Human or Technological Resources? A Dilemma in Education Provision

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Abstract: Results of the Program for International Student Assessment (PISA2012) of the OECD conclude that two of the strong education performers countries, Finland and Korea, have been able to effectively educate every child regardless their socioeconomic level. To do so, each country has implemented different strategies, leading to very different forms of education provision. While Finnish emphasise on high trained and empowered teachers, student early intervention and weekly (multidisciplinary) team teachers meetings, Koreans encourage student hard work (in and out of school) and active learning by integrating ICTs in their daily learning (digital textbooks and cyber-home) which is complemented with parent support/interest. These two ways of providing education clearly raises the question of the role played by human resources and/or technology in education provision. To do so, we use each countries individual sample of the PISA-2012 database at student and school levels, and given the nested nature of the data, we employ multilevel models. Estimations have been made from a comparative approach, in a case-to-case basis. Results suggest that human resources and technology influence student outcomes in both cases. Yet, for both countries a common set of technologies influence the overall set of outcomes.

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INTRODUCTION

A way to understand how education services are provided is by analysing education from a service perspective. Service and service innovation theory (Gallouj and Weinstein, 1997; Gallouj 1994, 2002) provides a powerful framework to understand (and measure) how education is provided by breaking down and representing education as a set of (service and social) characteristics, and more important, it clearly grips with and reveals ways to improve its dynamics, by modelling innovation in education and education (service) innovations. Galloujs & Weinstein's (1997) theoretical construct bases its fundamentals on the work of Lancaster (1966, 1971) and Saviotti-Metcalf (1984), by linking the intrinsic characteristics of education to a set of underpinning technical characteristics and competencies. Improvements in the technical characteristics and/or (actor's) competencies can lead to enhance the quality of the associated education characteristics that are of interest to students. This theoretical construct suggest that education (intrinsic) service characteristics (outputs) may depend on a bundle of technical characteristics and/or competencies, but more important, it also suggest possible overlapping of a bundle of technical characteristics and competencies underpinning (a single or) a set of service characteristics.

This latter concern is prominent to the point that Gallouj and Weinstein (1997) suggest that depending how technical characteristics, competencies and final service characteristics change or recombine will lead to different modes of innovation, clearly emphasising a specific relationships between each sets of characteristics. In fact, this issue has been highlighted by Windrum's (Windrum et al, 2009) reading over the Saviotti and Metcalf (1984) model relating technical and service characteristics - clearly extensible to the enhanced Gallouj and Weinstein's (1997) model - emphasising the possible existence of multiple and complex relationships between clusters of technical and service characteristics, but more interesting, the fluidity of their relationships over time. These considerations imply that education can become a complex service[1] in the sense that the delivery of education can combine several interfacing possibilities between learners and education providers influencing education outcomes in different ways.

Recent results of the Program for International Student Assessment (PISA 2012 Results in Focus, 2013) of the OECD[2] conclude that two of the strong education performer's countries, Finland and Korea, have been able to effectively educate every child regardless their socioeconomic level (including their origin or ethnicity)[3]. To do so, each country has implemented different strategies, leading to very different forms of education provision. While Finnish emphasise on high trained and empowered teachers, student early intervention

[1] Given the complexity of education services, OECD/CERI has launched several projects aimed to better understand its dynamics. Projects developed are Education and Social Progress, Governing Complex Educational Systems (GCES), Innovative Learning Environments (ILE), Innovative Teaching for Effective Learning and the Innovation Strategy for Education and Training.
http://www.oecd.org/edu/ceri/innovationstrategyforeducationandtraining.htm

[2] http://www.pearsonfoundation.org/oecd/ and http://www.oecd.org/pisa/keyfindings/pisa-2012-results.htm

[3] Recent results of the PISA 2012 conclude that both countries (Finland and Korea) combine high levels of performance with equity in education opportunities (PISA 2012 Results in Focus, 2013)

(special lessons and individual support) and weekly (multidisciplinary) team teacher (and other school staff[4]) meetings, Koreans encourage student hard work (in and out of school) and active learning (participatory, creative and independent) by integrating ICTs in their daily learning (digital textbooks and cyber-home) which is complemented with parent interest. From the service and service innovation theory perspective, these two ways of providing education clearly raises the questions of the role played by human resources and/or technology in education provision, but also (at the same time), the validity if the same set of technical characteristics and competencies influence several (and different) education outcomes (e.g. math, science and reading)[5]. Considering these facts, our research hypothesis guiding our work will be:

Hypothesis 1: Service and service innovation theory suggests that education outcomes are underpinned by a bundle of technical characteristics and competencies, but at the same time, possible overlapping vectors of these characteristics can exist influencing several but different outcomes (Gallouj and Weinstein, 1997; Windrum et al, 2009). Our first hypothesis will be to contrast to which technical characteristics and competencies influence several (but different) education outcomes (as measured by PISA 2012, namely 15 year old students math, science and reading test scores) for each of our cases analysed.

Hypothesis 2: Given the fact that different ways to provide education are equally effective (OECD/PISA 2014), our second hypothesis will be to (find out and) contrast to what extend the same technical characteristics (technology) and/or competencies (human resources) influence several but different education outcomes (as measured by PISA2012, math, science and reading test scores).

To do so, we will use each countries individual sample of the PISA-2012 database at student and school levels, and given the nested nature of the data, we employ multilevel (or hierarchical linear) models. Estimations have been made from a comparative approach, in a case-to-case basis. In the best of our knowledge, there is little evidence in research covering these issues (assessing education from a service and service innovation perspective) from an empirical point of view[6].

With this purpose, this paper is structured as follows. Section 2 presents the theoretical framework describing/representing education as a set of service (and social) characteristics, framing the link between the intrinsic characteristics of education to a set of underpinning technical characteristics and competencies. In the following sections, we present the data used, countries samples of the recently launched PISA2012 database, and describe the variables, namely those related to the technical characteristics, actors competencies and education (intrinsic) characteristics - 15 year student test scores in the domains of reading,

4 Which can include among others, pedagogues or school principals.

5 A third question would be how technical characteristics and competencies influence several (but different) final service characteristics over time. Given the data analyzed, this question becomes difficult to answer at this stage.

6 Examples in this field addressed by the service and service innovation literature are Miles (1961) and Fuch (1965) or more recently Soette and Miozzo (1989) and Miozzo and Soette (2001) which aim to explain (uncover, classify or even theorize) the complexity of relation between "technical (or actors competencies) and service characteristics" of general services, including education.

math and science (Section 3), and the methodology used, two-level hierarchical models (students in schools) are described and justified, including specification steps followed for modeling each case that gives answer to each of our research hypothesis (in Section 4). Section 5 presents the results and discussion, including a brief robustness analysis. Section 6 presents the concluding remarks and the general conclusions.

2. THEORETICAL FRAMEWORK: EDUCATION AS A SET OF CHARACTERISTICS

Education as a service has some specific characteristics; it is intangible, interactive, requires certain simultaneity and can be defined in terms of co-production. Furthermore, this service traits, involve human relations, which lead to social (and community) interactions, suggesting that learners and educational providers interact (and co-produce) within educational communities (Rubalcaba, 2013).

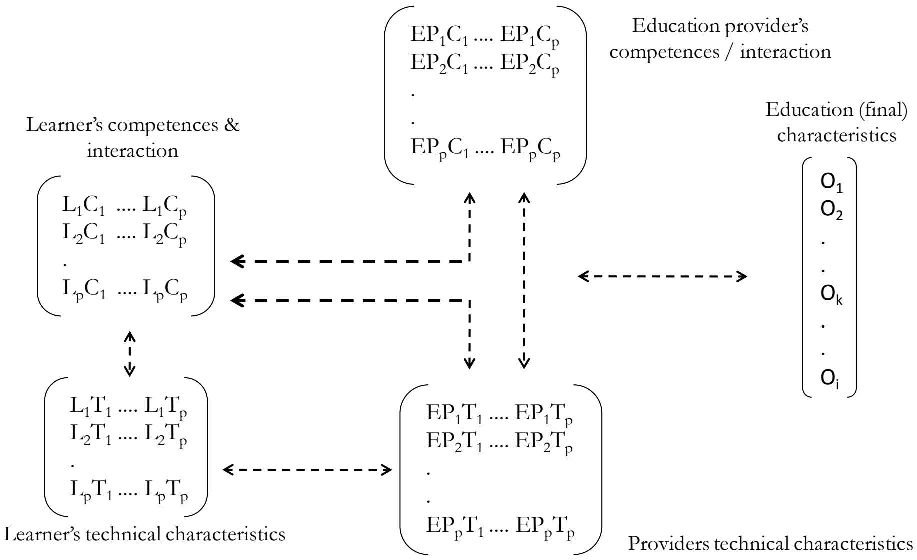
The framework. Considering these set of characteristics, education can be represented by the characteristics-based approach to goods and services (Gallouj and Weinstein, 1997; Gallouj 1994 and 2002)[7]. This theoretical construct allow us to represents education as a system of interrelated vectors/matrixes (See Fig.1). We present an extended version[8], which includes five vectors/matrixes. Matrix L_nC_p represents the competencies of the different users (knowledge and abilities), and their co-production abilities (student behaviours and student interactions)[9]. Matrix EP_mC_t represents the competencies (again, their knowledge and abilities) of the provider as well as their co-production abilities (highlighting again, provider's behaviours and providers interactions). The L_nT_q matrix represents the technical characteristics of education associated to users and matrix EP_mT_v represents the technical characteristics of the service (which normally are associated to providers). These later technical matrixes include tangible technical characteristics or intangible technical characteristics associated to the education service, in such a way that they can be used repeatedly for the provision (learning and teaching) of similar "ways" of education or different kinds of education (depending on whether they are more or less generic or specific). The final service outcome is represented by the vector O_i and is the result of the co-production capabilities of the user (matrix L_nC_p), the competencies of the provider (matrix EP_mC_t) and the technology of the users (matrix L_nT_q) and the providers (matrix EP_mT_v).

7 We must emphasise that Gallouj and Wesintein's (1997) theoretical construct can be applicable to services but also goods (Gallouj and Savonna, 2009; Gallouj and Djellal, 2010). This means, they integrate tangible and intangible elements applicable to goods and services, following the idea initially proposed by Lancaster (1966 and 1971), to define or represent a product by its characteristics.

8 Based on Montes, Gallouj and Rubalcaba (2014)

9 This way of representing the "user vector" as a matrix of serveral users is supported by the importance of users' interrelations (possibility of interactions), underppined in the case of education on the so-called peer effect (Nechyba 1999; Burke and Sass, 2011; Duncan and Murnane, 2011 Sacerdote 2011; Borgonovi et al 2013), which exerts influence over education provision and outcomes directly (face-to-face) either in school or out of school, or indirectly (e.g. throughout social networks, email, etc..). Similarly to providers (See De Vries, 2006), the existence of multiple users and their interrelations (including the co-production with providers) opens the need to enhance the individual user competence and technical vector to an array of different competences and technical vectors associated with each user. In fact this ideas was partly considered by Von Hippel (1988).

Figure 1: The characteristics-based representation of (education) services



Source: Own elaboration adapted to education building over Gallouj & Weinstein (1997) and De Vries (2006)

The model dynamics. Arrows in Figure1 draw attention on the co-production abilities of the users as being determinant of the service outcome. This means that student's play a relevant role in education provision including the use of a specific education service - the product (De Vries, 2006). Moreover, it also denotes the way service (education) is provided or deliver (high lightening the role of providers, its interactions and co-production with students), which could therefore be defined as the simultaneous employment of technical characteristics and competences ultimately used to produce the service (or final) characteristics (Gallouj, 2002; Gallouj and Savona, 2009), or what De Vries (2006) calls the co-production relationship, which can include several particular cases (Gallouj and Wesintein, 1997) such as: (1) a pure service (relating the users and providers competences and the service characteristics vector/matrixes), (2) a pure material good (linking the providers technical and service characteristics), as addressed by Saviotti and Metcalfe (1984) and Windrum et al (2009), or even (3) the link between users competences and providers technical and service characteristics, which can be considered the self-service characteristics (Gallouj and Wesintein, 1997; Gallouj, 2002 or De Vries, 2006).

These (special cases or) ways of provision or delivery of education, lead in fact to a better understanding of education characteristics, providing useful insights of the co-production abilities and technical characteristics. For example, one can think how traditional education is provided. Very briefly, education providers (normally "the" teacher) co-produce in class with a group of students where student also, interact between them and co-produce with the teacher. This co-production normally encompasses teachers explaining a group of students (or more individual explanation) the content of a topic (e.g. math). To do so, teachers use their competencies (e.g. math and pedagogical knowledge) and co-producing abilities (e.g. enthusiastic, organized and student sensible) and some specific "technical characteristics" of the service (e.g. explaining using a digital blackboard & based on a textbook). The outputs of the service can include a "better understanding of a difficult topic given teachers clear explanation", "student motivation given the teachers enthusiasm " and "higher test scores at the end of the year".

DATA AND VARIABLE DESCRIPTION

The Finnish and Korean PISA 2012 countries samples

The data used in this research come from the Program for International Student Assessment (PISA) 2012, and refer to the Finnish and Korean country samples. The selection criteria for choosing these countries (samples) has been on the one side, their excellent combination of high levels of performance with equity in education opportunities (PISA 2012 Results in Focus, OECD, 2013) and in the other, their markedly differences on their provision of education (OECD, 2011; Pearson/OECD video transcripts). PISA is an international assessment survey that measures students' abilities in the domains of reading, mathematics and science. According to the OECD (2012a), PISA focuses on young people's ability to use their knowledge and skills to face the challenges of real life and not to master a specific curriculum. Moreover, PISA takes place every three years, focusing on 15 year students, from OECD and partner countries. Five waves of PISA have taken place, namely 2000, 2003, 2006, 2009 and 2012. The PISA 2012 survey covers 65 countries and economies around the world. In addition, each wave has focused on a specific domain. In 2000 the focus was on reading, in 2003 its' focus was in mathematics and lastly, in 2006 it focused in science. The PISA-2009 and 2012 editions focused again in reading and mathematics literacy respectively. The Finnish and Korean countries samples contains 8.829 and 5.033 students from seventh to 11th grade (M_F = 8,81[10] and M_K =9,94; SD_F = 0.43 and SD_K = 0.24) nested in 311 and 156 schools respectively.

Variable description

When choosing the variables we have followed our theoretical framework discussed in section 2, the enhanced characteristics-based approach to goods and services. Collecting (from PISA2012 database) data following this framework allow us to clearly identify a wide set of variables related to each characteristics vector/matrix considered in the service provision (actors competences and co-production abilities, and technical and service characteristics). Further and more important, assessing education from a service perspective allow us to investigate the existing statistical relationship between actor’s competence and technical vectors and service characteristics. The variables considered in our analysis are presented herein below.

Dependant variable. The dependant variable are the standardized test scores achieved by students in the domains of math, science and reading. The argument for choosing these variables has been considering a set of education outcomes (service characteristics) normally result of education provision.

[10] In the case of Finland compulsory education begins at the age of 7, covering 9 more years, thus, when taking PISA-2012 tests, students are normally in 8th grade on average.

Table 1. Country Math, Science and Reading Test Scores: Finland and Korea

Variable	N	MIN	MAX	Mean (*)	SD (*)
FIN Math AVG	8.829	165,50	790,69	518,75	85,30
FIN Science AVG	8.829	128,44	852,87	545,44	92,96
FIN Reading AVG	8.829	99,71	817,83	524,02	94,67
KOR Math AVG	5.033	161,11	888,82	553,77	99,09
KOR Science AVG	5.033	182,26	815,68	537,79	81,91
KOR Reading AVG	5.033	109,42	784,34	535,79	86,54

Source: Own calculations using the Finnish and Korean countries samples of the Student PISA-2012 DB. (*) Countries average means and standard deviations have been computed as the average populations means and standard deviations of each plausible value (PV) for each domain. Further, each PV populations means and standard deviation for each domain has been computed using Balanced Repeated Replication (BRR) (OECD, 2009).

For each literacy-domain (reading, mathematics and science), PISA2012 data reports for each student, five plausible values (see Adams and Wu, 2002). The general scale used[11], is transformed to reach an average of 500 (points) with a standard deviation of 100 (points) using a linear transformation. When a student's score is close to a point of the scale, it's more likely that students successfully respond to the items that are at that point or below it (score) and likewise, students are less likely to respond to items that are above that score. For our empirical analysis, in order to estimate the unbiased "population" estimates of our interest, we have followed the PISA Data Analysis Manual (OECD, 2009, 129-130).

Independent variables. Independent variables are presented herein below following our theoretical construct in section 2 and the aims (hypothesis) of our research. This means first, we describe the student competencies (which include student general background variables, gender, origin and family composition), as control variables, general competencies associated to cumulative knowledge and abilities to the date, co-production abilities, namely related to behaviours and interactions and technical vector characteristics related to students, secondly, we describe the education providers vectors competence characteristics (namely those related to teachers, principals and parents), and lastly, we describe the technical vector characteristics of education, these latter variables are associated to the schooling process in broad sense, this means considering an ample set of characteristics that can be from particular school resources to more procedural and intangible know-how. Variables describing students competencies and technical characteristics are depicted in table 2. Regarding each learners background and general competencies (control variables), variables include gender, referred to boys (gender_M), the origin of students (native), if attending kindergarten for more than a year (kinder_more1), if students have not repeated any year in ISCED 1 (NOrepISCED_1) and ISCED 2 (NOrepISCED_2). All these variables are dummies, which take the value of 1 if the characteristic holds and 0 otherwise. One more variable has been included in this group, the student socioeconomic background index (SES), which is a continuous variable. This latter variable is an indicator that encompasses three components associated with the student's familiar and home environment, namely, (1) the level of parental occupation (job position), (2) the level of educational attainment of parents expressed in years of schooling and (3) the rate

[11] This is estimated on standardized scores, which are based on mean zero and standard deviation 1. OECD-PISA (2012a)

of student possessions at home. This last component in turn encompasses family welfare, cultural possessions and educational resources available in their homes, including the number of books.

The second and third group of learner's variables captures what we have called co-production abilities, which are related to student’s behaviours and interactions between them. Regarding student behaviour, variables considered include those suggesting big effort of students at home, this is, working hard on math homework (wHRDhw_1) and studying hard for a math quiz (studhq_1). Moreover, variables considered relate students with in-class behaviour, such as paying attention (payatt_1) and active listening in math class (lstclass_1). Lastly, we have considered a variable related to student individual work in class which is deciding the method to solve math problems (empsp_1). As for the third group of variables capturing those abilities that involve student interactions, they include helping often their peers in math (peerhlp_2) and talking sometimes with peers about math (mpeertlk_2). As for learners' technical vector characteristics they include those technologies (in our case tangible) supporting students interactions out of school. Variables considered where if learners had a computer a home that can use for school work (comphm_1), if students had educational software installed (Edsfthm_1) and if they had a computer linked to internet (www_1).

Table 2: Learners (Students) Competence & Technical Vector Characteristics

Variables	Type	FIN (N = 8.829)		KOR (N=5.033)	
		m/f	sd/%	m/f	sd/%
Student Socioeconomic Status (ses)	cont	0	0,83	0	0,74
Gender (gender boy vs girls)	dum	4.459	50,5%	2.691	53,5%
Native (native)	dum	7.406	83,9%	5.005	99,4%
Att Kinder 1 year or more (ISCED 0: kinder_more1)	dum	5.930	67,2%	4.163	82,7%
Grade repetition Never (ISCED 1: Risced1_NEV)	dum	8.269	93,7%	4.839	96,1%
Grade repetition Never (ISCED 2: Risced2_NEV)	dum	8.401	95,2%	4.826	95,9%
Working hard on math hwk (wHRDhw_2)	dum	1.542	17,5%	1.417	28,2%
Studying hard for math quiz (studhq_2)	dum	1.876	21,2%	1.179	23,4%
Paying attention in (math) class (pyatt_2)	dum	2.953	33,4%	1.537	30,5%
Listening in (math) class (lstclass_2)	dum	3.545	40,2%	1.603	31,8%
Empowering in solving process (empsp_3)	dum	1.723	19,5%	484	9,6%
Taking to peers (math: mpeertk_3)	dum	2.492	28,23%	1.659	32,96%
Helping peers (math: peerhlp_3)	dum	2.671	30,25%	1.605	31,89%
A computer (used for school homework: comphm_1)	dum	8.562	96,98%	4.712	93,62%
Education software (school oriented: Edsfthm_1)	dum	3.581	40,56%	2.678	53,21%
Computer linked to internet (educ use: wwwhm_1)	dum	8.634	97,79%	4.839	96,15%

Source: Own elaboration based on PISA2012 DB (*). T (type of variable), which can be continuous (C) or a dummy (D). Regarding the dummy variables, they take the value of 1 if the characteristics holds and zero otherwise.

Our second group of variables described are those associated to education providers (Teachers and Principals on the one side and Parents in the other). See Table 3. Variables considered can be associated to provider’s competencies and co-production abilities (behaviours and interactions). Variables associated to teachers competencies and knowledge are the percentage of math teachers with a major in math (MT_majM) and the percentage of math teachers with an ISCED 5A in pedagogy (MT_5aPED). These first sets of variables are continuous. Regarding teachers co-production abilities (behaviour and interactions), variables include empowered teachers in the domains resource management (TEACHq5b and TEACHq6b, where teachers have the responsibility for planning and allocating resources) and organisation of instruction (TEACHq7b, TEACHq8b, TEACHq9b and TEACHq10b, where teachers have responsibility of disciplinary, assessment and admission policies including textbook choosing). Further, variables include enthusiastic teachers (TCHenth_1) and teachers interested in trying new methods and teaching practices (TCHnewMet_1). All variables considered in this second set are in general dummies, taking the value of one if the characteristic holds and zero otherwise. Moreover, we have considered the index of teacher-related factors affecting school climate (tchSCHclim), which integrates a set of responses[12] from principal on how school climate can hinder student learning.

Table 3: Providers Competence Vector Characteristics: (Principals and Teachers)

Variables	Type	FIN (N = 311)		KOR (N=156)	
		m/f	sd/%	m/f	sd/%
(Math) Teacher with major in Math (MT_majM)	cont	0,626	0,324	0,734	0,305
(Math) Teacher with ISCED 5A Pedagogy (MT_5aPED)	cont	0,325	0,428	0,231	0,291
TEACH formulating sch budget (TEACHq5b)	dum	7	2,25%	10	6,41%
TEACH deciding budget allocation (TEACHq6b)	dum	46	14,79%	43	27,56%
TEACH estab stud discip policy (TEACHq7b)	dum	148	47,59%	52	33,33%
TEACH estab stud assess policy (TEACHq8b)	dum	138	44,37%	88	56,41%
Teacher Enthusiasm (TCHenth_2)	dum	207	66,56%	99	63,46%
Teacher behaviour/school climate (index: tchSCHclim)	cont	-0,08	0,81	0,08	1,12
Principal work towards school reputation (PRIreput_3)	dum	72	23,15%	52	33,33%
Principals work towards sch education goals (PRIeducG_2)	dum	125	40,19%	39	25,00%
PRIN estab teach starting salaries (PRINq3a)	dum	26	8,36%	11	7,05%
PRIN det salaries increase (PRINq4a)	dum	31	9,97%	6	3,85%
PRIN formulating sch budget (PRINq5a)	dum	118	37,94%	31	19,87%
PRIN deciding budget allocation (PRINq6a)	dum	271	87,14%	74	47,44%
Principal & teachers particip sch-decision-mk (PTdecMak_4)	dum	112	36,01%	45	28,85%
Principal & teacher joint work - sch culture (PTculture_4)	dum	75	24,12%	50	32,05%

Source: Own elaboration based on PISA2012 DB (*). T (type of variable), which can be continuous (C) or a dummy (D). Regarding the dummy variables, they take the value of 1 if the characteristics holds and zero otherwise.

[12] The main concern of the index was to consider how important some school factors (Q.18 of the paper questionnaire and SC22q01 to q19 of the school PISA2012 data base) such as students not being encouraged to achieve their full potential; poor teacher-student relations; teachers having to teach students of heterogeneous ability levels within the same class; teachers having to teach students of diverse ethnic backgrounds within the same class; teachers' low expectations of students; teachers not meeting individual students' needs; teacher absenteeism; school staff resisting change; teachers being too strict with students; teacher being late for classes; and teachers not being well-prepared for classes have the potential to hinder student learning (OECD, 2013, Volume IV, 175).

As for Principals, behaviours variables considered include empowered principals in the domains of human resources (prinq3b and prinq4b, having the responsibility over teacher's salaries) and resource management (prinq5b and prinq6b, having responsibility for planning and allocating resources). Regarding principals' interactions, variables considered namely targeted principals' abilities to joint work namely with faculty members and teachers, by empowering teachers-co-decision on decision making (PTdecMak_4) and for improving school culture (PTculture_4). Parents[13] (as well as external actors) normally participate in education services (schooling) by supporting teachers (active participating on student activities by providing specialized knowledge, technical support, resources or assist teachers (and students) in their daily work) as well as becoming highly involved in the development of schools (becoming part of school advisory or governing board or Parent-Teacher Associations, or even supporting administrative or school maintenance tasks) in order to improve school services. Variables considered for parents, deal with their interactions (with the rest of providers), namely with teachers. The set of variables include, the percentage of parents discussing with the teacher by own (PARbehOWN) or teacher initiative (PARbehTCH) child behaviour and child progress (PARprogOWN and PARprogTCH), the volunteering in extracurricular activities (PARextCV), assisting teachers teaching (PARassTCH) or participating in local government (PARsgb). Variables are depicted in table 4.

Lastly, we present the technical characteristics of education service (Table 4). We refer to resources implemented at school level which normally allow "providers interact and are considered as interfaces": In this last group of variables we have those related to school content, considering if the school uses a standardize curriculum in math (StdMTHcv_1) and if implements similar content in different levels in some classes (simCNTdifLVL_2). Moreover, variables dealing with methods and organisation, includes the no ability grouping and using adaptive pedagogy in some math classes (NOabgADTped_2) and if schools offer extra math lessons (adMATles_1). Regarding school resources we have considered those related to ICTs. For these group of variables we have consider not only the availability of specific devices at school but also their effective use by students, variables considered include a desktop computers (aDKtCOMP_1), laptops (aLapTOP_1), tablets or Ipads (aIPAD_1) and internet access (awwwSCH_1). Other variables considered where the ratio of computers liked to internet per student (compWEB) and as well as the index of quality of buildings and spaces (QUALphysST). This latter variable integrates variables related to school buildings and instructional spaces (Q.11 of the school questionnaire/SC14 of the school PISA2014data). Last, variables considered have been those labelled as traditional (or monetary controlled) by the

[13] Given that parents play a relevant role at home and school, and given the empirical strategy we used (HLM), we considered that parents' specific characteristics – e.g. education level, job status (including time availability effect captured by parent working full or partially or not working status) or even parents' origin - must come associated at "student level" as they impact students outcomes by interacting with their children out of school. Further, those characteristics (namely interactions) of parents at school (e.g. parent participating in extracurricular classes o assisting teachers at school or even participating in Governing Boards), should be considered as school resources, as their impact have the potential to benefit the student (and school) bodies. The former individual parent characteristics (affecting student resources) have been included in the student SES indicator (which include as mentioned before, parents education attainment level and job position). The latter are those presented in table 4, which include (and assumes) parental participation in school, suggesting potential effects over students. In any case, aggregated parental characteristics at school level of those parents actively participating in school activities (been these related to instruction or school development), can also be considered as school resources.

mainstream literature, this is, class size (Csize), school type or structure (SHtype_3) and student-teacher ratio (STratio).

Table 4: Providers Technical Vector Characteristics: School Actors (Principals and Teachers)

Variables	Type	FIN (N = 311)		KOR (N=156)	
		m/f	sd/%	m/f	sd/%
Standardize (math) curriculum (StdMTHcv_1)	dum	205	65,9%	132	84,6%
(Math) Similar content & different levels (simCNTdifLVL_2)	dum	101	32,5%	77	49,4%
(Math) NO abgroup & adpt pedag in-class (NOabgADTped_2)	dum	106	34,1%	80	51,3%
Sch offers extra math lessons (adMATles_1)	dum	180	57,88%	141	90,3%
Desktop avail sch & use it (aDKtCOMP_1)	cont	0,811	0,14	0,383	0,21
Laptop avail sch & use it (aLapTOP_1)	cont	0,323	0,30	0,086	0,09
Tablet/Ipad avail sch & use it (aIPAD_1)	cont	0,047	0,12	0,023	0,04
Internet avail sch & use it (awwwSCH_1)	cont	0,847	0,11	0,474	0,22
Computers linked to internet (index: compWEB)	cont	0,997	0,03	0,974	0,09
Quality of buildings and spaces (index: QUALphysST)	cont	-0,29	0,99	-0,17	0,93
Class Size (Csize)	dum				
School type Index (Public: SHtype_3)	dum	290	93,2%	85	54,49%
Student-teacher ratio: Stratio	cont	10,38	2,08	16,22	3,79

Source: Own elaboration based on PISA2012 DB (*). T (type of variable), which can be continuous (C) or a dummy (D). Regarding the dummy variables, they take the value of 1 if the characteristics holds and zero otherwise.

METHODOLOGY AND EMPIRICAL STRATEGY.

The technique employed where two level hierarchical linear models (HLM[14]). The consideration of this technique is based on the nested nature of the data used (PISA-2012 DB), where students are nested into schools, and schools in regions/countries, which properly accounts for the multilevel structure of the dataset and is useful to analyse the performances at different levels (e.g. student-level, school-level, etc.) while controlling for the variance across levels (Hox, 2002, Chapter 1). Furthermore, this technique has been considered in several studies in education (e.g. Bryk et al, 1993; Bryk and Raudenbush, 1988; Raudenbush, 1988; Calero and Escardíbul, 2007; Mancebón et al, 2010; Calero et al, 2009).

These grouping effects (nested data), suggest that the interaction between students of the same group are more similar than those of students in different groups, thus interaction between students in the same group cannot be considered statistically independent, violating the independent noise hypothesis. Hence, using traditional statistical methods such as regressions or ANOVA[15] to analyze this type of data are not entirely applicable (Goldstein, 1995/1999; Raudenbush and Bryk, 2002; Hox, 2002). In fact, failure to recognize the hierarchical nature of data, could lead to unreliable estimates regarding the effectiveness of

14 For building and running our modeling strategies we have used STATA V.13 software.
15 Analysis of Variance.

school characteristics and practices, which could lead to unfounded policies or practices (Raudenbush and Brick, 2002). Therefore, the use of hierarchical linear models appears to be the most appropriate statistical technique for treating nested data.

HLM displays different sub-models for each level of the data structure. These sub-models in turn capture the relationship between the variables at the same level, as well as the influence of higher-level variables on variables at lower levels. In our case, following our theoretical construct16), the general hierarchical linear model we implement in matrix notation is as follows:

$$(I) \qquad Y = Z\gamma + X\beta + R\mu + \varepsilon$$

Where Y (the dependant variable) is the n x 1vector representing the education outcomes (student test scores), X is the n x p covariate matrix representing the learner (student level) characteristics and Z is the n x q covariate matrix of education providers (at school level) characteristics. Further, R is n x p covariate matrix for the random effects μ and ε represents the n x 1 vector of individual errors, which we assume to be multivariate normal with mean zero and variance matrix$\sigma_{\epsilon}^{2}D$. Ɣ, β and μ are the n x 1 vectors of parameters to be estimated in the model.

Twelve models have been build (the null and the complete models for each literacy domain for each country sample) of which, the last six models address our research questions stated in section 1 of this paper. We followed a consolidated tradition in the applied statistics literature about student-level/school-level data, for which predictors have been included cumulatively (by level and set of variables), over the "null model" which has been considered our baseline specification (e.g. Lamb & Fullarton, 2001; Dronkers & Robert, 2008). The estimation approach (suitable for case analysis) has been made separately from a case-to-case approach.

The first six models are the null models for each literacy domain for each case (Finland and Korea), which considers only the dependent variable (math, science and reading student test scores, Y). This type of model is the indicator of the variability associated with the different levels involved in the analysis, and therefore serves as a reference for testing the goodness-of-fit of successive models. The null model specification in levels (for each of the literacy domains of both countries analyzed) is as follows:

$$Level\ 1: \qquad Y_{ij} = \beta_{0j} + \varepsilon_{ij}\ ; \quad where \quad \varepsilon_{ij} \sim N(0,\sigma^2)$$

$$Level\ \ 2: \qquad \beta_{0j} = \gamma_{00} + \mu_{0j}\ ; \ where \ \ \mu_{0j} \sim N(0,\tau_{00})$$

In level 1, we observe how the test scores of student i in school j[17] is explained by the average achievement of school j (β0j) and the individual error of student i in school j (εij). In level 2, we

[16] We must emphasis that we have taken into consideration the production function approach (Hanushek, 1986, Levin, 1971, 1994) as well as its “particular” considerations when specifying this type of functions in education (Boardman and Murnane, 1979; Todd and Wolpin, 2003), when building-up our model (specifying the set of variables used between students/learners and providers at student level and those considered at school level).

[17] Formally, the first level shows that the performance of student i in school j is determined by the average student performance of school j and the individual error ε_{ij} , of student i in school j. We assume this error has mean zero and constant variance σ^2, which is to be estimated. The second level shows that the average school performance of school j is determined by the overall performance of the schools (mean of school means) and school j random effect (or residual μ_{0j}). This residual μ_{0j} is assumed to be independent of the individual error

observe how the average achievement of school j is explained by the overall mean of schools means (γ00) and the school error term (μ0j). In addition this first model also provides estimates for the variance of the student error (σ2) and for the variance or the school level error (τ00), which in turn can be used to determine how much of the total variance is accounted for by students and schools.

Our second group of models (the last six models), take into account learners (student level) and providers (school level) characteristics. The model is specified as a random intercept model considering multiple covariates from level 1 and level 2.

The variable intercept specification in levels is as follows:

$$Level\ 1: \qquad Y_{ij} = \boldsymbol{\beta_{0j}} + \boldsymbol{\beta_{1j} Xij} + \varepsilon_{ij}\ ; \quad where\ \ \varepsilon_{ij} \sim N(0, \sigma^2)$$

$$Level\ 2: \qquad \beta_{0j} = \gamma_{00} + \boldsymbol{\gamma_{01} Z_j} + \mu_{0j}\ ; \ where\ \ \mu_{0j} \sim N(0, \tau_{00})$$

In Level 1 these group of models shows how the test score of student i in school j is explained by the average achievement of school j, the set of characteristics (competencies and technical characteristics) of student i in school j and the individual error term of student i in school j. Level two, shows how the average achievement of school j (the β_0j intercept) is explained by the (overall) mean of schools means, the school j (providers competencies and technical characteristics) general characteristics in school j and school j error term (μ0j).

A more comprehensive reference for the statistical theory behind and a detailed methodological approach to hierarchical linear models (or multilevel models), can be check in Raudenbush and Bryk (2002) and Goldstein (1995 and 1999), including Hox, 2002.

5. RESULTS AND DISCUSSION

Results achieved are presented in tables 5 to 7. For each country analysed we present three models, one for each education outcome (literacy domains in math, reading and science). Regarding the null models, we observe that the overall average performance (γ_{00}) for each literacy domain in both countries/cases, are statistically different from zero and show positive values. Scores achieved are 507,5; 511,1 and 528,2 points and 551,1, 533,9 and 535,8 points for the math, reading and science domains of each case. Furthermore, for all models, statistically significant differences exist as first-level variance (σ^2) and second level random effect (τ_{oj}) clearly rejects the maximum likelihood contrast ($p <0.01$) where the null hypothesis[18] assumes that both variations are (the same and equals) zero. These facts supports that the intraclass correlation coefficient (ICC) is likewise significant, indicating the pertinence and need of multilevel modelling of our data. In the case-to-case analysis we can see how for each literacy domain, Finnish ICC's reaches the values of 11,7%, 12,2% and 12,4 respectively. Likewise for Korea, ICC's reach the values of 39,2, 36,6% and 36,2% respectively. This means that the 11,7%, 12,2% and 12,4% of Finland's and the 39,2%, 36,6% and 36,2% of Korean's

term ε_{ij}. The subscripts i and j refer to each of the students (where i = 1 .. n) and each of the schools (where j = 1 .. k), respectively.

18 Statistically we consider a LR-type contrast, such that H0: $\sigma^2 = \tau_{00} = 0$

variance of the average math, reading and science literacy domains performance of learners is due to differences between schools. When analyzing more in detail each of the countries ICC's, we observe that on average they vary considerably between countries, being higher in the case of Korea (for each literacy domain). Seen this situation from a different perspective[19], we can say that differences within schools (within any group) are higher in Finland (the highest) than in Korea. Moreover, the deviances for each case are, 103.853,3 ; 105.814,64 and 105.697,77 for each literacy domain in Finland, and 58.540,76; 57.431,95 and 56.861,75 for Korea. If not needed at this stage of the analysis their value sets each model's baseline, which will help us test the goodness-of-fit of successive models when additional predictors are included which are supposed to reduce significantly this indicator. In summary, regarding the null model for each of the literacy domains in each country (six models), we can see the need for multilevel modelling given the data used.

Regarding the fixed effects, table 5 shows the results for the case of Finland and table 6 presents the results for the case of Korea. This distinction has been made to clearly identify the influence of actors' competencies and technical characteristics over different educational outcomes for each country. To prevent possible misspecification errors we have also included control variables related to student socioeconomic background, gender and geographic origin variables.

Therefore, regarding the Finnish case, we observe that in general (except for the learners technical characteristics), learner's and provider's competencies and co-producing abilities and technical characteristics influence all three literacy domains, as some characteristics (for each literacy domain) are statistically different than zero and show positive and negative effects. This means that in general there is a set of competencies and technical characteristics that influence a set of education outcomes, measures as student test scores in the domains of math, reading and science.

By characteristics vectors, learner's competencies and co-producing abilities include knowledge and abilities (learnt) as a consequence of attending kinder for more than 1 year (Att_Kinder) and never repeating a grade (ISCED 1), being responsible with their own learning (studying hard for math quiz's - studhq - and paying attention in math class - payatt) and supportive with their peers (helping their peers with a subject - peerhlp). The rest of abilities analysed (highlighting empowered students in problem solving, talking with peer's about a subject, small group working or group working using a computer) influence differently or have not influence at all over each student outcomes (different literacy domains), as some of these variables are statistically different than zero and show positive or even negative effects over different literacy domains. Regarding the technical vector of learners, students having a computer (comphm_1) in their house for school purpose is statistical different than zero and show positive effects for the domains of reading and science but have no effect over the math domain.

19 ICC for school level is computed as the ratio between level 2 variance (schools) and the sum of level 1 and level 2 variance (schools and students). This means in our model ICC sch = $V(\tau_{00})/ [V(\sigma^2)+V(\tau_{00})]$

Regarding the provider's competencies & coproducing abilities and technical characteristics, we must say that except for those co-producing abilities relating the joint-working of principals and teachers aimed at building a school culture (once a month) and the technical characteristic of specific class size, in general, the pattern observed is that of some variables being statistically different than zero and showing positive or negative effects over specific (but different) outcomes (one or two literacy domains) and other variables show no effects at all. Highlight the relevance of (math) teachers with an ISCED5A degree over reading and science test scores, the role of empowered teachers in budget allocation and principals in establishing teachers starting salaries over math test scores on the one hand, and the impact of the availability (and use) in schools of technology, desktops computers and laptops over math test scores and internet access availability over reading and science test scores on the other.

Table 5: HLM2 Results for Finnish Sample (Outcomes)

Variables	Math	Reading	Science
Constant (ɣ00)	281,02***	162,387***	176,89***
Student Socioeconomic Status (ses)	20,208***	19,304***	20,378***
Gender (Boys)	9,931***	-51,970***	-6,193***
Native (native)	39,453***	51,382***	61,844***
Att Kinder 1 year or more (ISCED 0: kinder_more1)	10,679	13,321***	11,242***
Grade repetition Never (ISCED 1: Risced1_NEV)	41,331	42,668***	51,096***
Studying hard for math quiz (studhq_4)	9,674	8,641***	12,474***
Paying attention in (math) class (pyatt_1)	22,997	18,436***	21,504***
Listening in (math) class (lstclass_1)	7,113**		
Empowering in solving process (empsp_3)		4,620**	
Helping peers (math: peerhlp_2)	26,681	15,207***	20,08***
A computer (used for school homework: comphm_1)		20,11***	20,98***
(Math) Teacher with ISCED 5A (MT_ISC5A)		52,675***	50,158***
PRIN estab teach starting salaries (PRINq3a)	10,514**		
TEACH deciding budget allocation (TEACHq6b)	-5,384		
Principal & teacher joint work - sch culture (PTculture_4)	-7,155	-8,476	-10,760
(Math) Similar content & different levels (simCNTdifLVL_2)	-4,970		
Desktop avail sch & use it (aDKtCOMP_1)	45,654		
Laptop avail sch & use it (aLapTOP_1)	13,271		
Internet avail sch & use it (awwwSCH_1)		76,026***	80,373***
Class size (Clsize)	0,817**	1,616***	1,985***

P-values: *** p< 0,0.1; ** p< 0,05; * p<0,1

We focus in the common (or core) competencies and technical characteristics influencing all outcomes (literacy domains), we observe that learner's competencies and co-producing abilities play key role in contrast to provider's competencies and technical characteristics. This consideration suggest that students co-producing abilities play a key role over all set of outcomes (all domains), but individual provider's competencies/co-producing abilities and technical characteristics play specific roles over different (but individual) outcomes (literacy domains).

Shifting our analysis to the Korean case (table 8), general results achieved likewise show that student's and provider's competencies/co-production abilities and technical characteristics influence all set of outcomes (literacy domains). But more interesting and in contrast to the Finnish case, is that all vectors of all actors have common (or core) competencies and technical characteristics influencing all outcomes. These results suggest that Korean education provision is arranged in a way that more competencies and technical characteristics target a wider set of education outcomes.

More in detail analysing each vector, we observe for the learner's competencies and co-producing abilities some specificities. Abilities (and attitudes) include student engagement and responsibility with their own learning (paying attention in math class - payatt) and with their peers (helping their peers with a subject - peerhlp) which are statistically different than zero and have positive effects over each literacy domains. Moreover, student's technical vector becomes relevant as having a computer at home (comphm), with an education software (edsfthm) and a link to the internet (wwwhm) for school purpose becomes statistically different of zero and shows positive values over all education outcomes (literacy domains).

Table 6: HLM2 Results for the Korean Sample

Variables	Math	Reading	Science
Constant (ɣ00)	277,178***	304,863***	285,794***
Student Socioeconomic Status (ses)	9,518***	6,684***	4,297***
Gender (Boys)	11,585***	-27,677	
Native (native)	48,138***	31,971**	31,899**
Att Kinder 1 year or more (ISCED 0: kinder_more1)	7,495***	7,14***	
Grade repetition Never (ISCED 1: Risced1_NEV)	23,734***		
Working hard on math hwk (wHRDhw_2)	11,295**	11,759***	
Studying hard for math quiz (studhq_1)	12,479**		6,551***
Paying attention in (math) class (pyatt_1)	13,7***	9,378***	17,804***
Empowering in solving process (empsp_4)			10,228***
Helping peers (math: peerhlp_2)	25,384***	10,405***	17,383***
A computer (used for school homework: comphm_1)	10,741**	16,751***	14,934***
Education software (school oriented: Edsfthm_1)	6,372***	6,739***	6,579***
Computer linked to internet (educ use: wwwhm_1)	32,266***	25,365***	24,085***
TEACH formulating sch budget (TEACHq5b)		-28,057	
TEACH estab stud discip policy (TEACHq7b)		15,577**	
Teacher Enthusiasm (TCHenth_1)	13,847*	16,618**	
Teacher behaviour/school climate (index: tchSCHclim)			5,917**
PRIN formulating sch budget (PRINq5a)	32,958***	29,2***	23,659***
Principal & teachers particip sch-decision-mk (PTdecMak_1)			75,983***
Parent discusses - child progress - own initiative (PARprogOWN)	0,533***	0,3645***	0,386***
Same (math) textbooks (SAMEtxbksM_1)	-24,474	-25,281	22,754***
(Math) ability grouping within classes (ABGwthCLASS_3)	16,71**	13,677**	12,755**
Purpose xtr math les_ENRICH&REM (PURadMATles_3)	39,588***	27,012***	39,391***
Quality of buildings and spaces (index: QUALphysST)			-5,651
Laptop avail sch & use it (aLapTOP_1)	67,734*	62,085*	

P-values: *** p< 0,0.1; ** p< 0,05; * p<0,1

Regarding the provider's competence and co-producing abilities mention the relevance of empowered principals when formulating school budget (PRINq5a) as well as parent's interest in their child's progress (PARprogOWM) becomes relevant over all outcomes. This variable captures parent's discussion with teachers of child progress by own initiative. Last regarding the technical vector (associated to providers), we observe that not using the same (math) textbooks in every class (SAMEtxbksM_2), the non existence of ability grouping within (math) classes (ABGwthCLASS_3) and the existence of extra classes of math for enrichment & remedial purpose (PURadMATles_3) show positive effects over all outcomes (literacy domains).

Table 7: Complete Model - Random Effects and Model's Fit Statistics

	FINLAND			**KOREA**		
OVERALL MODEL	**MATH**	**READING**	**SCIENCE**	**MATH**	**READING**	**SCIENCE**
Constant (ɣ00)	281,02	162,38	176,89	277,17	304,86	285,79
Random Effects-Parameters						
Intercept (τ0j)	248,82	537,54	499,36	1.444,10	1.067,06	1.002,15
Residual (σ2)	4.858,28	5.907,75	6.105,82	5.257,41	4.153,82	3.836,68
TOTAL	5.107,11	6.445,30	6.605,18	6.701,51	5.220,87	4.838,83
Model Fit Statistics						
Wald Chi 2 (34)	4.560,24*	4.658,89*	4.099,19*	945,84*	1.043,24*	830,36*
LR test vs Linear Regression (Chibar Sq)	152,16*	353,68*	309,00*	733,34*	684,17*	690,40*
Deviance (2 x min Likelihood)	100.117,50	101.975,16	102.237,49	57.581,68	56.383,97	56.017,40
AIC	100.191,52	102.039,16	102.303,48	57.647,68	56.451,97	56.077,40
BIC	100.453,68	102.265,92	102.537,34	57.862,96	56.673,78	56.273,12
Proportion Explained						
Schools	73,84%	56,50%	59,70%	62,63%	61,61%	59,08%
Students	31,85%	33,57%	30,40%	12,25%	13,92%	10,99%
Total (R2)	36,80%	36,37%	34,02%	32,01%	31,35%	28,41%

NOTE: (*) indicates that the P-value < 0,0.1

Finally, highlight that the random effects (see Table 9) in all cases - the Finnish and Korean samples - are statistically significant, as we reject the null hypothesis of the maximum likelihood contrast of variances being zero. Moreover, when analyzing the goodness of fit of each model, it's worth mentioning two issues. First, comparing the deviance in all cases (100.117,50 ; 101.975,16 and 102.237,49 for each domain in Finland, and 57.581,68, 56.383,97 and 56.017,40 for each domain in Korea), we see that all deviances[20] have been reduced in comparison with each case null models, as different predictors/covariates have been included. Second, we observe that the proportion of variance explained at schools level for the Finnish case is able to explain more than a 55% of all literacy domains and for Korea more than the 60% for each literacy domain. To this end, following our research hypothesis we can conclude that in general all set of technical characteristics and actors competencies not always influence

[20] It concerns the complete models, which are sensible lower than the null models for each case.

all education outcomes (test scores in the domains of math, reading and science), but there are some core (or common) technical characteristics and competencies that do influence all outcomes. Our results show that for Finland, core characteristics influencing all outcomes (for each domain) have to deal with student competences and co-production abilities. As for Korea, surprisingly, core (or common) characteristics influencing all outcomes belong to the students and provider's competencies/co-production abilities and technical characteristics of both student's and providers. In this context of common characteristics, we can mention a key role of competencies and co-production abilities of student's in the case of Finland. As for Korea, surprisingly, technical characteristics (including ICTs), and competence/co-producing abilities play a key role. In any case, we must emphasise that some specific technical characteristics or actor competences and co-producing abilities play a relevant role (given their effect size), over some specific outcomes. Highlight that in Finland, technical characteristics (including ICTs) play an important role in some education outcomes.

6. FINAL REMARKS AND GENERAL CONCLUSIONS

From an empirical point of view, we have analyse the extent to which the same set of technical characteristics and competences influence several education outcomes (as measured by the PISA2012 math, reading and science test scores) in two top performer countries, Finland and Korea. Further, given the fact that different ways to provide education are equally effective in terms of performance and equity, our research has address the role of technical characteristics and competences in the two cases analysed.

Results suggest that human resources (competencies) and technology (technical characteristics) influence all set of student outcomes in both cases analysed. Nevertheless, when focusing on core (common) actor competences and technical characteristics influencing the overall set of outcomes (math, reading and science test scores) in Finland student competences and technical characteristics (engagement and responsibility in their own and peer learning) play a key role. As for Korea, surprisingly, learner's and provider's competences and technical characteristics of both, learner's and provider's become relevant.

More in detail - over these core characteristics - for the Finnish case, trained teachers and empowered principals, student engagement and responsible class attendance and the use of ICTs at school show positive effects over all outcomes. In the case of Korea student engagement with school, the use of ICTs' for school work, empowered principals and parental interest/support show positive effects over all outcomes domains. Hence, human and technology play a key role in education.

Having in mind that educational systems (and countries) are different given their social and cultural characteristics, our research suggest that by better understanding how education is provided, and more important, identifying for each case the core characteristics underpinning education outcomes, field for policy measures (and innovation) aiming to improve education outcomes is placed. In any case, further research must be encourage, especially empirically investigating the link between actor and technical vector characteristics with education characteristics.

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