EXTENDING THE LIFESPAN OF LEARNING OUTCOMES APPLICABILITY

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Abstract

Learning outcomes are a part of contemporary norms of higher education system. Implicit, yet regularly utilised, characteristic of learning outcomes is their assumed rather long applicability. Having in mind a number of emerging qualitative changes in modern world in general, thus the higher education system in particular, one may argue that even preserving the established learning outcomes is by no means trivial.

This article discusses factors contributing to lifespan of established set of learning outcomes. Within the set of such factors we extract a subset containing factors with significant potential for extending the lifespan of established learning outcomes.

Keywords

learning outcomes, lifespan, life-cycle, higher education

1 INTRODUCTION

Well structured higher education system includes a set of measures that contributes to the preservation of the system's structure and to the proper conduction of its processes in dynamic, rather unpredictable environment.

In order to make possible human intervention into the education process, thus to make possible establishing of the education system, the environment is projected onto the set of scales with a definite range of thereby introduced variables and a definite range of their optimal values. Operationally, a society establishes education system in order to contribute to its latency and possible development within the given (societal and natural) environment. As was previously stated "for ... clear benefit to all citizens, economy and the entire society in a country, it is crucial to understand all components of qualifications, such as learning outcomes, units of learning outcomes and modules, and to analyse a minimal set of their basic measurable properties" [1].

Because of environment dynamics, of all the introduced set of scales and of other notions related to positioning the society within the environment, one may argue that at least a part of such a dynamics is present and manifest within the education system and its parts. That situation is regularly encountered in analyses of the meaning of a technology within its contemporary technical system on the one hand, and of an institution within its contemporary societal system. Yet, processes brining about alignment of the technologies and societal needs with understood environment dynamics have accompanied costs and a variety of resources involved. It is opportune to try to optimise these costs. However, many of the changes in higher education system are unique in time and place, and partially their consequences are observed only *a posteriori*, after the introduction of the changes in the regular practice. Modelling of education system, or some of its parts, is a methodology useful in extracting the most probable consequences of its proposed modifications, prior to implementation of modifications.

This article has twofold character. First, it researches the learning outcomes, an extracted tool of a general education system. In particular, the article interprets learning outcomes as a technology product with a spatially, temporally and disciplinary determined scope and other attributes. The focus is put onto the lifespan of established learning outcomes as extended lifespan marks optimal involvement of costs and other resources attributed for previously stated alignment. Based on that interpretation the article provides the readers with guidelines for establishing further learning outcomes as well as for the use of learning outcomes based on a more thorough interpretation of the context. It is our on-going research [2] to demonstrate that such an approach will contribute to lessening, ideally to ceasing of some challenges of education systems, such as the often underestimated development of guidelines, tools and handbooks, or a danger of bad assessment practices, over-defining assessments, or other challenges [1].

Secondly, the article describes model of a part of education system focused onto learning outcomes which will serve as a starting point for simulations of possible future modifications, ranging from minute to thorough changes. The focus regarding that point is to formally express the context and regular dynamics of learning outcomes.

Regarding first point, the article continues researches of engineering education [1, 3]. Regarding the second point, the article broadens the scope of modelling of a part of higher education institutions [4]. Still, the part of the modelling presented here is focused onto the education process and its links with extracted segments of environment, such as market [5], knowledge society [6] or international directives [7] are left for further development.

In section two the basics of product life-cycle management and analysis are given. In section three, these basics are applied onto the analysis of learning outcomes. Section four concludes the article with guidelines for practitioners.

2 PRODUCT LIFE-CYCLE IN A COMPLEX ADAPTIVE SYSTEM

Product life-cycle is a set of processes describing possible stages of some product. The stages of a product within its life-cycle are introduction, growth, maturity and decline [8]. The relative order and duration of the stages are variable. Each stage is conducted usually within the same environment, however for their conduction the impact onto appropriate stakeholders is needed [9]. Introduction is related to initial providing the society with the product. Usually market serves as specification of the part of society broadened with new product. Growth phase incorporates intense rise in societal demand for the product. Third stage, maturity, is the interval during which the societal demand for the product changes non-significantly. Last stage is decline, the stage characterised by the ceasing demand for the product. That is a simplified description describing general trends of society toward the product and it is to be expected that stages in a detailed analysis reveal fluctuations in the societal demand for the product.

Let us apply stated stages onto learning outcomes. In the context of higher education introduction of education based on outcomes is done once by decision makers such as are governmental bodies or managements of higher education institutions. That is introduction of new technology. Introduction of its products, such as learning objectives is conducted by professors, either individually or within faculties. Part of the society to which a product is introduced consists of professors and students. Growth, the second stage, implies complete reformulations of the curricula throughout levels. That stage is conducted prevalently by professors. Stage growth is characterised with a variety of attitudes toward newly implemented methods and techniques, such as is active learning [10]. Third stage denotes higher education as a fully developed education based on learning outcomes. During that stage prospective and newly enrolled students formulate their vision of classes based on learning outcomes, lectures and tests are aligned with outcomes, etc. Fourth stage occurs when a particular learning outcome is declared obsolete or otherwise unsuitable. One may argue that, in a typical higher education institution, stages of introduction, growth and decline are of constant duration which is independent of a particular institution. Stage maturity lasts as long as there is no significant discrepancy between a given learning outcome and learning outcome assumed by professors to be optimal.

Higher education system is a complex adaptive system. The forces requiring its adaptation are within the higher education represented as industry and government [11, 12]. Industry is the locus of production, government is the guarantee of stability while higher education is a source of new knowledge and technologies.

3 LEARNING OUTCOMES AS TECHNOLOGY TOOL

In the context of higher education, learning outcomes are statements about verifiable significant and essential learning that students have achieved [13]. The possibility of verification through students' demonstration is crucial for learning outcomes [14]. As such they are cornerstones of the Outcomes based education, which is a restructuring of curriculum, assessment and reporting practices in education and which reflects the achievement of high order learning and mastery rather than the accumulation of course credits" [15]. Regarding verification, Dželalija and Balković state that "The proven usage refers to the conditions in which the knowledge and skills are used, including the spatial, temporal and other conditions." [1]. However, some authors consider learning outcomes to be non-measurable but uniquely related to measurable notions such as performance indicators. Learning outcomes are divided into exit, programme and specific (or course) outcomes. The specific (course) outcomes are of the narrowest scope among listed types. The units forming a learning outcomes, the very set of statements which form a particular learning outcome are elsewhere defined [1]. For simplicity of presentation here we assume that learning outcome is uniquely related to a well-defined change in learners' achievements.

(Re)formulating the higher education so that it becomes based on learning outcomes is an example of a technology development. Therefore, activities brining about the characteristics of learning outcomes, of statements about competences and of other accompanied statements, can all be interpreted as products of a technology having their own life-cycles. Specifically, a formulated learning outcome is a product we will focus onto, developed within a given technology.

It is of interest to analyse general characteristics of a learning outcome's life-cycle. The analysis has static and dynamic part. Static part includes describing the context, while dynamic part analyses interplay and duration of product life-cycle stages.

The model is developed with the following assumptions about higher education system:

- it is sufficiently developed that its prevalent dynamics is realised through gradual changes (modifications) of established measures,
- encountered variabilities of characteristics are normally distributed,
- for each and every class, variabilities of initial achievements of enrolled students negligibly influence variabilities of their final achievements.

In case of a contemporary Croatian higher education, restrictions imposed by stated assumptions are the highest for first one, and smallest for the third one. This is a consequence of recent reform of a higher education which is why currently there simultaneously exist different systems [16].

In a static analysis we start with description of functioning of a one higher education course, otherwise unspecified. In a given term there is a group of K students enrolled to that class. Let vector $\boldsymbol{x}_i$ denotes achievements of a student i:

$$\boldsymbol{x}_i = (x_{i,1}, x_{i,2}, ..., x_{i,N})^T \qquad (1)$$

where a component $x_{i,j}$ is a measure of achievement of the i-th student (i = 1, ..., K) in the j-th component, (j = 1, ..., N). Number of vector's components N denotes number of measured achievements. Each component refers to i-th student result in some relevant (thus developed because of the education system, and tested in a proper way [16]) category such as knowledge, skills and attitudes. The details of basis of introduced vectorial representation is in details described elsewhere [1].

Higher education process is represented as a set of transformations f of achievements,

$$f_a(\boldsymbol{x}_i) = \boldsymbol{x}_i' \qquad (2)$$

with $\boldsymbol{x}_i'$ denoting vector of i-th student final achievements and a denotes any of assumed M transformations. One course does not generally correspond to one transformation. But for simplicity we assume so in further text. Depending on definitions of vectors' components, some achievements becomes larger as a result of the transformation, while some becomes smaller, nevertheless all changes correspond to an improvement in achievements. For simplicity, further in the text we assume that all achievements are positive numbers, defined in such a way that the improvement corresponds to its rise. Formally f-s denote processes so the additional parameters are needed in order to uniquely define changes introduced by f_a for a given student. For simplicity we omit these parameters from expressions. For similar reasons, notion of time is suppressed although, naturally, any of the transformations f_a occurs gradually, during a finite time such as is one or more terms. Before proceeding, let us remark that an important part of the higher education process is represented as a series of transformations, some of which are separated in time while other are at least partially simultaneously conducted.

Learning outcomes are attributed to achievements as conditions imposed to final achievements. Regarding that point, within a group of K enrolled students, there is a variety in (2) of initial as well as of final achievements, $\boldsymbol{x}_i$ and $\boldsymbol{x}_i'$, respectively. Variety in initial achievements is a consequence of final achievements from previously finished transformations and of ongoing changes in achievements because of other simultaneously performed transformations. The third assumption about the higher education system here figures as a rather important assumption since it changes the character of transformations f from processes to state functions.

In general, one learning outcome can contribute to several conditions. Moreover, each transformation does not have to change all the achievements. Nevertheless, for simplicity of the formalism presented, we assume that a separate learning outcome $L_{a,j}$ is formulated for each and every of N achievements for a given transformation f_a, as a minimal admissible value of final achievements of students involved. The starting point is the minimal value of j-th achievement possible within a group of enrolled students:

$$\min_{i=1,...,N} f_a\left[(x_{i,1},..,x_{i,j},...,x_{i,N})^T\right], \qquad (3)$$

with note that the assumed ways of checking these achievements are not regular exams. Expression (3) generally is of different value for different groups (e.g. generations) of enrolled students. However, well-defined learning outcomes should minimally depend on the particular group of enrolled students. Following the assumption about the sufficient overall quality of the higher education process, we assume complete independence of learning outcomes from characteristics of a particular group of enrolled students, so the minimum in (3) is to be evaluated on the complete domain of the j-th achievement:

$$L_{a,j} = \min_{x_{\min} \le x \le x_{\max}} f_a\left[(x_{i,1},..,x_{i,j},...,x_{i,N})^T\right]. \qquad (4)$$

If we consider expression (4) to represent one component of a vector, then one may introduce the vector of learning outcomes for a given class:

$$\boldsymbol{L}_a = \min_{\boldsymbol{x}} f_a(\boldsymbol{x}), \qquad (5)$$

as evaluated for the unspecified, yet readily formulated domain of the vector of achievements $\boldsymbol{x}$ [1].

Expressions (1)-(5) belong to describing the context. Despite representing constant transformations of students' knowledge, skills and attitudes, these expressions refer to the idealised situation of learning outcomes being independent of particular students' generation achievements. That is rather stringent assumption while a more realistic one is that learning outcomes depend on some measure of achievements derived from the achievements of the groups of students enrolled in a given class within several generations, i.e. undertaking transformation f_a. We denote the corresponding measure as $\boldsymbol{\mu}_a$. It can be an average, or some other statistical quantity evaluated on the group of students involved. Learning outcome based on the measure $\boldsymbol{\mu}_a$ is denoted as $\boldsymbol{L}_a^{(\mu)}$ and it is an estimate of the ideal learning outcome.

Learning outcomes $\boldsymbol{L}_a^{(\mu)}$ are time-dependent. Their evolution is observed in scales considerably larger than the representative average duration of transformation f_a. Mentioning of the time-dependence marks the end of the static analysis of learning outcomes and beginning of their dynamic analysis. Dynamic of measures consists of gradual and sudden changes. Sudden changes include creation, annihilation, branching or binding of learning objectives or, in typical terms their introduction, growth, maturity and decline. Gradual changes include modifications which do not change the number of learning objectives. Since learning objectives are qualitative, categorical expressions their modifications are of finite amount. Let us present some typical details of processes brining about modified learning outcome. A modification $\Delta\boldsymbol{L}_{\mathrm{a}}^{(\mu)}$ is induced by implicit yet longer-term observed discrepancy between the stated and achieved learning objectives. Because of stated assumptions about the higher education system quality the modification is expected to be small enough to bring about the following linear relation:

$$\Delta\boldsymbol{L}_{a}^{(\mu)} = c_a(\boldsymbol{L}_{a,\infty}^{(\mu)} - \boldsymbol{L}_{a}^{(\mu)}), \tag{6}$$

with $\boldsymbol{L}_{a,\infty}^{(\mu)}$ representing extreme value of a learning outcome which is obtained asymptotically, while c_a measures a generalised force that induced the change and that is considered constant throughout the change. So, transformations determine learning outcomes, yet one must bear in mind that learning outcomes serve as a basis for formulating the transformations. There is thus a feedback between a learning outcome and a transformation related to it, the part of which is not considered here explicitly. Learning outcomes $\boldsymbol{L}_{\mathrm{a}}^{(\mu)}$ are evaluated based on the measured achievements of group of enrolled students. In that sense, change (6) is also to be measured on the group of enrolled students.

Both (5) and (6) imply information transfer which realises the transformation f_a. One may generally expect that within a group of enrolled students all possible levels of achievements will be realised, yet with different frequency. We utilise information entropy as a measure of information content of achievements of the group of enrolled students. It is important to note that information entropy is interpreted as a measure of uncertainty of information content within the group of enrolled students. But, its initial value is assumed smaller than its final value. That is because initially the students are expected to have rather low achievements $\boldsymbol{x}$. There exists certain variability among initial students' achievements but is localised within a rather small interval around low initial value. After transformation f_a, the achievements are generally larger. When measured (tested), they span considerably larger interval so the uncertainty of achievement of some student, as quantified using information entropy, is rather large. It marks the enlargement of corresponding information content of the group of enrolled students. That is in accordance with previously introduced simplification that transformation brings about only the rise in achievements. Generalisation of that approach to the one in which some achievements are lowered brings about, conversely, lowering the uncertainty in possible value of final achievements of some student within the group of enrolled students. Knowledge and skills are achievables the uncertainties of which rise because of a transformation while attitudes are achievables the uncertainty of which becomes smaller because of a transformation.

Transfer of information implies that students achievement of skills, knowledge and attitudes has changed. In fact, the very change is indicator of an information transfer. Otherwise we speak of information emissions which do not necessary imply adopting of pieces of information by students. If the probability $p(\boldsymbol{x})$ denotes that student group adopted some information content and has achievement $\boldsymbol{x}$, the corresponding information entropy is

$$H_a = -\sum_{\boldsymbol{x}} p_a(\boldsymbol{x})\,\mathrm{ld}\,p_a(\boldsymbol{x}), \tag{7}$$

with utilised dual logarithm $\mathrm{ld}(\cdot) \equiv \log_2(\cdot)$. The sum in (7) is transformed into integral for components of achievements $\boldsymbol{x}$ measured on a continuous scale. In the realistic case of measures of learning outcomes μ_a, one may argue that the conditional entropy represents well the effect of transformation f_a onto the involved students' achievements from the viewpoint of transferred information,

$$H_a(\boldsymbol{x}'|\boldsymbol{x}) = -\sum_{\boldsymbol{x},\boldsymbol{x}'} p_a(\boldsymbol{x}',\boldsymbol{x})\,\mathrm{ld}\frac{p_a(\boldsymbol{x})}{p_a(\boldsymbol{x}',\boldsymbol{x})}, \tag{8}$$

with $p_a(\boldsymbol{x}', \boldsymbol{x})$ being the probability that both the initial achievement equals $\boldsymbol{x}$ and final $\boldsymbol{x}'$. In ideal case, when learning outcomes $\boldsymbol{L}_{\mathrm{a}}^{(\mu)}$ transform into ideal learning outcomes $\boldsymbol{L}_{\mathrm{a}}$, mutual entropy is independent of the initial achievements $\boldsymbol{x}$, thus (8) becomes equal to (7).

Generalised forces, c_a from (6), are externally defined, and dynamics of learning outcomes cannot change them explicitly. One may argue that these forces are determined by management on the basis of observed dynamics of learning outcomes so in some aggregated way eventually learning outcomes partially determine generalised forces. That is expected to be realised on time scales considerably longer than characteristic time scale of learning outcome dynamics which is why we consider generalised forces c_a as independent on learning outcomes. Because of fixed c_a, extending lifespan of a learning outcome is based on analysis of (5) and (6). Lifespan is maximal if right hand side of (6) is smallest, which is in a non-trivial way possible for realistically founded assymptotic learning outcomes $\boldsymbol{L}_{a,\infty}^{(\mu)}$. In addition to that, from (5) one expects that larger learning outcomes are possible in case of a well-formed group of enrolled student, i.e. a group consisting of students who are motivated and who have been acquainted with learning of a given class in advance. That is achieved with sufficient information available about study programmes. Consequences of modifications of learning outcomes and accompanying course practices can be followed through changes in accompanied information entropy (8). Let as assume that prior to changes in learning outcomes information entropy was evaluated for a rather broad range of achievements $\boldsymbol{x}'$. Modifications of learning outcomes is expected to bring about lowering of information entropy (8) in two ways. First, modifications of learning outcomes $\Delta \boldsymbol{L}_a^{(\mu)}$ can induce changes in transformations f_a, that rises minimal achievements of enrolled students. In that way, interval of achievements becomes smaller, same as uncertainty attributed to testing of achievements, the information entropy. Secondly, modifications may leave the intervals of achievements untouched but bring about changes in overall distribution of achievements $p(\boldsymbol{x}')$, in a way which again lowers information entropy. The meaning of the later change is that distribution of achievements becomes more centred around some definite value of achievements, ideally their maximum. However, one may not rely solely on (8) in order to analyse consequences of introduced modifications of learning outcomes, as information entropy may become lower because of a degradation of education process. E.g., it becomes lower in case when maximal achievement becomes smaller. That situation is similar to the one of making larger the minimal achievement, in that both changes are attributed to reducing the interval of achievements.

4 CONCLUSIONS

Learning outcomes, an important part of contemporary education systems based on outcomes, posses dynamics which influences their validity and more or less justifies resources involved in formulating them. We formalised the dynamics of learning outcomes. From developed formalism we concluded about the possibility for extending the lifespan of once established learning outcome.

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