper II). Everything is based on the data collected from valid and relevant sources; these depend on the study topic. In validating the data sources, our recommendation is to apply the principles of *systematic literature review* to guarantee that all

important sources are found and that new ones no longer provide the kind of new information that should be taken into account.

2. Two methods are used to analyze the data. *ype cycle* based analysis (Section 6) is used to find pre-embryonic technologies to understand the delay of their commercial appearance. *ife cycle model* based analysis (Section 5) is used to understand the life cycle and renewal power of the technology analyzed. There is also an arrow between the hype cycle curve and life cycle curve. Since the hype cycle represents the pre-embryonic phases of the phenomena analyzed, it ultimately feeds the embryonic phase of the life cycle analysis; pre-embryonic becomes embryonic, unless the exit (not valid for mass and commercial use) is realized before it.

3. The *changes are classified* according to their importance by using the four categories of Perez and Freeman (Section 4).

4. The last part of the analysis is publishing. Based on the analyst's best knowledge as an expert in the topic area, the result phenomena (in our case ICT-related technologies) are published in visually informative form. We have selected a mind map.

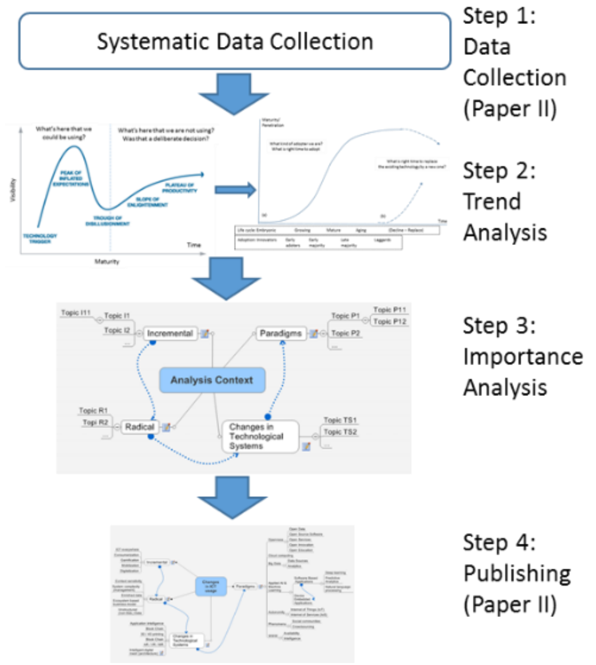

Figure 5. Technological Change Analysis and Categorization (TCAC) Framework – summary of the components of the analysis

As part of the publishing – because in any case the analysis remains the subjective opinion of the analyst (group) – it is good to implicitly define the interpretations of the four importance classes.

VIII. CONCLUSION

The paper introduces a framework that provides a systematic approach for analyzing real world phenomena from their life cycle point of view. It is the pair of another paper published in the same forum as this one (Paper II; [10]), in which we have applied the TCAC framework to analyze ICT-related technological changes. However – the model is context-free, and it can be used for a variety of analysis contexts and topic areas. The paper introduces the background of the work, its components, and its use – without real application in this paper.

As the model represents an artifact, the method used to develop the model follows the principles of *design science*. Hevner et al. [3] state that in design science research the novel knowledge and understanding come from the design process of an artifact. Hevner et al. give very clear guidelines for the design science research process, defining seven steps. The steps both provide a design path for the researcher and provide the *means to validate* the work. We have included both aspects in the following list of design science guidelines:

1. *Design as an artifact*. The artifact is a model.

2. *ro lem relevance*: The model handles a relevant problem in a society, e.g. in the education sector.

3. *Design evaluation*. The design is evaluated by several earlier pilot models. The final model is an iteration of these, taking into account the weaknesses and strengths of the earlier versions, and finally synthesized into the process introduced in this paper.

4. *esearch contri utions*: The model provides a practical tool for analysts in different (life cycle) analysis tasks.

5. Research rigor: The model is rigorously validated by the developers.

6. Design as a search process. During the research process the authors have, in addition to a lot of fun in collaboration, increased their understanding both of the innovation diffusion process and the phenomenon analyzed.

7. *Communication of research*: The earlier versions of the work are communicated in several earlier publications in order to get feedback. The feedback and the developers' own critical findings are taken into account in the result model.

Finally, our model will be validated in a practical case in Paper II in a real analysis environment. This proves its usefulness and also its use in creating new knowledge related to the ICT-related technological changes in the education environment.

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