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**Conference Paper**

## Measuring Human Capital in Education

51st Congress of the European Regional Science Association: "New Challenges for European Regions and Urban Areas in a Globalised World", 30 August - 3 September 2011, Barcelona, Spain

**Provided in Cooperation with:**

European Regional Science Association (ERSA)

*Suggested Citation:* Walukiewicz, Stanislaw; Wiktorzak, Aneta (2011) : Measuring Human Capital in Education, 51st Congress of the European Regional Science Association: "New Challenges for European Regions and Urban Areas in a Globalised World", 30 August - 3 September 2011, Barcelona, Spain, European Regional Science Association (ERSA), Louvain-la-Neuve

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# Measuring Human Capital in Education<sup>1</sup>

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**Abstract.** We consider education as a number of multistage creative processes and analyse one of them - teaching knowledge (Process P1) - in detail.

In Part 1 we describe the idea of Virtual Production Line (VPL), introduced by Walukiewicz in 2006 as an extension of Classical Production Line (CPL), an epitome of our perception of Henry Ford's assembly line. Teachers connected by modern ICT network (in most cases it will just be the Internet) provide education to students on a VPL – kind of a virtual belt - instructing a given set of subjects (tasks) in a prescribed sequence, offering knowledge by a prescribed methodology, etc. In contrast to CPL, teachers on VPL will use their brain power mostly and divide the teaching process into a number of tasks in what we will call 'self-organization of VPL'. In that perspective, VPL shall be defined as a conscious act of division of labour into tasks (self-organization) via the Internet, while CPL will just remain a partition of labour into a fixed number of jobs (tasks).

In Part 2 we introduce the value of human capital of a given student as a measure of P1 efficiency and compare it with the indicators used so far. In Poland the problem is that different skills of students are not measured within one, integrated system. We propose a solution to this problem, furnish relevant field study results and, in conclusion, formulate suggestions for further research.

**Key words:** Human capital; Virtual Production Line (VPL); Classical Production Line (CPL); efficiency of education.

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<sup>1</sup> This study was sponsored through a grant UDA-POKL.04.02.00-00-083/08-00 "Human and Social Capital as new Academic Subjects", awarded by the Ministry of Science and Higher Education of Poland.

## 1. Introduction

In this paper we first study general education as a number of creative processes and analyse two of them: teaching knowledge (process P1) in detail and teaching skills (process P2) in brief. While P1 has been around for centuries, skills-oriented teaching (P2) was brought to practice some 30-40 years ago and has become increasingly popular ever since its debut.

The strategic aim of our study is to evaluate the efficiency of P1. To analyse that we use Virtual Production Line (VPL) introduced by Walukiewicz in 2006 - a natural extension of Classical Production Line (CPL). While we describe VPL in education in Section 3 and, in the next Section, use it to model P1, in Section 5 we discuss our research results and - in Conclusion - formulate three recommendations which we strongly believe will be relevant not only for Polish but worldwide education.

## 2. The Methodology

Since we consider a school where the processes P1 and/or P2 are in place as a (closed) system, a **firm**  $F$  (see Walukiewicz, 2008 or 2010 for the definition) with its inputs and outputs and with its more or less defined objective (see Fig. 1), so the question of how efficient the processes P1 or P2 are can be rephrased as:

What is the value of school  $F$  at a given time  $t$  -  $V(F, t)$  in a relevant education market?

Here, the natural time measure is school year, in Poland between 1 September one year and 31 August next year.

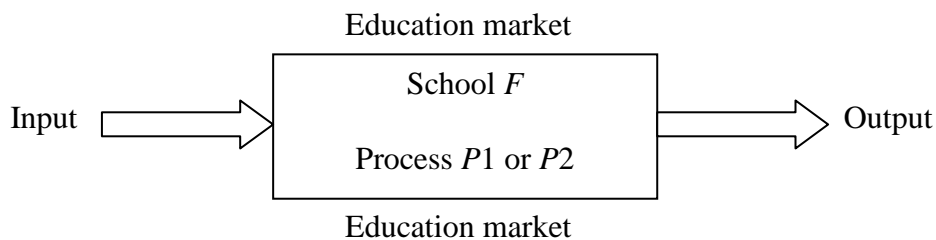


Fig. 1. School  $F$  as a system

To answer the question as above we need to consider all and absolutely all assets of a given firm  $F$  at a time  $t$ . Walukiewicz introduced the so called **Orthogonality Principle** in 2008 and proved that all assets of a given firm can be partitioned into two disjoint forms: **tangible** and **intangible assets**, with intangible assets further partitioned into **human** and **social** and tangible into

**financial** and **physical capital**. Thus we arrive to the **fundamental equation** which says that the value of a firm  $F$  at a moment  $t$  equals the sum of the values of the four above capitals (assets), that is

$$V(F,t) = v(FC,t) + v(PC,t) + v(HC,t) + v(SC,t) \quad (1)$$

for any moment  $t$  in the “past”, “present” or “future” of firm  $F$

(see Walukiewicz, 2011 for details). So, although the four above forms of capital closely ‘cooperate’, we can add their values as they are disjoint or orthogonal.

### 3. Virtual Production Line

The concept of the Virtual Production Line was introduced by Walukiewicz in 2006 as a model for analysis of creative processes . To describe our idea, we need general information about its predecessor a (classical) assembly/production line, which we would like to explain with an example from the automotive industry.

Before 1913 cars were manufactured in so-called production circles (see Fig.2), where a few highly skilled craftsmen produced a car from beginning to end using parts and raw materials. The division of labour in such a production process was very flexible, in fact, craftsmen could easily substitute for one another, and the obvious limit for productivity was the number of highly skilled craftsmen in a given society.

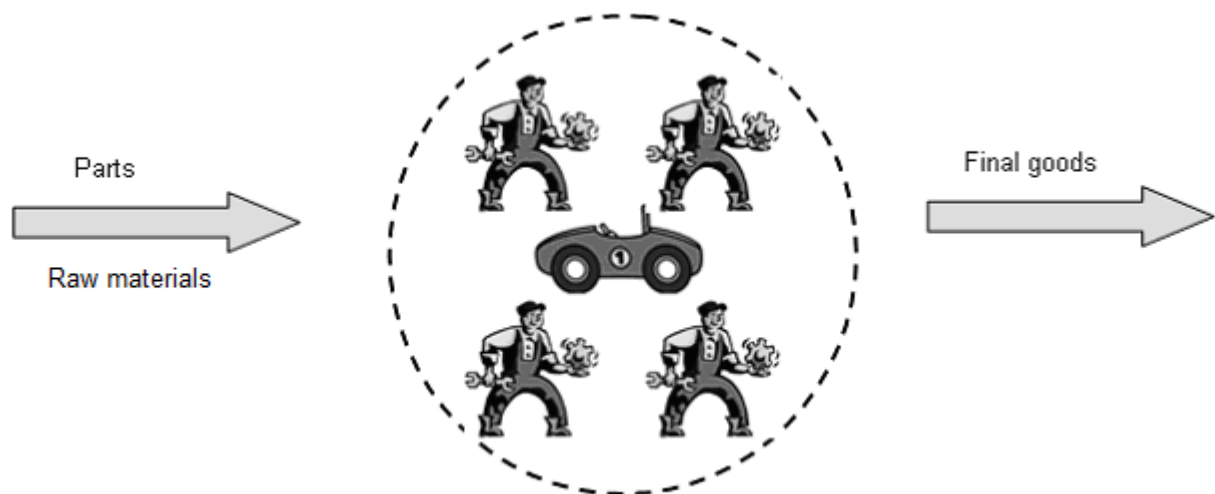


Fig. 2. Production circle

Henry Ford was the first who put into practice the following observation: if we partition a complex car manufacturing process into a fixed number of simple

operations (jobs) done by simple workers (blue collars) on a line (belt) (see Fig.3), then its productivity will increase and the problem of limited number of highly skilled craftsmen should be solved. It is one of the greatest achievements in management science and economics, which completely changed our world. The idea of the assembly line was then applied in many production and service processes. If we have many production/service lines manned by people or robots, then for the purpose of our analysis, we combine them into one production/service line which we will call the **Classical Production Line (CPL)**.

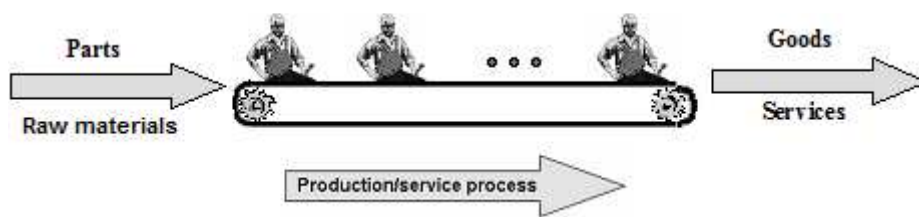


Fig. 3. Classical Production Line (CPL)

Let us assume that a given worker has increased his/her skills (his/her human capital) and now can do the job assigned in half the previous time. Does it have any impact on the organization/productivity of the production process concerned? The answer is no, it does not. His/her extra skills may be used in the design and implementation of another production process on another CPL, but not in the one in hand as its organization is fixed. We conclude that CPL does not allow of any **self-organization** and workers (blue collars) are to work on it, not to think.

**Definition 1. Classical Production/service Line (CPL)** is a partition of a complex production/service process into a fixed number of simple operations (jobs) described to the smallest detail. Such a partition is fixed for a time and does not allow of any **self-organization** (see Fig. 4).

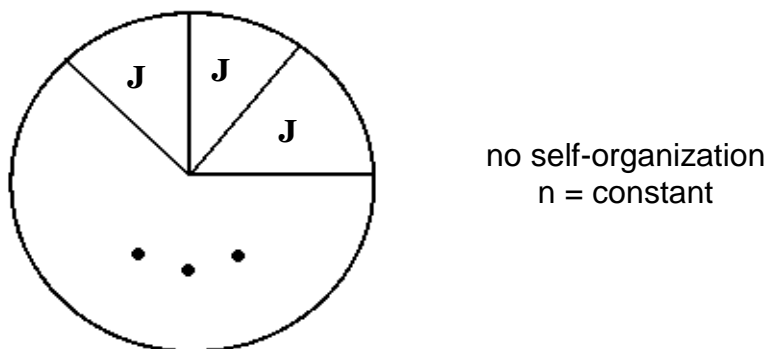


Fig. 4. CPL as a rigid partition of labour

A bit exaggeratedly, we can now say that high-skilled craftsmen are not needed in automotive industry where organization is a priority. Due to excellent organization, very simple workers can produce very sophisticated cars.

Let us consider a **Virtual Production Line (VPL)**, pictured in Fig. 5, where a number of experts (teams of experts), scientists, specialists, etc., backed by data processing and computing machines in Fig. 5 we show their keypads and monitors - get together via the Internet or any ICT networks to solve in a creative process a more or less accurately defined problem of our firm  $F$ . Since there is no material representation of VPL (our experts can be located in different parts of the world), we mark it in Fig. 5 with a dotted line (for VPL in education go to Section 4).

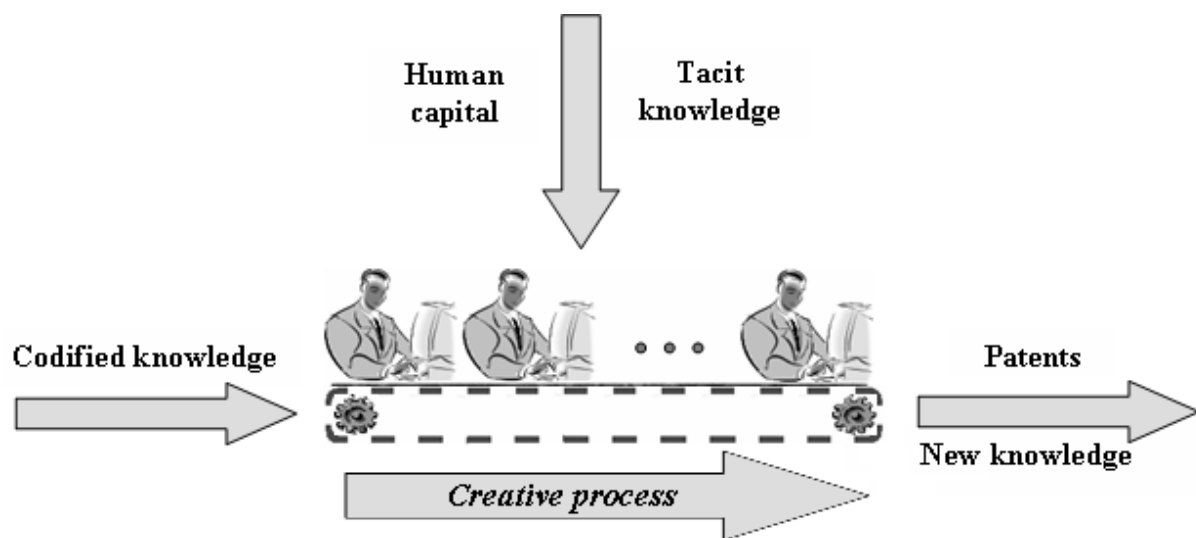


Fig. 5. The concept of Virtual Production Line (VPL)

As shown above, on VPL experts combine their human capital - mostly their tacit knowledge - with codified knowledge to solve a problem in a creative process. At the beginning, the problem may be murky or poorly defined, but due to their efforts (**self organization**), it will get more and more explicit and definable. This is so because experts on VPL not only work but – mostly - think. See Fig. 6 below.

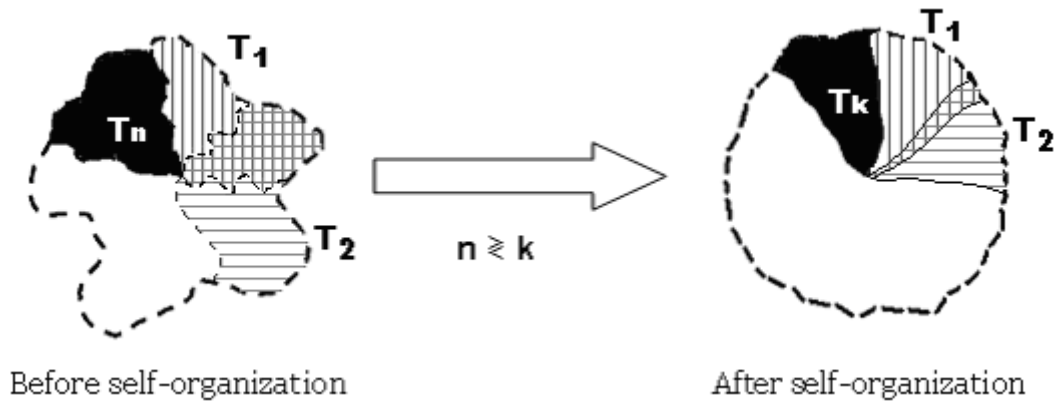


Fig. 6 VPL as a flexible division of labour and self-organization

In Fig. 6 we see that at the beginning of creative process, the problem is usually not well defined - we mark it with a dotted line along the perimeter. Tasks often overlap and their limits are not well delineated - we mark it with a waved line. After self-organization, the problem is much better defined (it is almost a circle), with overlapping of tasks substantially smaller and their limits almost straight lines. If the problem is initially divided into  $n$  tasks  $T_1, T_2, \dots, T_n$ , then, after self-organization, it is  $k$  tasks  $T_1, T_2, \dots, T_k$ , where  $k$  can be equal, bigger or smaller than  $n$ . We conclude that VPL allows for a **flexible division of labour**, while CPL is based on a **rigid (stiff) partition** of that (see Fig. 4) where production/servicing process is minutely defined - a circle on Fig. 4 - jobs  $J_1, J_2, \dots, J_n$  do not overlap and limits between them are straight lines.

**Definition 2. Virtual Production Line (VPL)** is generally a division, not a partition of a complex creative process into more or less precisely described tasks (jobs), with paramount use of modern ICT. The division of the creative process into tasks and the number of tasks alone may be changed throughout the process by actions of experts involved in it. Such a- modifications shall be called **self-organization of virtual production line** and may recur over the course of the process.

We note that unlike CPL, VPL is not a simple division of labour but a more complex structure composed of three elements: division of labour, self-organization and modern ICT. We realize that it is only in the 90's that social capital made its way into the spotlight and it is also in the 90's that humans began to be able to send information electronically, now reaching virtually every corner of the world at almost zero cost.

To sum up, we may say that VPL is an instrument (a virtual conveyor belt) that experts use to combine codified knowledge with their tacit knowledge, competence, experience, etc. to introduce improvements in products, services, technology and management, and contribute to the world's stock of knowledge,



codified and tacit (see Fig 5). Otherwise stated, it is a device on which social capital of firm  $F$  makes money (financial capital) in a creative process using human capital of its experts and physical capital of its assets (computers with software, data bases, communication networks, patents, licenses, books, buildings, furniture, etc.).

#### 4. VPL in education

In this Section, we will see school (our firm  $F$ ) as a closed system where a number of creative educational processes are employed. With an example of P1 (teaching knowledge) and P2 (teaching skills) in a secondary school (SS) we will demonstrate how useful VPL is in modeling and analysing of such processes (see Fig. 7).

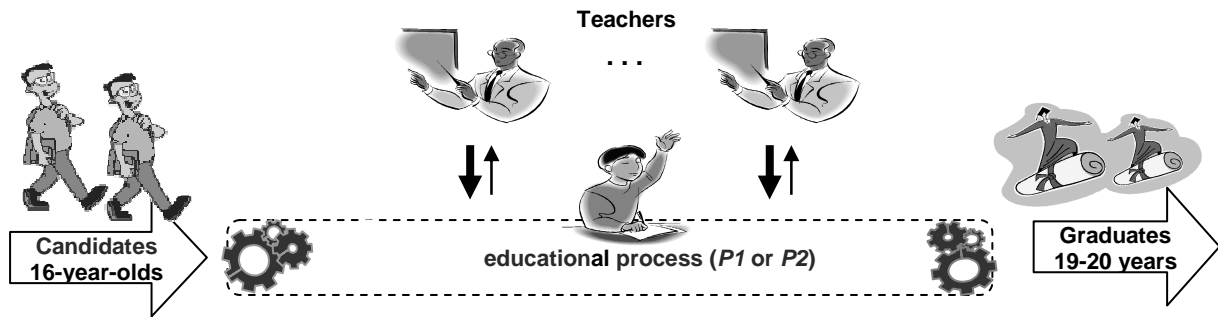


Fig. 7 VPL in education

At the input are 16-year-old candidates (SS entry age), with their knowledge, physical and mental competency level, health and other human capital (HC). By  $v(HC, s_i, t)$  we denote the value of human capital of a given student  $s_i$  at time  $t$  of (school) year, in most cases at the end of the year. When we gauge human capital of e.g. all students in a class instead of a single individual, we skip  $s_i$  - which leaves us with  $v(HC, t)$ . Human capital has a lot of similarities to financial capital and, in general, should be measured in monetary units (see Walukiewicz, 2008 and 2009). Also, it is a **cumulative property**: student knowledge, experiences, etc. accumulate and build up as their schooling progresses, though, realistically, we never assume that  $v(HC, t)$  is always on the rise. We understand that it does not always work that way. We assume that entrance value  $v(HC, t)$  on entering school  $F$  equals the exit value  $v(HC, t_0)$  on leaving previous-stage school. Presently in Poland,  $v(HC, t_0)$  is determined by the standard (all-Poland) middle school exit exam test.

At the output of our VPL (school  $F$ ) are graduates who have passed final examinations (in Poland – Matura Exam) after  $k$  years of education (in Poland  $k=3$  or 4). The value of human capital of a given student is denoted as



$v(HC, s_i, t_k)$ . Over  $k$  years of study in P1 process students are instructed a given set of courses (tasks) in a prescribed sequence and teaching load and methodology are carefully selected. In contrast to CPL, teachers on VPL mostly think, use brainpower to e.g. divide the teaching process into a sequence of tasks, with the inclusion of human and social capital of students. This is what we call **self-organization (of P1 process)** on VPL. So, VPL is a virtual belt which transmits a given student  $s_i$  with his/her human capital  $v(HC, s_i, t_0)$  to a graduate level at which the human capital is  $v(HC, s_i, t_k)$ .

Obviously, a process as above never happens in isolation. To give due credit to the impact of the community (parents, school administration etc.), we assume that since they take all their concerns to teachers and exert all the pressure on them, they affect self-organization of teachers' VPL. We also note that there is an obvious asymmetry in volume between information going from teachers to students and that going the other direction. Note the different arrows in Fig. 7.

Before concluding, let us emphasise two points. First, unlike CPL, VPL in education is normally nonlinear - a teacher can teach e.g. physics one year and in the next year it could be chemistry. Then the concept of human capital in education is much, much wider than the mere measure of student achievement, like with **value added score** (Niemierko, 2008 and 2009), **grade equivalent method** (Niemierko, 2009) and the **vertical scales method** (Tomkowicz, 2008). The difference will be seen once ICT is fully implemented, particularly in school administration (electronic class register, data bases etc.). Clearly, a load of practical and legal problems have to be discussed and solved before it happens and this goes beyond the scope and ambit of this paper. On VPL students will never be treated as CPL parts or components, but on the other hand, with the human capital concept all and absolutely all characteristics of a student can be tracked and measured (his/her knowledge: codified or tacit, experiences, talent, health etc.) . In the next Section, based mostly on the Ph. D. Dissertation of Wiktorzak, 2009 (see also Wiktorzak, 2011), we demonstrate how the concept of human capital can be used in the **value added score** method.

## 5. Process P1

The value of human capital of a given student  $s_i$  in year  $t$ , denoted as  $v(HC, s_i, t)$ , can be regarded as a statistic which represents a population of  $n$  students from a class/school/region/country. So we can determine certain population parameters getting the **mean value of social capital (for that population)**

$$\bar{v}_t = \frac{1}{n} \sum_{i=1}^n v(HC, s_i, t) \quad (2)$$

or the **standard deviation** defined as

$$\sigma_t = \sqrt{\frac{1}{n-1} \sum_{i=1}^n [v(HC, s_i, t) - \bar{v}_t]^2}. \quad (3)$$

We define the efficiency of school  $F$  in the completion of P1process, or the **efficiency of P1**, as the difference between the output and input values at the relevant VPL. From **student ( $s_i$ ) perspective** the efficiency of a given VPL equals the subtraction

$$v(HC, s_i, t_k) - v(HC, s_i, t_0). \quad (4)$$

In Poland, different methodologies are applied to exam tests at  $t_0$  and  $t_k$ , different subjects are chosen and results are measured on different scales. Wiktorzak, 2009 suggests a way out: use **(linear) regression analysis** to calculate the difference at issue. To do so, we first work out the **Pearson's correlation coefficient** for input and output results on a VPL for the population of  $n$  students (class, school, region or country), defined as

$$r = \frac{\sum_{i=1}^n [v(HC, s_i, t_k) - \bar{v}_k] [v(HC, s_i, t_0) - \bar{v}_0]}{\sqrt{\sum_{i=1}^n [v(HC, s_i, t_k) - \bar{v}_k]^2 [v(HC, s_i, t_0) - \bar{v}_0]^2}}. \quad (5)$$

Next we calculate the value of human capital of a given student  $s_i$  at final exam stage, denoted as  $v(HC, s_i, t_k)$ , taking into account his/her exam results at year  $t_0$ , defined as

$$v(HC, s_i, t_k) - \bar{v}_k = r[v(HC, s_i, t_0) - \bar{v}_0] + V(F, t_k), \quad (6)$$

where  $V(F, t_k)$  is so called **value added score** or the **school  $F$  contribution (to the growth of human capital of the population concerned)**.

We can consider the linear regression analysis as a linear transformation of input results into those of output stage. If we denote  $x = v(HC, s_i, t_0) - \bar{v}_0$  and  $y = v(HC, s_i, t_k) - \bar{v}_k$ , we will arrive at a formula for the **regression line**

$$y = rx + V(F, t). \quad (7)$$

The idea of linear regression analysis for input/output exam scores scaled on the **standard nine** scale is given in Fig. 8.

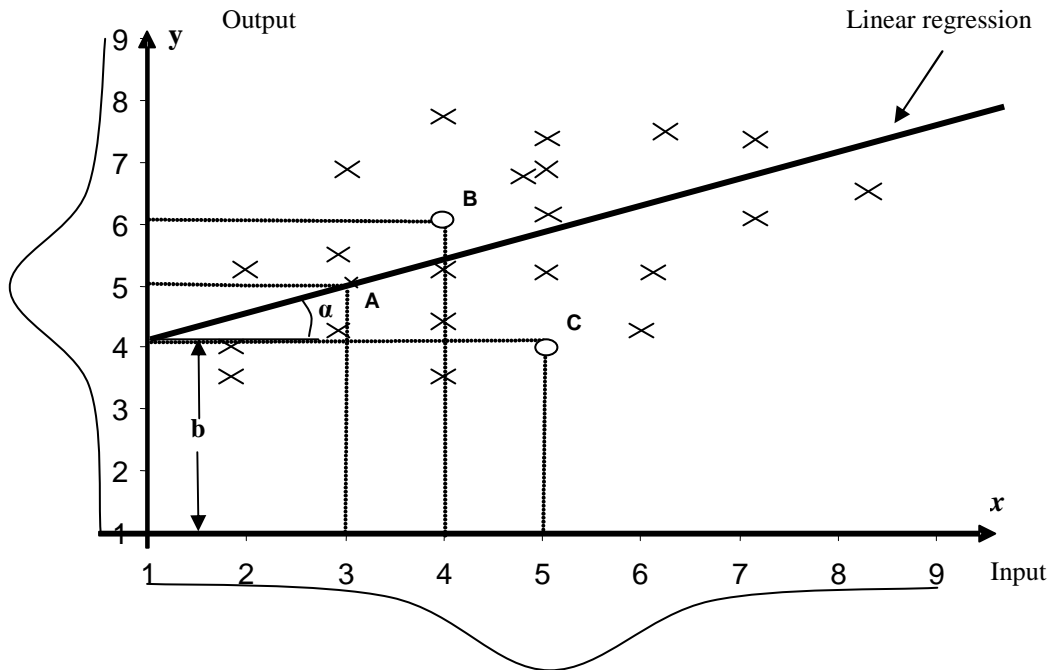


Fig. 8. The idea of linear regression analysis

Thus we can consider the linear regression analysis as a linear transformation of input results into those of output stage. Extensive secondary education results obtained by this approach are given in Wiktorzak, 2009.

In Fig. 9 we present Polish education as a chain of VPLs starting from primary school up to a secondary school level. In fact, the system includes kinder garden at its beginning and university at its end, but we do not include them in this early stage of our study. Rather than that, we focus on how the system affects human capital value of students as they progress from six-year old beginners at primary school to high school graduates (see (4)). As a measure of human capital we use marks obtained at exams at a given level of education. Thus we combine all VPLs into one virtual production line which reflects the Polish system of education and transmits a six-year child into a 19-20-year old graduate (see Fig. 9).

- 6YE – exam test after Year 6
- ME – middle school exam test
- Mat E – Matura exam (Standard Secondary School Leaving)

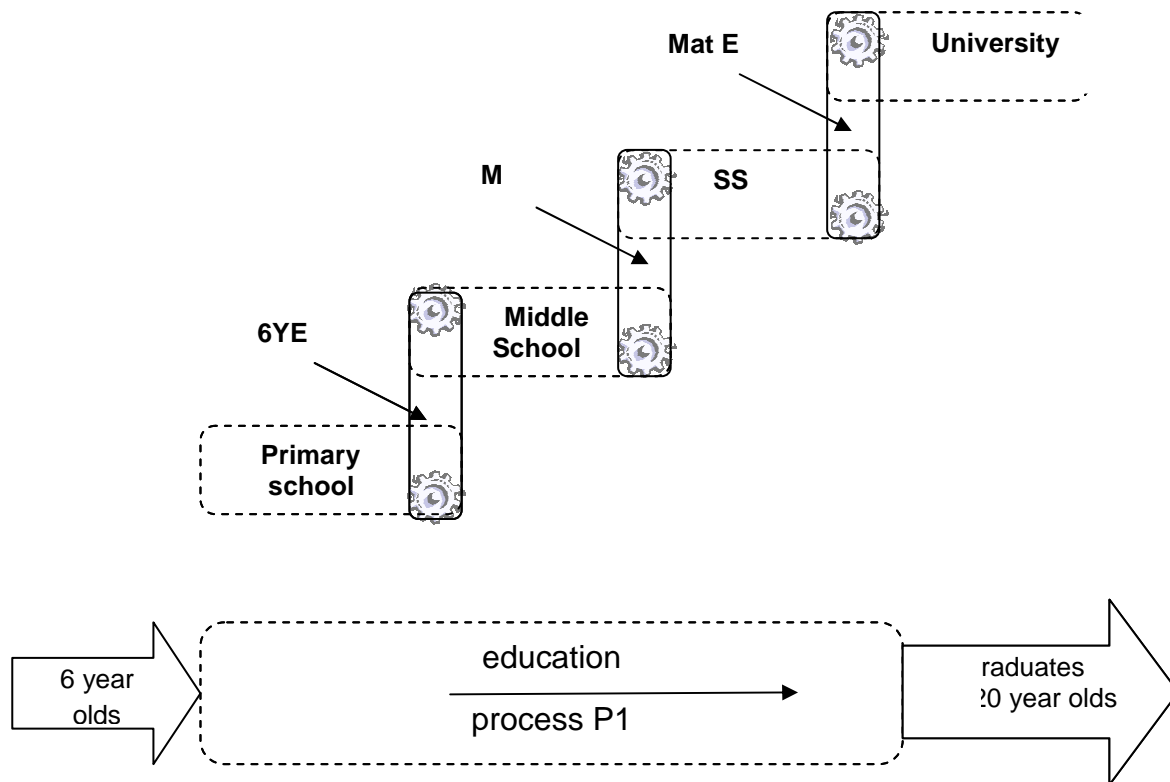


Fig. 9. Polish education as a chain of VPLs

In Poland, exams between consecutive levels of education, shown in Fig.9, differ in methodology, different subjects are chosen and results are measured on different scales. To control this, we propose to measure student's achievement as a percentage of the maximum mark obtainable at a given exam. In Fig. 10 we compare the results of Janek Kowalski (JK) with the expected results obtained by linear regression for the population of 156 students in the north-east Poland.

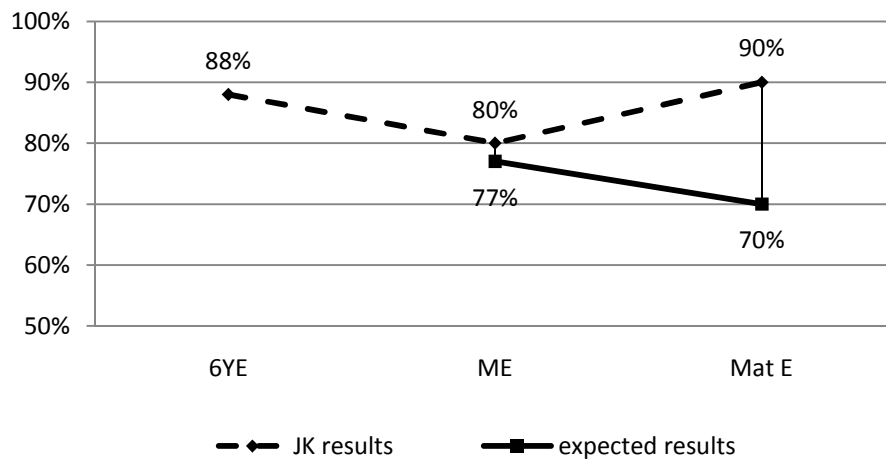


Fig. 10. Comparison of JK's achievement with the results of linear regression for  $n=156$ .

In Fig. 11 and 12 we present regression analysis results for two consecutive exams. JK scores are marked as a big dot. Although the population is small, we easily note that the regression lines are more and more horizontal as the level of education becomes higher. It can mean that insufficient care is given by teachers to good and outstanding students.

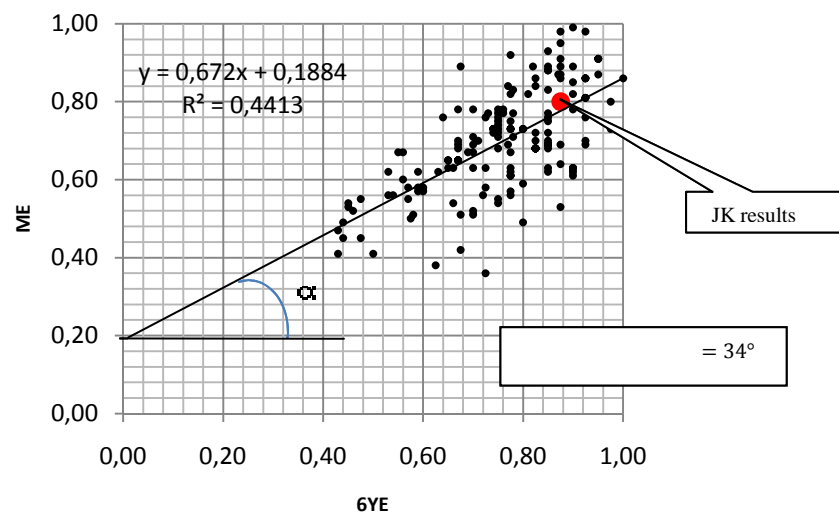


Fig.11. ME on 6 YE scores

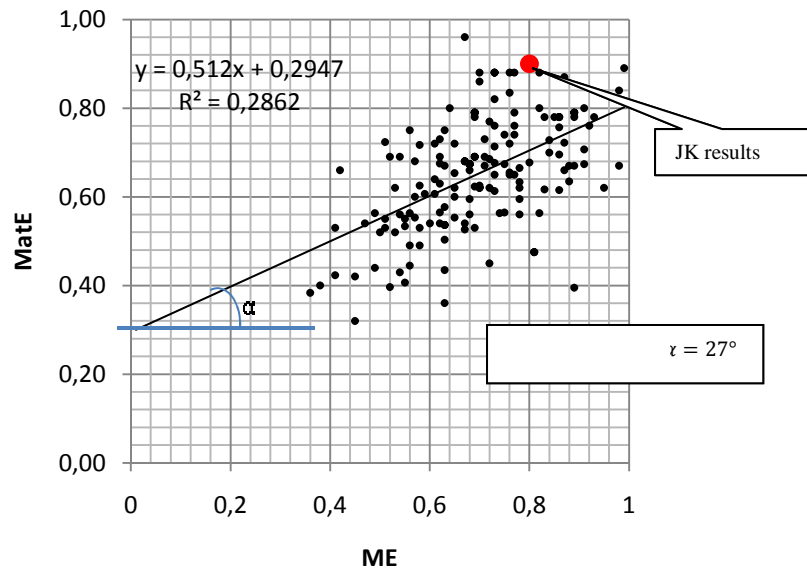


Fig.12. MatE on ME scores

## 6. Recommendations and conclusions

Although human capital build-up is a lifelong process, it is the school education from kindergarten to Ph. D. - for many - that plays a key role in it. A bit exaggeratedly perhaps, we can say that in a knowledge-based economy each community member is a capitalist with his/her own human capital and communities/regions/countries where such 'human capitalists' unite will be the most successful in global economy. Given that, we suggest considering education as one, logical and consistent system aiming at development of human and social capital of each several student and each several group of them. Let us put some light on what our goals are with a handful of recommendations (R1-R3) below.

**R1: Consistency.** Exams on each level of education should be delivered under the same methodology (the same subjects/skills, the same form, external evaluators, etc). This allows reliable and timely assessment of the development of human capital for each student or group of students and the contribution of school/university/institute to the process.

**R2: Accuracy of measurement.** For obvious reasons, the results of exams on each level of education should be assessed/evaluated on the same scale (Tomkiewicz, 2008).

**R3: From P1 to P2.** We recognise the fact that transformation from teaching more or less loosely connected courses (P1) to teaching skills (P2) requires

time, money and extra effort. Schools need more ICT, fewer students per class, a lot of change in curricula and teachers should be better assigned to tasks. Granted that it needs a step-by-step approach, it needs to start right now. P2 promotes the growth of human capital much better than P1.

The Internet is dramatically changing worldwide education. A teacher is becoming a tutor-captain helping students navigate in the practically unlimited ocean of knowledge. We are confident that VPL with its self-organization and social and human capital will stand in good stead in doing so. Self-organization matters a lot in education and with VPL, teachers can make a difference and schools 'produce genius'.

This paper should be considered as an application of systems research in education. We hope that the Orthogonality Principle and VPL, as well as the concept of human and social capital, will form a firm base for further studies.

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