

Walukiewicz, Stanislaw; Wiktorzak, Aneta

Conference Paper

Social Capital in Education

50th Congress of the European Regional Science Association: "Sustainable Regional Growth and Development in the Creative Knowledge Economy", 19-23 August 2010, Jönköping, Sweden

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Walukiewicz, Stanislaw; Wiktorzak, Aneta (2010) : Social Capital in Education, 50th Congress of the European Regional Science Association: "Sustainable Regional Growth and Development in the Creative Knowledge Economy", 19-23 August 2010, Jönköping, Sweden, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

<https://hdl.handle.net/10419/118935>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Social Capital in Education

Stanisław Walukiewicz and Aneta Anna Wiktorzak

Systems Research Institute, Polish Academy of Sciences

ul. Newelska 6, 01-447 Warsaw, Poland

E-mail: Stanislaw.Walukiewicz@ibspan.waw.pl

We consider education, and the final stage of secondary education in particular, as a number of creative processes and analyse two of them in detail: teaching knowledge/subjects (process P1) and teaching skills (process P2).

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 teaching load using a prescribed methodology, etc. In contrast to CPL, teachers on VPL will use their brains 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 experience of a division of labour into tasks (self-organization) involving the Internet, while CPL will just remain a partition of labour into a fixed number of jobs.

In practice, students enter the teaching process, or VPL, having passed the entrance examinations. They leave the process having passed the final exams (in Polish 'Matura Exam'), which happens at the age of 19 or 20, after 3-4 years of studies. We define the main objective of (secondary) education as an effort to maximise human capital of a given individual (his/her knowledge, whether codified or tacit, skills, etc.). Since, unlike financial capital, there is no commonly accepted measure yet of human capital, shall represent it by assessment marks obtained by a student in entrance and exit exams. As nature of these two exams differs substantially in Poland, we propose a way to overcome this difference. We also present P1 results for selected schools.

In part 2 we discuss P2 process. We claim that its efficiency depends heavily on social capital of a given school (cooperation of teachers, trust, etc.) Again, we will use VPL as a tool to perform necessary measures. We will introduce a problem of optimal assignment of teachers to tasks using the concept of cognitive and emotive proximity. In conclusion, we formulate suggestions for further research

1. Introduction

In this paper we first study the impact of education, upper secondary education in particular, on intangible assets of a nation - its human and social capital - then we reverse the act and study the effects of human and social capital of teachers on education. We consider education

as a number of creative processes and analyse two of them in detail: teaching knowledge (process P1) and teaching skills (process P2). While P1 has been around for centuries, P2 was brought to practice some 20-30 years ago and has become increasingly popular ever since its debut. The strategic aim of our study is to evaluate the efficiency of either. We believe that this is a first step towards achieving that goal.

In Section 2 below we briefly present the Orthogonality Principle, a basic tool in our methodology for measuring the efficiency of creative processes P1 and P2 (for details see Walukiewicz, 2008b and 2009b). To analyse such processes we will use Virtual Production Line (VPL) introduced by Walukiewicz in 2006 - a natural extension of Classical Production Line (CPL). We describe VPL in education in Section 4 and, in the next Section, we use it to model P1 process. In Section 6 we disclose our research results and, in Section 7, introduce the concept of proximity and demonstrate how it can be used for assigning teachers to tasks on a given VPL. Finally, in Conclusion, we formulate three recommendations which we strongly believe will be relevant not only for Polish but worldwide education.

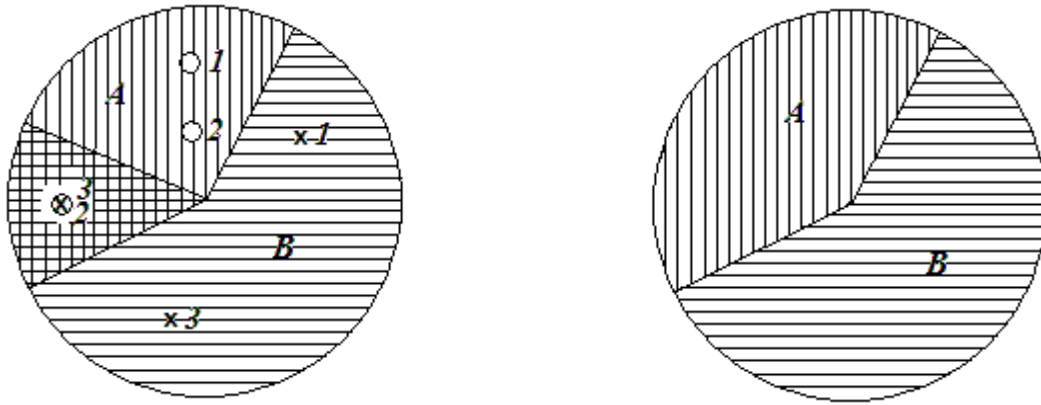
2. The Methodology

We consider a school where the processes P1 and/or P2 are in place as a (closed) system, a firm F with its inputs and outputs and with its more or less defined objective (see Fig. 1). Then 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. A school F as a system

To answer the question posed above we need to consider all, absolutely all assets of a given firm F at a time t . The fact that we analyse all assets of a given firm or a piece of reality (set) X will be represented graphically as a (full) circle (see Fig. 2). If we find X too complex (difficult) to analyse, we will divide it into two parts (subsets) A and B . Then there are two options: i) either subset A , marked by vertical lines, partially overlaps (covers) subsets B , marked by horizontal lines (their overlapping is marked as a crossed part of circle X), as shown in Fig. 2a, or ii) subsets A and B form a **partition** of X (see Fig. 2b). In Fig. 2a it is a **division** of X . What we see in the diagrams below is that a partition is a division, but not the opposite.



a) Division of X into A and B

b) Partition of X into A and B

Fig.2 The difference between division and partition

Let us assume that we determine the value of A by summing up values of its elements 1, 2 and so on, marked by circles in Fig 2a and next determine the value of B by summing up its elements marked by crosses. The second element of B in Fig. 2a is exactly the same as the third element of A , so here we have violation of a very basic rule of accounting, which says that any item/element should be taken into account once and only once. This does not happen in Fig. 2b, where we have a partition of X into A and B . Since in social sciences like economics, management, sociology and political sciences a piece of reality X cannot be represented graphically as Fig. 2a or 2b, in the following Section we formulate Orthogonality Principle which regulates when two forms (concepts, categories, processes, dimensions etc.) A and B are disjoint, as in Fig. 2b, or orthogonal.

Orthogonality Principle: Two forms (concepts, categories, processes, dimensions, etc.) A and B are **orthogonal** or **disjoint** if and only if there exists an objective, simple, one-dimensional **decision rule** of the yes-no type, by which we can always and everywhere decide whether an object from the considered part of reality X belongs either to A or to B .

Now we discuss four conditions we put on the decision rule in the Orthogonality Principle. The condition '**objective**' means that the application of the decision rule does not depend on who, where and when applies it. A decision is '**simple**' when it can be formulated in one-two plain language sentences. To illustrate, let X be a balance sheet of a given firm F , then a decision rule given in academic lingo on, say, 10 pages to understand what accountants should study in academic books is obviously far from simple. For the same reason, we require a decision rule to be **one-dimensional** and of the **yes-no type** as it impractical to assume that in a foreseeable future accountants will start using multicriteria decision making techniques or the fuzzy set theory in their everyday practice.

Since the Orthogonality Principle plays a key role in our considerations, we shall represent it in a mathematical (set theory) format. The Orthogonality Principle **partitions** a nonempty set X into two and only two nonempty sets A and B such that

$$X = A \cup B, A \cap B = \emptyset, A \neq \emptyset, B \neq \emptyset. \quad (1)$$

Consider a plate (our set X) dropped down on the floor. If it breaks, then we have a **partition** of X into at least two pieces. The graphical interpretation of the Orthogonality Principle is given in Walukiewicz, 2008b.

Using the Orthogonality Principle Walukiewicz proved that tangible assets (capital) of firm F are disjoint or orthogonal to its intangible assets. The decision rule here says that tangible assets (money, buildings, machines, energy, software, patents etc) can be physically measured, whereas intangible assets (competences, experiences, talent, trust, cooperation etc., but also distrust, suspiciousness etc.) cannot. Similar reasoning allows us to prove that two forms of tangible assets: financial capital (money, savings, debts etc.) and physical capital (buildings, furniture, computers etc) are disjoint/orthogonal to each other since there exists a decision rule dividing tangible assets into such two subdivisions, see Walukiewicz, 2008b and 2009.

It is a common belief that intangible assets are extremely difficult to analyse and evaluate (see e.g. Sobel, 2002; Quibria, 2005, but also Arrow, 1999; Chow, 2006; Edvinsson and Malone, 1997; Edvinsson, 2002; Li, 2007; Lin, 2001; Pownar, 2006; Putnam, 1995 and 2000; Sabatini, 2005; Westlund, 2006). For such complex objects we apply our idea from Fig. 2 and divide all intangible assets of a given firm F into two forms: human capital and social capital. We prove (see Walukiewicz, 2008b and 2007) that these two forms are disjoint or orthogonal. The decision rule here says: one man – human capital, two or more – social capital. It is easy to see that such a decision rule satisfies all four conditions of the Orthogonal Principle. In other words, human capital is always associated with a single human being, more precisely with his/her competences, experiences, talent, health etc., while social capital is always connected with a group of at least two people, the way they cooperate, how much they trust or distrust each other etc. So the kind of relationship between two individuals is a very basic component of social capital. Anyway, whatever the standard to measure intangibles (money, scoring points, etc.), we can add up human and social capital, though obviously, we cannot add dollars to points - human and social capital should be measured in the same units on the same scale. All in all, however, Fig 2b shows the relation between human and social capital.

Relationships around the world, our firm F included, can be divided into two very broad categories: formal and informal. The analysis of social capital would be much, much easier if these two forms are orthogonal. Unfortunately, Li 2007, p. 229, demonstrated that we need a 5-dimensional decision rule to distinguish between formal and informal relations, which leaves them not disjoint or orthogonal to each other (see Fig. 2a) and we cannot add their values. According to Li 2007, p. 229, the five dimensions we need are the following:

- i. **Codification.** Formal relations are explicitly prescribed in constitutions, codes, regulations etc., while informal are not.
- ii. **Formation.** Formal relations are exogenously imposed by history, experiences, tradition etc., while informal are endogenously embraced.
- iii. **Enforcement.** Formal relations are or should be rigidly enforced by law with its vertical structure, while informal are flexibly enforced by horizontal peer pressures.
- iv. **Power.** Formal relations are executed/realised by vertical authority powers, while informal make all people equal, on the same level.
- v. **Personalization.** Formal relations are between depersonalised posts/ranks etc., while informal are between people with all their merits and faults.

In Section 6 we will study much narrower concept of proximity and apply the Orthogonality Principle to it. We conclude that the Orthogonality Principle is a heart of the **static model** for social capital analysis, in which we consider it as a static value at a given moment t .

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.3), 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. 3 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.4), 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)**.

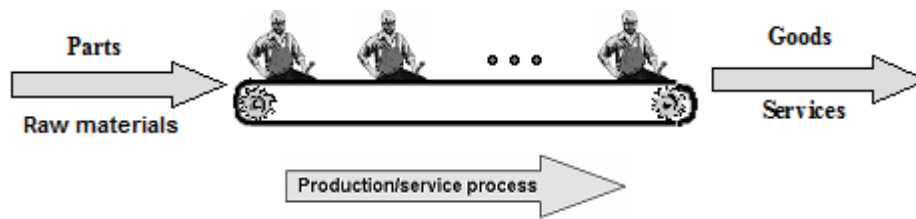


Fig. 4 Classical Production Line (CPL)

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. 7).

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. with their laptops, computers, data bases, etc. (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. How VPL works in education we describe in the next Section.

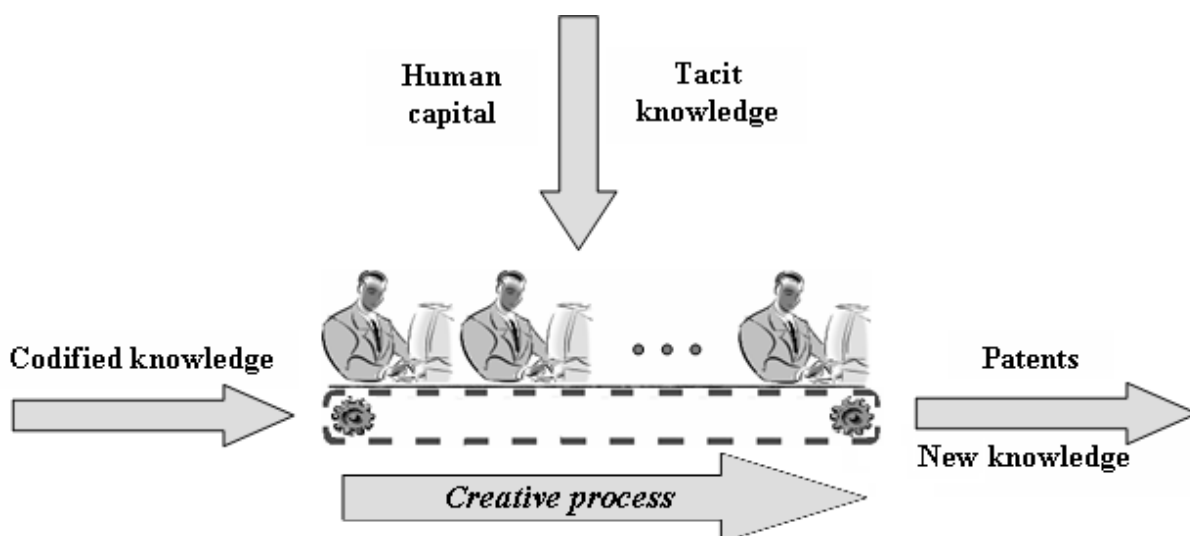


Fig. 5 The concept of Virtual Production Line (VPL)

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.

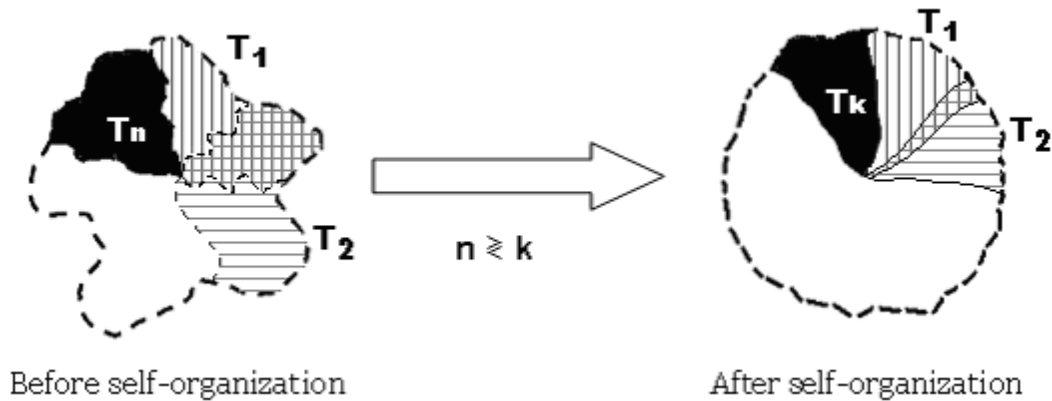


Fig. 6 VPL as a flexible division of labour and self-organization

In Fig. 6 we see that at the beginning of creative process, the problem is 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. The problem is initially divided into n tasks T_1, T_2, \dots, T_n , then, after self-organization, into k tasks T_1, T_2, \dots, T_k , where k can be equal, bigger or smaller than n . We conclude that VPL allows a **flexible division of labour**, while CPL is based on a **rigid (stiff) partition of labour** (see Fig. 11), where production/servicing process is minutely defined - a circle below - jobs J_1, J_2, \dots, J_n do not overlap and limits between them are straight lines.

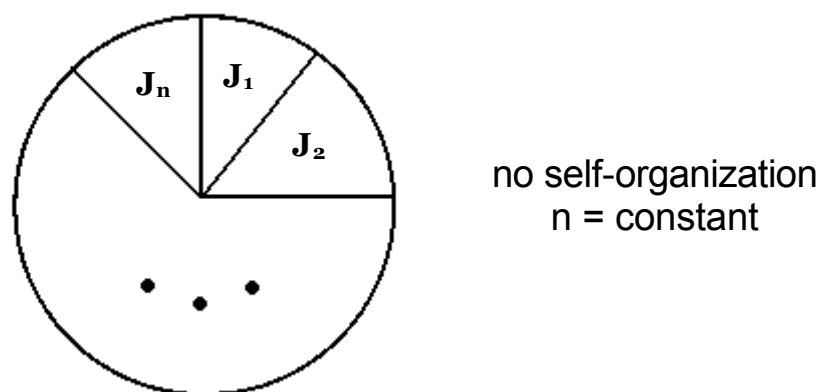


Fig. 7 CPL as a rigid partition of labour

Definition 2. Virtual Production Line (VPL) is a division, in general not a partition, of a complex creative process into more or less precisely described tasks (jobs), combined with modern ICT. The division of the creative process into tasks as well as the number of tasks may be changed throughout the process by actions of experts involved in it. Such a

modification is called **self-organization of virtual production line**. Self-organization may recur over the creative 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 can now make two conclusions:

Conclusion 1 (The Past). Modern ICT increases substantially the efficiency and the value of social capital.

This is true insofar as 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 we began to be able to send information electronically to virtually every corner of the world at almost zero cost. John Chambers, chairman and chief executive of Cisco, world's biggest maker of data networking equipment, gives a good example of the importance of ICT in solving business problems (by our standards, running VPL). Cisco's acquisition in 2005 of Scientific Atlanta, a maker of set-top cable boxes for US \$ 6.9 billion took 45 days. The popular feeling was that the contract was signed, or VPL run, at a break-neck speed. 18 months later, in 2007, Cisco paid US \$ 3.2 billion for Webex, a web conferencing and on line collaboration company. With a new high-end videoconferencing system, the entire process, including the signing of the final contract, took only 8 days. "There was no data room, it was virtual" – says Mr. Chambers (for details see FT of July 16, 2007). The problem was solved, or the VPL run, in only 8 days.

Conclusion 2 (The Future). The history of improvement/development of CPL delineates directions for research on VPL. In fact, VPL is a natural development (phase) of CPL.

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 9). Otherwise stated, it is a device on which social capital of firm F makes money (financial capital) for that firm 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.). VPL is a heart of the **dynamic model** for social capital analysis.

4. VPL in education

In this Section we will see a secondary school (our firm F) as a closed system where a number of creative didactic processes are realized. With an example of P1 process – teaching knowledge - and P2 – teaching skills, we will demonstrate how useful VPL is in modeling and analysis of such processes (see Fig. 8).

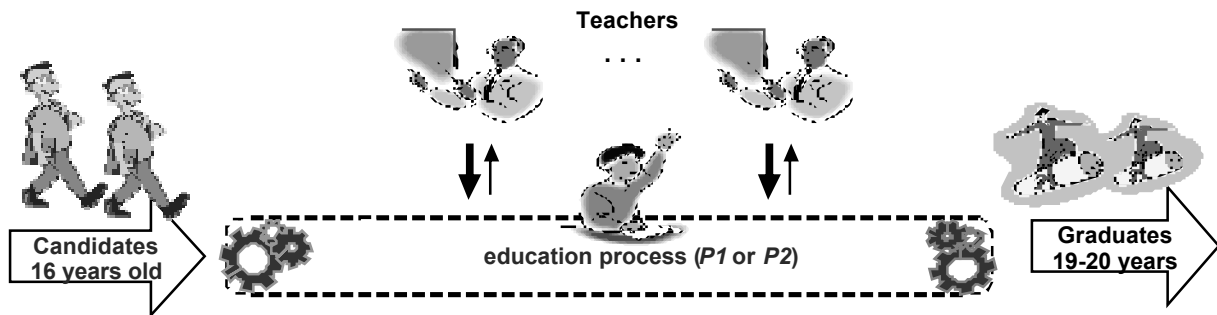


Fig. 8 VPL in education

At the input are students who enter the school at age 16, with their knowledge, physical and mental competency level, health and other human capital (HC) aspects. By $v(HC, s_i, t)$ we will 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. We will further use $v(HC, t)$ and skip the symbol s_i when human capital is not confined to a single individual and can e.g. be a collective figure for all students in a class. Meanwhile, human capital has a lot of similarities to financial capital and, in general, should be measured in monetary units (see Walukiewicz, 2008b and 2009). One of very important features of human capital is its **cumulative property**: knowledge, experiences, etc. of students are cumulated throughout their education. We never assume however, that $v(HC, t)$ would only increase in time. Students obviously attend school to increase their human capital, but since it does not always work that way, we also provide for otherwise. We assume that $v(HC, t)$ at the entrance of school F equals the exit value $v(HC, t_0)$ at leaving the previous school. Presently in Poland, $v(HC, t_0)$ is determined by the standard (all-Poland) middle school exit exam.

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), with the value of human capital of a given student denoted as $v(HC, s_i, t_k)$. During these k years, in P1 process students are instructed a given set of subjects (tasks) in a prescribed sequence, teaching load and methodology carefully selected. In contrast to CPL, teachers on VPL mostly think, use their brains to e.g. divide the teaching process into a sequence of tasks including human and social capital of students - we will call this **self-organization (of P1 process)** on VPL. So VPL is then defined as 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, such a process as above never happens in isolation, but given its complexity, in our first attempt to model it we assume that the community (parents, school administration etc.) take all their concerns to the teacher and exert all the pressure on them, affecting 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 in the other direction. Note the different arrows in Fig. 8.

Concluding, let us emphasise two points. First, unlike CPL, VPL in education is normally nonlinear - a given teacher can teach e.g. physics one year and in the next year chemistry. Second, the concept of human capital in education is much, much wider than the mere measurement 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 in education, particularly in school administration (electronic class register, data bases etc.). Obviously, a lot of practical and legal problems have to be discussed and solved before that, but these questions are not the subject of the present paper. On VPL we never treat students as parts or components on CPL, but on the other hand, with the human capital concept we can investigate all, absolutely all, characteristics of a given student (his/her knowledge: codified and tacit, experiences, talent, health etc.). In the next Section, based on the Ph. D. dissertation of Wiktorzak, 2009, 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. It can be viewed from at least two perspectives:

- i) **Student (s_i) perspective.** Here, the utility of simple subtraction

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

is markedly low. In Poland, different methodologies are applied to exam 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 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)**.

- ii) **Statistical perspective.** In this approach we compare statistical parameters, such as the mean value, standard deviation, etc. for a population at t_0 and t_k .

The idea of linear regression analysis for input/output exam scores scaled on the **standard nine** scale is given in Fig. 9.

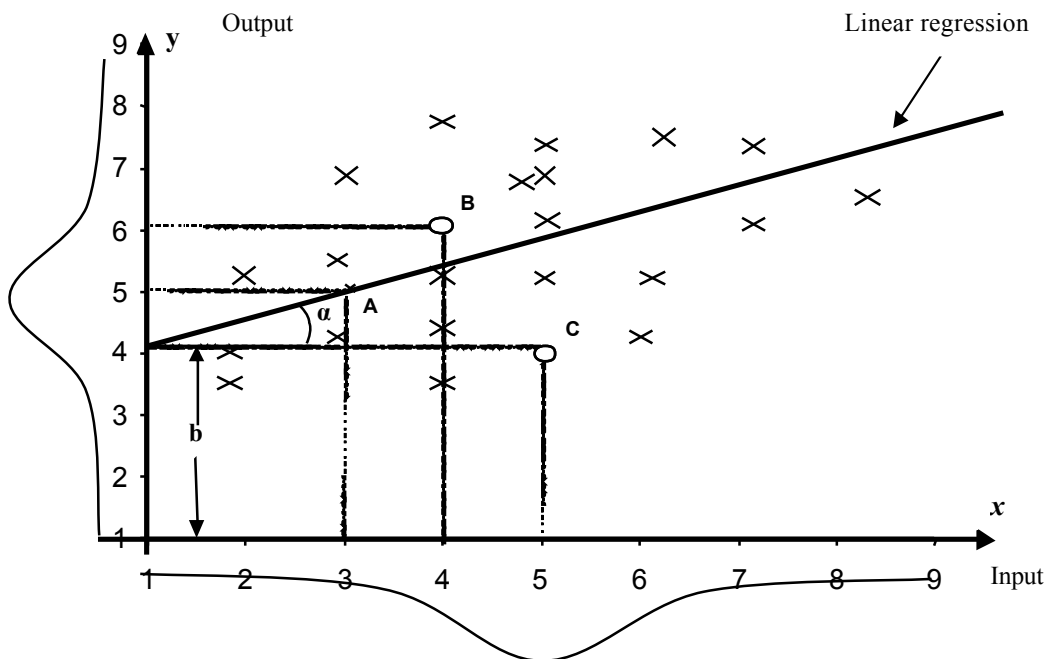


Fig. 9 The idea of linear regression analysis

We can consider the linear regression analysis as a linear transformation of input results into those of output stage. For such a transformation we have

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**

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

Extensive secondary education results obtained from the first approach are given in Wiktorzak, 2009. As an example, in Fig. 10 we provide results for first 30 students in a sample with $n=180$.

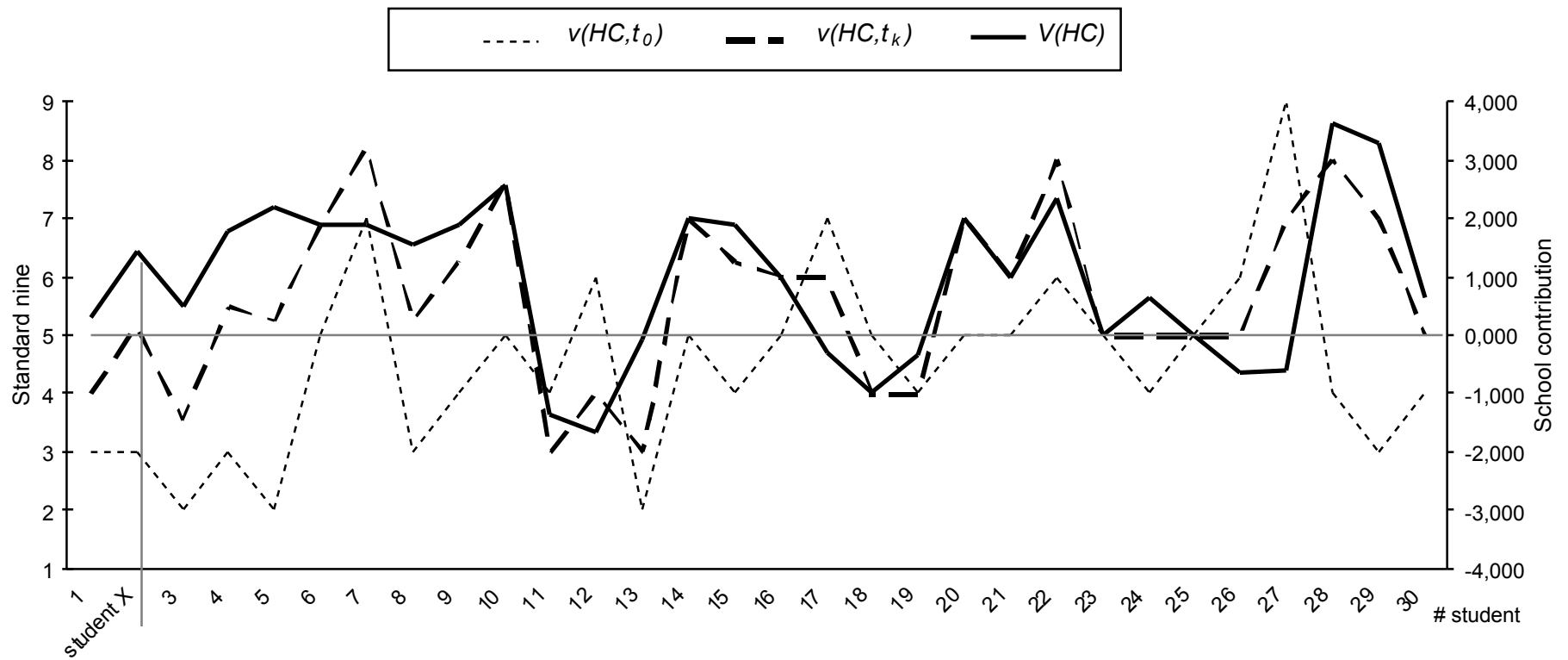


Fig. 10. Results for P1

6. Proximity and Process P2

Extensive collaboration between teacher educators plays a key role in P2 process of teaching skills. In Section 2 we demonstrated that such a collaboration is not a function of formal or informal relationships between teachers since they are not disjoint (see Fig 2a). Let us now introduce a much tighter concept of proximity to address a relationship between teachers aimed at teaching skills on VPL at school F . The concept of proximity was introduced and developed by the French proximity school (Torre and Gilly, 2000; Torre and Rallet, 2005; Rallet and Gilly, 1999), and recently studied by Menzel, 2006.

Proximity literally means nearness, closeness, contiguity and propinquity. We will use this proposition to describe relations between different actors working on VPL, a central concept in our analysis of social capital. Like capital, proximity is complex and multidimensional and depends on time. Moreover, proximity, as we demonstrate below, is a subjective concept. Menzel, 2006 demonstrated in a deductive way that there are four forms or dimensions of proximity. As with capital (see Walukiewicz, 2008b), we will provide an indicative description of each, employ the Orthogonality Principle and show that they are either mutually orthogonal or disjointed. We will define them in a standard way, always referring a creative problem to VPL. The order of presentation matters.

The four forms of proximity are as follows:

1. **Technological proximity (TP)** or **cognitive proximity** - describes the so-called cognitive distance (Nooteboom, 1999) between two experts E and H , differences and similarities in the shared knowledge (both codified and tacit) relevant to problem solving, technological distance between them, etc. Technological proximity between experts E and H exists, or they are technologically close, if technology-related collaboration between them is possible for a given moment/period of time t in the “past”, “present” or “future” on a given VPL or solving a given problem. This is the most complex form of proximity and it depends on VPL (problem).
2. **Emotive proximity (EP)** is related to personal relations, emotions, common experiences, trust, etc. between two particular experts as human beings. Emotive proximity forms a social environment which always surrounds any such cooperation. Emotive proximity between two experts E and H exists if such cooperation between them as two human beings is possible for a period of time t in the “past”, “present” or “future”. This form of proximity does not depend on VPL (problem).
3. **Spatial proximity (SP)** describes the geographical (spatial) context of cooperation, the ability and possibility of actors to engage in face-to-face contacts. We note that in the Internet era spatial proximity is not a permanent thing but generated temporarily, whenever necessary (Torre, 2006). Scientific conferences, kick-off meetings, industrial fairs, working lunches/dinners, etc. are examples of spatial proximity. Spatial proximity exists between two experts E and H when it is possible for them to engage in face-to-face contacts, whenever necessary, for a period of time t in the “past”, “present” or “future” on a given VPL (problem).
4. **Organizational proximity (OP)** describes the organizational context of a relationship, a structure or framework (like firm, network, cluster, etc.) that defines contacts between experts. Menzel, 2006 calls it structural proximity. Organizational proximity between

two experts E and H exists if it is possible for them to cooperate within a given organizational structure at any time t in the “past”, “present” or “future”. It does not depend on VPL (problem). It is the simplest form of proximity.

The first two proximities describe direct interactions (relationships) between experts, teams, etc., therefore we call them **direct proximities (DP)**. We hardly imagine robots working on a given VPL, i.e. solving a given problem, although the work of experts on VPL will be changing alongside the improvement of ICT – see Cisco case in Section 3. Once again, direct proximities are always connected directly with human beings. The other two proximities describe indirect factors that influence contacts between humans, so we call them **indirect proximities (IDP)**. All in all, proximity is a subjective description of a relationship done by an expert or experts involved.

We have defined the above four forms of proximity in a very specific way to facilitate introduction of **the utility measure u of a given proximity**, called in short **proximity u** . It is a binary function defined in the following way:

Definition 3. Technological proximity between experts E and H equals

$$u(TP, E, H, t) = \begin{cases} 1, & \text{if } E \text{ has a technology-related collaboration with } H \\ 0 & \text{otherwise} \end{cases}$$

for any time t of their mutual relation in the “past”, “present” or “future” on a given VPL.

In a similar way, we can define **emotive proximity $u(EP, E, H, t)$** , **spatial proximity $u(SP, E, H, t)$** and **organizational proximity $u(OP, E, H, t)$** .

We observe that - in general - emotive proximity is **asymmetric (ASP)** - the fact that e.g. expert E trusts expert H at a given moment t on a given VPL does not imply that H trusts E at the same moment t on the same VPL. So,

$$u(EP, E, H, t) \neq u(EP, H, E, t).$$

The same reasoning shows that technological proximity is asymmetric too but spatial and organizational proximities are **symmetric (SSP)**. Thus we formulate

Lemma 1. Both technological proximity and emotive proximity are asymmetric, therefore direct proximities are asymmetric. Both spatial proximity and organizational proximity are symmetric, therefore indirect proximities are symmetric.

In practical terms, to gauge symmetric proximity we can choose to ask only one expert, E or H , but to gauge direct or asymmetric proximity we will have to ask both, E and H , regardless of questionnaire type. A somewhat more elaborated approach to measuring technological proximity is studied in Walukiewicz, 2008b.

One may easily observe a striking likeness between the four forms of capital and the four forms of proximity. Since each form of proximity may be considered as a two argument relation or a binary function of two variables, we can now employ the Orthogonality Principle to analyse their relationships.

Clearly, asymmetric and symmetric proximities are mutually disjoint or orthogonal. Here the decision rule is whether

$$u(.,E,H,t) = u(.,H,E,t),$$

where the dot stands for any of the above four forms of proximity.

Consider an instance of technological cooperation (technological proximity) between two experts E and H on a given VPL looking for a solution to a given problem. Since such cooperation may or may not be going on another VPL and emotive proximity is always surrounding any contact between E and H , then technological proximity is disjoint or orthogonal to emotive proximity. Since spatial proximity is defined by face-to face contacts (geography) and organizational proximity concerns organizational structures, then they are disjoint or orthogonal to each other. That way we prove

Lemma 2. Technological proximity, emotive proximity, spatial proximity and organizational proximity are mutually disjoint or orthogonal and form a partition of proximity as entirety.

In our analysis of P2 process we divide all courses and programmes instructed at a given secondary school into 6 groups and consider collaboration of teachers from different groups. We naturally focus on their technological and emotive proximity since the remaining two proximities must be in place and clearly need no proof. The results of the study are in Wiktorzak, 2009.

A good (optimal) assignment of workers (blue collars) to operations (jobs) determines the efficiency of CPL. There are thousands of academic text-books and papers on that, offering theory or providing practical guidance. No wonder the emphasis should be on optimal assignment of expert to tasks on VPL. We believe this will be a major concern in social capital analysis in the years to come. We come back to this issue in conclusions to this paper, by reference to P2 process.

We assume that we have a “core” team of teachers ready to teach skills at our school F and we would like to hire a few new teachers in order to maximise the value of the school in the coming years. Thus we propose the following

Sequential assignment problem (on VPL). For a given “core” team of teachers on VPL, assign new teachers, one by one, from a given set of candidates E_1, E_2, \dots, E_n , taking into account their technological (cognitive) and emotive proximity to optimise the value of social capital of “extended” VPL.

7. 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 (Tomkowicz, 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 better assigned to tasks. Although it should be done step by step, it needs to start right now. P2 supports much more the development of human capital than P1.

The Internet is changing education dramatically. A teacher is becoming a tutor helping students in navigation on the practically unlimited ocean of knowledge. We claim that VPL with its self-organization and social and human capital load is a useful tool in it. Self-organization matters a lot in education and with VPL, an ordinary teachers can 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, form a firm base for further studies

8. References

Arrow, K.J. (1999) *Observations on Social Capital, in Dasgupta and Serageldin, eds.*

Chou, Y. K. (2006) *Three simple models of social capital and economic growth*, The Journal of Socio-Economics, **35**, 889-912.

Dasgupta, P. and Serageldin, I. (1999) *Social Capital: Multifaceted Perspective*, Wold Bank, Washington, DC.

Edvinsson, L. and Malone, M. S. (1997) *Intellectual Capital. The Proven Way to Establish your Company's Real Value by Measuring its Hidden Brainpower*, HarperBusiness, London.

Edvinsson, L. (2002) *Corporate Longitude*, Pearson Education, London.

Li, P. P. (2007) *Social tie, social capital, and social behavior: Toward an integrative model of informal exchange*, "Asia Pacific J. Management", **24**, s.227-246.

- Lin, N. (2001) *Social capital: A theory of social structure and action*, Cambridge University Press, New York.
- Menzel, M.-P. (2006) *Dynamic Proximities. Towards a Concept of Changing Relations*, presented at 5th Proximity Congress, Bordeaux, 2006.
- Niemierko, B. (2009) *Diagnostyka edukacyjna*, Wydawnictwo Naukowe PWN, Warszawa.
- Niemierko, B. (2009) *Grade Equivalent as a Measure of Value Added for Student and School achievement*, submitted to Polish Journal of Social Science, Warsaw.
- Nooteboom, B. (1999) *Innovation, Learning and Industrial Organization*, Cambridge Journal of Economics **23**, 127-150.
- Parkin, M. (2000), "Economics", 5th edition, Addison-Wesley.
- Powar, M. (2006) 'Social' 'capital', The Social Science Journal, **43**, 211-226.
- Putnam, R. (1995) *Bowling Alone: America's Declining Social Capital*, Journal of Democracy 6, 65-78.
- Putnam, R. (2000) *Bowling Alone: The Collapse and Revival of American Community*, Simon and Schuster, New York.
- Quibria, M. G. (2005) *The Puzzle of Social Capital: Critical Review*, MPRA Paper No. 2640, <http://mpra.ub.uni-muenchen.de/2640/>
- Rallet, A. and Torre, A. (1999) *Is Geographical Proximity Necessary in the Innovation Networks in the Era of Global Economy?*, GeoJournal, **49**, 373-380.
- Sabatini, F. (2005) *An Inquiry into the Empirics of Social Capital and Economic Development*, PhD Programme in Political Economy, Department of Public Economics, University of Roma La Sapienza.
- Sobel, J. (2002) *Can We Trust Social Capital?*, Journal of Economic Literature, XL, pp139-154.
- Solow, R.M. (1999) *Notes on Social Capital and Economic Performance in Dasgupta and Serageldin*, eds.
- Sveiby K.-E. (1996, 1997, 2001) *The Intangible Assets Monitor*, <http://www.sveiby.com/Portals/0/articles/CompanyMonitor.html>
- Tomkowicz, J. (2008) *Development and use of vertical scales to measure student achievement*, in Niemierko, B. and Szmigiel, M. K. (eds) *Uczenie się i egzamin w oczach nauczycieli*, PKDE, Kraków.
- Torre, A. (2006) *Clusters and Temporary Geographical Proximity*, presented at ERSA Conference in Volos (Greece).
- Torre, A. and Gilly J. P. (2000) *On the Analytical Dimension of Proximity Dynamics*, Regional Studies, **34**, 169-180.
- Torre, A. and Rallet, A. (2005) *Proximity and Location*, Regional Studies, **39**, 47-59.
- Walukiewicz, S. (2006a) *Systems Analysis of Social Capital at the Firm Level*, Working Paper WP-1-2006, Systems Research Institute, Warsaw.
- Walukiewicz, S. (2006b) *Trzy modele do analizy kapitału społecznego, (in Polish), w "BOS 2006 Wiedza systemowa" pod red. Stachowicz J., Straszak A., Walukiewicz S., 25-40.*

- Walukiewicz, S. (2007) *Four Forms of Capital and Proximity*, Working Paper WP-3-2007, Systems Research Institute, Warsaw.
- Walukiewicz, S. (2008a) *Piękno liczby cztery (w naukach społecznych)*, (in Polish), Working Paper WP-2-2008, Instytut Badań Systemowych PAN, Warszawa.
- Walukiewicz, S. (2008b) *The Dimensionality of Capital and Proximity*, Proceedings of ERSA 2008, Liverpool, August 27-30, 2008.
- Walukiewicz, S. (2009a) *Zasada Ortogonalności i przykłady jej zastosowań*, (in Polish), Working Paper WP-1-2009, Systems Research Institute, Warsaw.
- Walukiewicz, S. (2009b) *Orthogonality Principle*, Proceedings of ERSA 2009, Łódź, August 25-28, 2009.
- Walukiewicz, S. and Dewalska-Opitek, A., (2008) *WP5: Regional Case Studies – SILESIA*, Working Paper WP-1-2008, Systems Research Institute, Warsaw.
- Wiktorzak, A. A. (2009) *Analiza systemowa i obliczenia inteligentne w modelowaniu kapitału ludzkiego i społecznego na przykładzie szkoły ponadgimnazjalnej*, (in Polish), Rozprawa doktorska, Instytut Badań Systemowych PAN, Warszawa.
- Westlund, H. and Bolton, R. (2003) *Local Social Capital and Entrepreneurship*, Small Business Economics, **21**, 77-113.
- Westlund, H. and Nilsson, E. (2005) *Measuring Enterprises' Investments in Social Capital: A Pilot Study*, Regional Studies, **39**, 1079-1094.
- Westlund, H. (2006) *Social Capital in the Knowledge Economy. Theory and Empirics*, Springer, Berlin, Heidelberg.