ITALIAN JOURNAL OF SOCIOLOGY OF EDUCATION
Editor-in-Chief: Silvio Scanagatta | ISSN 2035-4983

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Article first published online

June 2016

HOW TO CITE

Giambona, F., Pitzalis, M., Porcu, M., & Sulis, I. (2016). Measuring Digital Teaching Innovation Using Item Response Theory Models. *Italian Journal of Sociology of Education*, *8*(2), 68-109. doi: 10.14658/pupj-ijse-2016-2-5

PADOVA UNIVERSITY PRESS

Measuring Digital Teaching Innovation Using Item Response Theory Models

Francesca Giambona[*], *Marco Pitzalis, Mariano Porcu and Isabella Sulis*

Abstract: In the last few years, two central questions have emerged in expert and academic debate on innovation policies in education. The first is the measurement of the effectiveness of innovation policies, the second regards the measurement itself and its methodological improvements. The problem of measurement is not only a methodological and technical issue; it is also a theoretical one. Every technical choice is made on the basis of a theoretical frame, so will have broad theoretical consequences. This article aims to focus on the problem of the definition and measurement of innovation in teaching activities. Its goal is mainly the application of the IRT methodology as a tool to assess propensity or attitudes in different domains pertaining to the use of ICT in schools. Our starting point is the hypothesis that the "propensity of innovation" may be defined as a latent variable defined by different dimensions. This paper considers the main results of a research project on digital teaching innovation carried out in 2013-2014. Digital teaching innovation was investigated through a sample survey addressed to teachers. An *ad hoc* questionnaire was used and Item Response Theory models were applied to analyse responses provided by teachers: propensity to digital teaching innovation was assessed with five indexes together with a further five related to other specific topics (e.g. the perception of the school climate, the school context). Finally, each indicator was related to potential explanatory variables in order to evaluate relationships between the salient characteristics of teachers and schools and the main dimensions of analysis.

Keywords: ICT, learning, teaching, innovation, IRT

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Introduction

The question of innovation has been a central element of the educational debate since the nineteen-sixties. This period was characterized by a drive for reforms in both school and university institutions.

In 1970, the notion of "innovation" was put forward as a guide to the investigation by a group of national experts called upon to describe the state of innovation processes in their respective countries. First of all, the notion of innovation was counter-posed to the concept of "change". According to statements made by the Organisation for Economic Co-operation and Development (OECD), innovation is meant to be a purposeful orientation toward the solution of impelling problems for society (OECD, 1970).

The themes put forward by the OECD in 1970 were ranked according to the following list: 1) coping with increased numbers of students; 2) equality of opportunities; 3) content and structure of studies – interdisciplinary approach; 4) specialization of institutions of higher learning; 5) organisational structures – institutional autonomy –administration and management; 6) recruitment and status of teachers; 7) teaching and research; 8) organisation and methods of teaching – teacher-student relations; 9) role and status of students in the academic community; 10) higher education and the outside world; 11) evaluation and planning; 12) cost and financing. Although all these topics are still relevant in the public debate today; we can nevertheless assert that "technological innovation" is by far the most central issue in current education policies and debate.

Grignon and Passeron were the authors of the case study dedicated to "innovation in higher education" in France. These authors, close collaborators of Pierre Bourdieu, during this period, criticised the notion of innovation: "Innovations are easy enough to define in the case of industrial firms, whose main aim is to achieve a measurable return. […] But in a system such as education, where the social effects are many and have no common measure, it is not so easy to assess the innovatory nature of an institutional change: if we accept those technical inventions which have radically transformed the communication of knowledge – such as the creation and dissemination of the printed book which has greatly helped to reduce illiteracy in European countries – the significance of most of the institutional, pedagogical and even technical changes which affect an educational system is […] uncertain. This is because their effects are different and sometimes even contradictory […].

Over the last 30 years, the Information and Communications Technology (ICT) revolution has intrinsically changed the framework of innovation. Essentially, we are facing a radical transformation in the area of knowledge dissemination. Technology has radically changed the process of creation and diffusion of knowledge and we are affected by this change in every action of our daily lives. For this reason, the notion of innovation much criticized by Grignon e Passeron, appears today to be taken for granted. Whereas organizational and pedagogic innovations are related to the normative dimension of values, and may concern a variety of different issues, technological innovation seems to be untarnished by political reservations or objections.

First of all, the ICT revolution has put pressure on schools to respond to the demand to improve the digital literacy of citizens and workers. The reality is that technological innovation is linked to the general technological change brought about by the Internet society. Moreover, a clear parallel can be drawn between the discourse on the Digital Divide, i.e. the need to increase digital competencies in the general population and the traditional discourse on literacy and equality. As this transformation has been accompanied by much debate on the role of schools in the construction of the "knowledge society", the school system has been called upon to take the role of essential vehicle in a political and social project aimed at creating a sort of Utopia. In addition to its social and economic importance, this project is first and foremost a cultural one. It will most likely work by producing self-cultural assessment that can go by the name of cultural hegemony. This hegemony expresses the widespread common sense notion, which accepts that old style schooling is in crisis and that radical technological and educational change is the only way forward.

Recently, Neil Selwyn (2012) singled out three main ways in which digital technology is being used "*to reconfigure the nature and form of educational institutions* […]". The first is the use of digital technology to represent the structures and processes of school – what is often referred to as "virtual schooling." The second is the use of digital technology to reconstitute the structures and processes of school – what is sometimes referred to as digitally driven "re-schooling." The third is the use of digital technology to replace the structures and processes of school altogether – what might be termed digitally driven "de-schooling". However, according to Selwyn, these challenges to the traditional school remain more symbolic than substantial. In any case, they embody the framework of a wide and complex process of change boosted by two main factors: the belief that digital technology offers a better way of "doing education" and the general dissatisfaction with current types of schools and schooling" (Selwyn, 2012). In this perspective, the technological revolution in education can be considered as one answer to the crisis of the "institutional program" (Dubet, 2000). In the fragmented world of schooling, today's school teacher (Benadusi & Consoli, 2004) is called upon more and more to cope with the capacity to control and manage the school class instead of focusing their energies on school subjects (knowledge). Educational technologies are seen as an instrument that serves to revitalise schooling, providing solutions for specific problems with the creation of innovative learning environments that recapture the attention of students. This optimistic view on the use of technology to achieve key educational goals is, in any case, fairly widespread (Zucker, 2010) and governmental agencies have espoused such initiatives and given them their full support.

Theoretical research and empirical analysis developed over the last 15 years, starting from the Lisbon Strategy recommendations, have stressed the importance of competition and innovation. The latter is seen as a veritable social process and not just as a simple effect of scientific progress. By looking at innovation in this way, the processes of teaching/learning have become the core of the concerns of policy makers and administrators (OECD, 2001, 2004). The topic of innovation and of its measurement (and benchmarking) has also become a major issue for the OECD. On this point, Shapiro (2007) notes that "Particularly within the field of educational policy, definitions of innovation and subsequently methods to study innovation within education and training are still in their early stages".

The other great challenge that schools are dealing with today is evaluation and assessment. In the last 15 years, OECD-PISA (Program for International Student Assessment) has provided the main model of an international large-scale evaluation system of learning outcomes and, in Italy, the National Institution for the Evaluation of School System (INVALSI) is trying to build up a national model of evaluation. Finally, measuring and producing data has become a central device for governing the changing processes in the country's school system. Giancola and Vitteriti (2015) define this process as "naturalization of educational policies through the numbers that become powerful policy tools". In recent years, measuring and assessment have become a primary activity for school administrators, while methodological innovation in measuring is now a strategic issue in the international debate.

Indeed, the OECD has recently intensified its efforts to measure innovation in teaching and schooling, producing the report "*Measuring Innovation in Education. A New Perspective*" (2014). Addressed to the academic and expert community, the report highlights strategic objectives concerning both innovation in education and its measuring.

Surveys carried out over the past few years by the OECD-TALIS (Teaching and Learning International Survey) have been designed to compare educational results at international level, and have become a key international tool for the comparative measurement of teaching innovation and for describing and analysing the practices of both teachers and school leaders/managers. The OECD-TALIS report for 2013 pointed to the complexity of introducing technological innovation in schools. Furthermore, with specific regard to Italy, a report devoted to digital strategies adopted in Italy has highlighted the central role played by education and training to support teachers and managers in facing the challenge of teaching digital innovation (Avvisati, 2013). Remaining in Italy, the plan known as 'Digital School' (SD) implemented by the local government authorities in the region of Sardinia aims to modify teaching practices toward the definition of new learning environments in which technology plays a central role in helping students develop their skills (skills which are rewarded and required by the OECD and by rating agencies).

Identification of the key issues concerning innovation processes and their procedural character and social nature led to the positing of specific research questions and new methodological perspectives to be adopted. What essentially emerges from the OECD-TALIS (2013) report is the existence of a positive correlation between "professional development" and the use of "innovative pedagogies". Leading on from this standpoint, the main aim of this research has been to summarize the information gathered in order to assign a set of indexes for each teacher to follow, some of which are related to digital teaching innovation.

As regards the methodological difficulties of measuring innovation, the 2014 OECD report recommends two different approaches. The first consists in using a survey on innovation to measure specific levels of innovation at any given time. The second is an organisational approach that consists of analysing changes that have occurred in educational practices. In any event, the OECD's objective was to consider innovation and change as a value *per se* and to produce a ranking list of countries using its indicators of innovation.

In Italy, the Fondazione Agnelli recently ran a national research project focused on collecting information on the program "Classe 2.0" sponsored by central government. The aim of the program was to introduce interactive whiteboards (IWB or LIM) in selected classrooms. The research project adopted a counterfactual method that yielded contradictory results (see Campione et al., 2014) showing serious methodological difficulties in applying such (counterfactual) methods of analysis to the evaluation of educational policies in schools. Researchers has acknowledged that they were unable to find out what kind of use (if any) was made of the IWB by teachers in the classroom. Nevertheless, the report states that no significant association was found between the presence of technological tools in the classroom and expected "learning outcomes". In point of fact, a number of studies today have challenged the effectiveness of this alleged relationship (see Calvani et al., 2013). Recently, Biagi and Loi (2013) measured the association between "learning outcomes" and the intensity of use of technologies in school and leisure activities. Surprisingly, they found that gaming is the only activity presenting a positive association between PISA test scores and intensity of use of technological devices. On the contrary, "creation of content and knowledge and problem solving activities" shows a negative effect; what an interesting hypothesis this is, given that the core *curriculum* recommendation of contemporary constructivist pedagogies recommends and supports the introduction of educational devices for the creation of digital learning environments (Pitzalis & De Feo, 2016; Pitzalis et al., 2016). However, another "evaluative" study on the effect of ICT on school life (Giusti et al., 2015), carried out on a sample of teachers, revealed the existence of a positive effect of employing IWBs and the use in general of ICT devices on the learning performances of students (performances were assessed by INVALSI tests). Indeed, international and national surveys show two emerging problems in contemporary debate: (i) the definition of "innovation" in educational processes; (ii) the definition and the measurement of educational and learning outcomes (which give rise to a whole series of fresh consequences for they open up a Pandora's box of ethical and educational controversies) together with the problem of how to define the productivity of innovations.

Since choices in methodological and technical measurement also involve making theoretical assumptions, the aim of this article – which is fundamentally practical – is not to assess a level of suitable innovation or create indicators to measure innovation in competitive terms. Moreover, we are not attempting to measure the effect of a policy in terms of learning outcomes or to measure the association between the introduction of educational tools and learning outcomes. We consider "innovation" as a social process, one that takes place in the form of micro-negotiations at a micro-level in the context where interaction and practice are intertwined.

Therefore, we are interested in identifying the *ensemble* of factors which produce a socially favourable attitude to innovation: what we define as a "propensity to innovate". It is crucial to understand this concept as a label pointing to a set of factors that depend on the social, organisational and professional context. Specifically, this study was instigated by findings of an *ad hoc* survey carried out among teachers in primary, low secondary and upper secondary schools in Sardinia. The survey aimed to collect information on digital teaching innovation within the research project Digital School-Semid@s (for a general overview of the project see De Feo & Pitzalis, 2014). It seems that the school "environment" is a key factor in promoting technological diffusion; for example, in small schools there is a greater tendency to the diffusion of ICT, compared to medium or larger sized schools. More intense social relations and collegiality seem to positively influence the attitude of teachers (Wu et al., 2007). Nevertheless, while other studies have found such factors to be not significantly influential (Drent & Meelissen, 2008), it does seem that "Social relations" have a fundamental role in promoting the introduction of a technology (Frank et al., 2004). Through networks of social relationships, it is possible to share expertise and information and, at the same time, to build up a "culture" of shared professional competences (at least in terms of common definitions). These issues highlight the importance of the social dimension that will depend on the following two factors: 1) the commitment of institutions in terms of the responsibilities shown in management and organizational aspects; 2) "professional competences", described by actions denoting the membership to a community. These two concepts are associated with different dimensions of the phenomenon. Furthermore, we consider the influence of socio-demographic and professional characteristics and practices adopted in order to draw a clear outline of the processes that can influence the attitude to innovation.

Finally, this article does not sponsor a thesis "in favour" or a thesis "against" the use of digital technologies; it does not even assess their effectiveness in terms of the processes of learning and teaching. On the contrary, it aims to acknowledge that the school environment is a pluralistic, differentiated and stratified universe. Since every school and every group of teachers have their own history, the condition of the school and the professional environment is likely to be very different and the overall context will produce further variables. In other words, each school represents a universe of concrete practices, situated in specific social contexts and material spaces, which have a historical dimension and inherent characteristics. For this reason, we believe that it is not particularly helpful to talk about the "efficiency" of educational technologies in general terms. By the same token, the assessment of a policy ought to consider that its application and implementation is a process where conflicts, negotiations, and interpretations may, from time to time, change its evolution. Educational policies, reforms, technological and educational innovations spawn changes in the area of discourse and practices, which in turn produce a mobilization of people co-opted into new courses of action. This means that the implementation of a policy is likely to produce results that are largely unpredictable. As Van Zanten (2004) says, the transposition of the political is always accompanied by "creolization processes" which involve the translation of these policies into the relevant categories of the social actors and their adaptation within specific institutional contexts.

Therefore, our purpose is to consider the ensemble of factors that may facilitate the emergence of a propensity towards innovation as the direct and indirect effect of a collection of variables generated by different dimensions of the professional or organizational life of the teacher and the school. Thus, given that the goal of the article is fundamentally applicative and methodological, we will not elaborate on specific central issues, which will remain in the background, but we will discuss the methodological issues of the construction of indicators and methods of measurement suitable to constructing a measure of the "propensity to innovation". Moreover, an analysis carried out on a regression setting will enable us to investigate the effect of personal characteristics on teachers' position alongside the assessed latent traits, and thus also help us to define which factors potentially boost digital teaching innovation.

An *ad hoc* questionnaire with items measured on dichotomous and polytomous Likert-type scales was adopted to gather information on several domains of digital innovation. The information provided by each domain has been summarised in a metrical measure using Item Response Theory (IRT) tools. IRT is considered the main probabilistic approach for the analysis of questionnaires composed of categorical items. The main advantages of this approach is that the characteristics of each item in terms of the information that it provides on the individual's latent trait value are taken into account in defining a unique metrical score (which represents the respondent's position in the latent trait). Specifically, only respondents who have exactly the same response pattern have the same score.

The structure of the paper is as follows. *Data*: data will be described. *Selection and definition of dimensions under analysis*: a selection and definition of each considered dimension of digital innovation will be introduced. *Measurement tools: Item Response Theory* contains a brief introduction to the measurement approach based on Item Response Theory. *IRT empirical findings*: the results arising from the measurement approach for each of the dimensions are discussed. And *Assessing relationships among ICT indicators and teachers' socio-cultural characteristics* focuses on empirical findings followed by a section with conclusions. The Appendix provides detailed description of the manifest and latent variables considered in the analysis.

Data

Digital teaching innovation was analysed by means of a structured questionnaire completed by a sample of teachers. The survey was carried out by undertaking a census of the target population (mapping of schools in the region of Sardinia, Italy) and using a two-stage sample selection procedure which works by firstly selecting a sample of schools (first-stage) and then a sample of teachers (clustered in the previously selected schools).

Specifically, at the first stage schools were selected from a proportional stratified systematic sampling of 10% of the 1,153 schools existing in the region in February 2013. The stratification variables adopted at the first stage were the size of the municipality where the school was located and the highest level of non-tertiary education certificate available there (primary, low and upper secondary schools). The secondary level schools were stratified as academic (or Licei), technical and vocational. The population of schools was also stratified according to their location in two sub-populations: large municipalities (N_1 = 648) and small municipalities (N_2 = 505). For each kind of municipality, a sample of 10% of schools was selected. In the second stage, teachers were selected by adopting a simple random sampling scheme with a sample rate equal to 10% of the population of teachers in each school (the population size was set on the basis of the number of teachers in each school as recorded in the website of the central government schools authority in March, 2014). At least one teacher was selected for each school, taking into account their subject area (for the lower secondary school and higher education).

In the following, we adopt measurement tools for the analysis of questionnaires (Bertolucci et al., 2015) to summarize the information gathered in the survey. Specifically, ten indicators on a metrical scale were built up at teacher level (as a summary of the individual responses provided to the multi-item questionnaire) in order to define the ten domains of interests for the analysis of teachers' teaching practices. At the second stage, the relationship among the dimensions was analysed and an assessment was made of the effect of individual factors on the propensity to digitally innovate.

Selection and definition of dimensions under analysis

To obtain measurements of the latent traits (such as attitudes, skills, or achievement) it is necessary to provide a valid and reliable measurement tool. In Social Sciences, a measuring instrument is often a questionnaire consisting of a batch of items (also called scales) addressed to collect information on the different aspects of interest contained in the survey. A hypothesis frequently adopted is that there is a *latent continuous variable* underlying the observed responses of individuals to the items and that the position of respondents on the latent *continuum* is estimated according to the *pattern* of responses to the items. Consequently, individuals who provide exactly the same pattern of responses have the same intensity of the underlying latent trait. The assumptions underlying this measurement theory require that the measurement scale is valid, and that the concept is clearly defined (if necessary, splitting the different domains in sub-dimensions). The *validity* of the measuring instrument indicates its ability to measure the underlying latent concept of interest; this is mainly assessed by asking the opinion of experts and the evidence already established in literature. The validation of the questionnaire items is usually carried out by looking at surveys on similar topics (for example, the items of the questionnaire used in the survey to get information on the latent trait "school climate", were largely similar to those used in the OECD-PISA 2009 survey).

The *reliability* of the scale is determined by the ability of the measuring instrument to accurately reproduce the latent variable providing stable results when the scale is used under similar conditions. In Classical Test Theory (CTT) this feature is considered to be constant along the latent trait and it is assessed by Cronbach's *alpha* (Cronbach, 1951) – or coefficient of reproducibility of the scale – that is

$$\alpha = \frac{J\bar{\rho}}{1+\bar{\rho}(J-1)}$$

$\bar{\rho}$ where J is the number of items and is the mean of the J(J-1) correlation coefficients calculated considering all pairs of items. If there are no errors in the measuring process the residual component is zero, the correlation between pairs of items is always equal to the maximum (therefore =1) and the Cronbach α is equal to 1; as the share of residual variability increases, the mean coefficient of correlation decreases, indicating a lower degree of reliability. It is also useful to evaluate changes in the index as items are removed from the scale (omitting one item at a time from the calculation of the coefficient); in this way the measuring instrument is defined as a function of the set of items which maximize the reliability index. Indicatively, the threshold values to evaluate the reliability of the scale are: 0.70 – acceptable, 0.80 – good , 0.90 – excellent (Cronbach, 1951; Lovaglio, 2003). We used Chronbach's alpha as a first explorative tool to assess the reliability of the dimensions of the questionnaire. In the second stage, these dimensions were analysed using Item Response Theory (IRT) tools (Rasch 1960; Samejima, 1969). This is a class of probabilistic models that allows us to measure item and person characteristics. In such an approach, the reliability of the measurement instrument is not considered to be constant along the latent trait and the precision of the individual values along the latent trait is a function of the parameters that define the items (de Ayala, 2013; Toland, 2014). In the survey here presented, the items of the questionnaire were addressed to measure ten dimensions: five mainly relating to digital teaching innovation and five related to other aspects such as teacher training or teacher commitment and so on. A key aspect of the measurement process is the definition of an instrument that ensures a reliable position of the individual values along the latent trait.

This requires the selection of items that have a high discriminatory power and that provide information on all segments of the underlying latent traits (Edelen & Reeve, 2007; De Ayala, 2009; Toland, 2014). The statistical tool must therefore be properly calibrated according to the measurement purposes in order to appropriately detect differences in the intensity of latent traits among individuals in a population.

Table 1 (Appendix C) lists the relevant descriptive information for each dimension (labels, the number of items that compose them and Chronbach's alpha values), while Appendix contains the item list used to define each dimension of interest.

Measurement tools: Item Response Theory

Item Response Theory (Fischer and Molennar, 1995; Baker and Kim 2004; Edwards, 2009; Toland, 2014) is a probabilistic modelling tool mainly used in psychometrics. It is addressed to the measurement of a latent variable (θ) when a related set of manifest categorical (dichotomous, nominal or ordinal) variables (items) is observed. It is considered the main family of models for the construction of scales of measurement, the analysis of the characteristics of the items and the building up of indicators on a metrical scale starting from responses provided to a set of manifest categorical items (measured on a nominal or ordered scale). Item categories and individuals are described by parameters whose magnitudes indicate their positions on the latent trait. Specifically, the individual value of the latent trait is measured by the *person parameter* (θ_i), while the characteristics of the items are described by the *location parameters* (that identify the position of categories of responses along the continuum) and by a parameter that indicates their *discrimination power* (λ_j). Specifically, if the item is dichotomous, there are two categories of responses and only one location parameter β_j (therefore, for each dimension we have *J* parameters) that identifies the threshold between the two response categories, whereas for items with *K* categories of responses there will be (*K-1*) threshold parameters.

It is usually assumed that the latent trait has a Standard Normal distribution. Therefore, assuming perfect normality, we expect that nearly 99% of the individuals have a value in the range $\mu \pm 3\sigma$. The discriminatory parameter indicates how the item is related with the underlying latent trait: the higher its value, the greater the variability in the responses that is attributable to real differences in the values of the latent trait. Item location parameters and person parameters are measured with the same metric (on logit scale) and are then placed on the same line.

The higher the value of the person parameter θ_i with respect to the location parameter of item β_j ,the closer to 1 the probability that the individual provides a positive response will be. *Vice versa*, the preference for positive responses decreases as the value of the person parameter approaches the location parameter; it will be equal to 50% when the two parameters coincide and less than 50% when the first is located below the second. For this reason, in the psychometric field, the location parameter is also called the *difficulty parameter* of the item. For example, in a test designed to measure skills in mathematics, the harder the question, the greater the ability required to provide a correct answer will be.

The functions that describe the variation in the response probability (for a certain item category) take the name of Item Category Characteristic curves (ICCs). The shapes of these curves allow us to quickly highlight the level of the latent trait required to prefer one response category to another.

The value of the item discrimination parameter (λj) indicates the slope of the Item Category Characteristics curves. The higher the value of this parameter, the greater the change in the probability of response in one category rather than another, as the value of the latent trait varies. High values of the item discrimination parameters indicate a greater ability of the item to differentiate between individuals with different values of the latent trait; on the other hand, low values indicate that the curves are flat and that the items discriminate poorly.

For each item, the Item Information Function (IIF) measures how much information the item adds to the measurement of the latent trait. Its functional shape depends on the item characteristic parameters (discrimination and location parameters) and its peaks are observed in proximity of the item/item-category location parameters with intensity that depends on the discrimination parameter (Edwards, 2009). The inspection of the function is important to identify the information that each item adds to the scale and in which segment of the latent trait it is found. The Test

Information Function (TIF) is the sum of the IIFs and allows us to ascertain the degree of reliability of the scale with respect to each point of the latent trait. There is an inverse relationship between TIF and the standard errors of the person parameters. Thus the higher the TIF, the more accurate the individual latent trait values will be. The joint reading of TIF and IIF enable us to highlight redundant items and pinpoint which traits of the latent variable are poorly measured.

IRT empirical findings

A step-by-step analysis of the survey data using IRT models will be presented in the Appendix for each of the above mentioned dimensions of the questionnaire. In the following, we will report the results in terms of description of location parameters and item discriminatory power only for the first dimension that refers to what extent the teacher is trained in ICT (TRAINICT). Next section will present how the individual parameters are associated with other relevant information on teachers' and schools' characteristics. High values of the index correspond to higher intensities of training in ICT. Figure 1 for example shows that the item related to *ICT advanced use* (d190_1_3, see Appendix for variable coding), which has a location parameter of β_{d190_3} = 1.298, is "more difficult" than the item related to the attendance of *basic courses* (d190_1_1), which has a value of the location parameter equal to $\beta_{d190\_1\_1}$ =0.500.

Among the dichotomous items (in this section of the questionnaire) the most difficult is the use of *ICT for teaching* (d190_1_5, $\beta_{d190\_5=}$ 3,22) and the easiest is *interactive whiteboard basic courses* (d190_1_2,$\beta_{d190\_1\_2}$= -0,085). The scale consists of thirteen dichotomous and one polytomous item. The discriminatory power of the items varies between 0.911 and 3.892. The most informative item refers to the *time spent in training* (d190_5), as is shown by the IIFs which dominate the others. The shape of the TIF shows that the individual measures are less accurate for negative and high individual values of the latent trait.

Figure 1: Dimension TRAINICT. Item Response Category Characteristic Curve

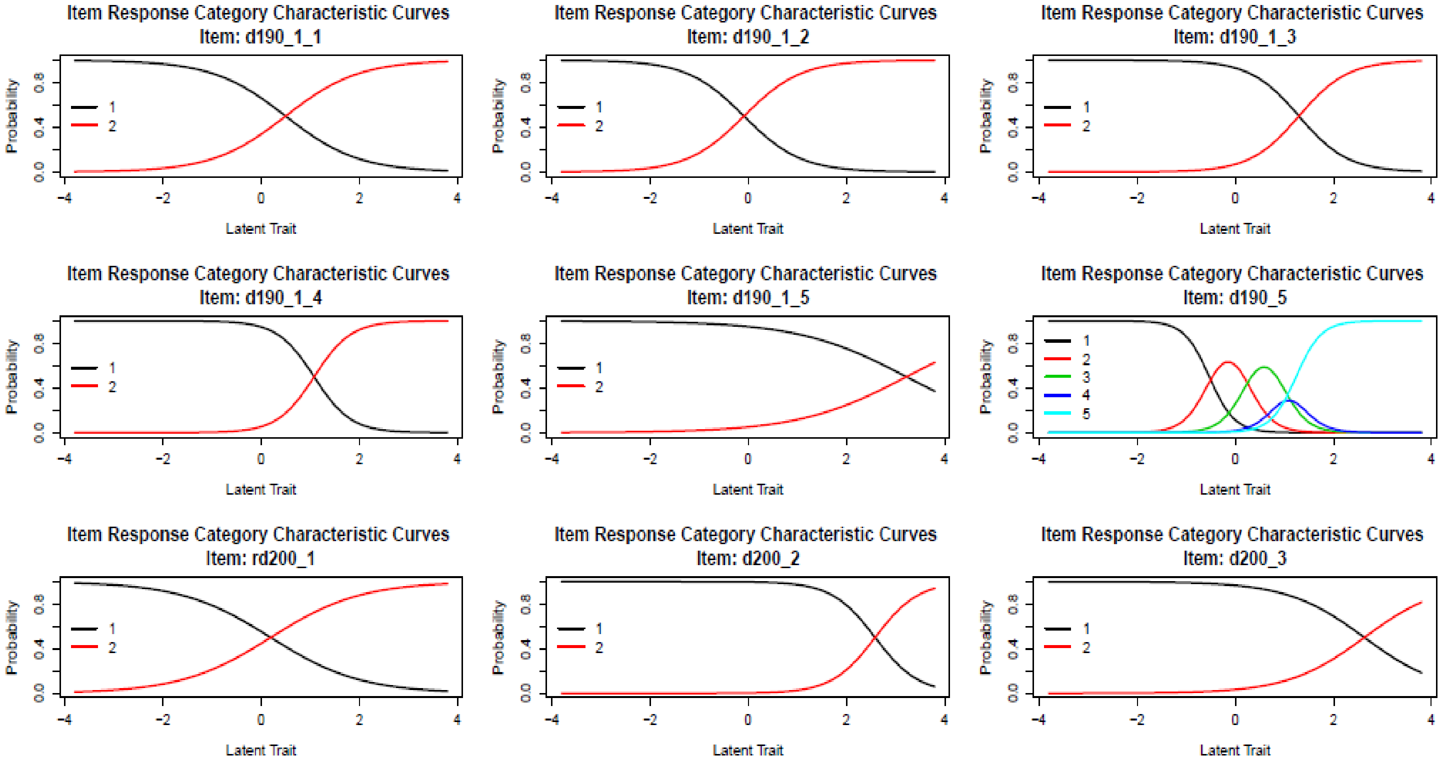
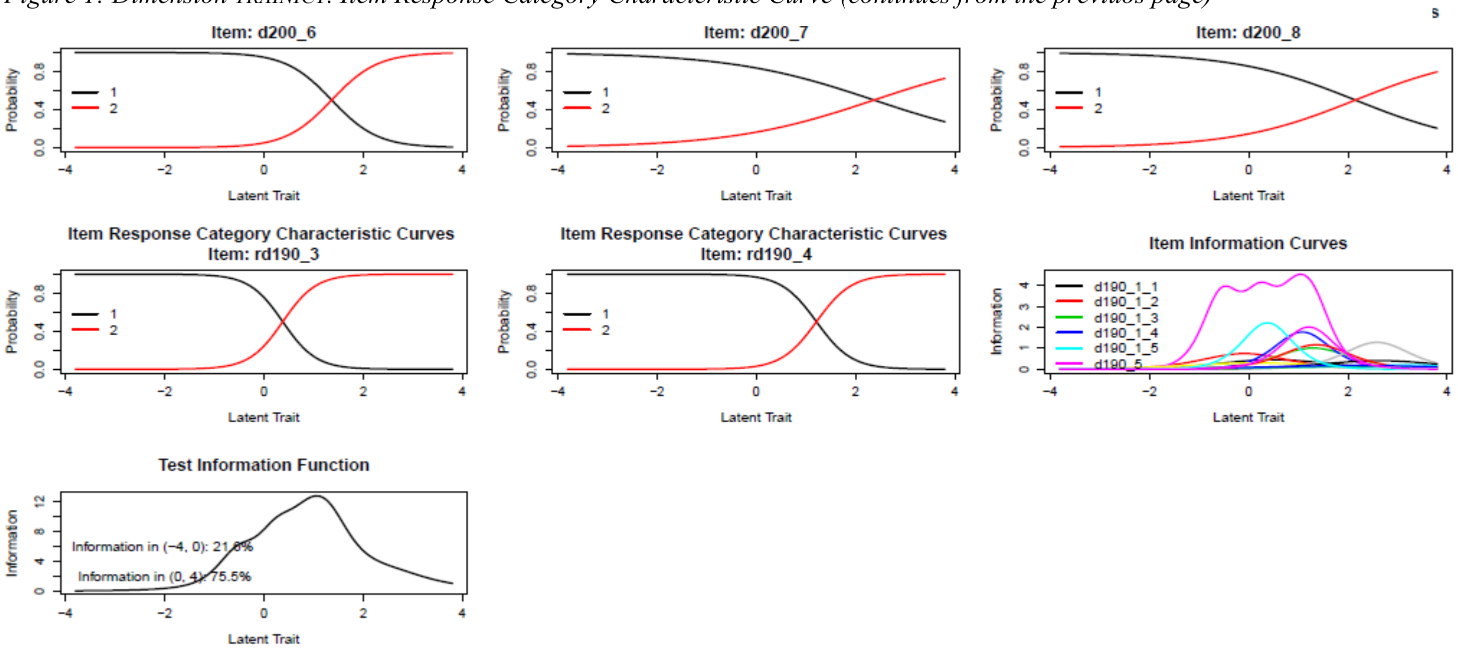


Figure 1: Dimension TRAINICT*. Item Response Category Characteristic Curve (continues from the previuos page)*



Assessing relationships among ICT indicators and teachers' socio-cultural characteristics

The above-described indicators that measure each of the considered dimensions in the relevant latent trait have been correlated with each other and with certain characteristics of the respondents and of the schools.

Table 2 shows the correlations matrix for the ten indexes. It emerges that the index of innovation to teaching (INNOVTEACH) shows a medium-low association (0.44) only with membership of the professional community (PROFCOMMUN). The propensity to use ICT (ICTTEACHUSE) is on average positively correlated with ICTPERSUSE, LIMUSE, ICTTIMEUSE and ICTTEACHPERC, with an intensity that goes, however, from medium-low to medium-high (0.40 to 0.62). It is interesting to highlight that, unsurprisingly, the strongest association is between the "time spent by teachers for the digital" and "the use of ICT in teaching".

Regression analysis was used to highlight the main relationships between the ten indicators and the characteristics of respondents. The information about the teachers has been sorted into three sections (a) socio-demographic characteristics of respondents, (b) characteristics related to their training history and profession, (c) characteristics of the school where they work.

Table 3 shows empirical estimates of regression models (significant coefficients have been reported in blue, with the corresponding p-value). In *group (a)* the following covariates have been classified: gender (female, male), age (min=27, max = 66), marital status (Single, Married/Cohabitant, Widowed, Separated/Divorced), the presence of children living with them (yes, no), the highest qualification held by their parents (none, primary school, lower middle, upper middle, graduate).

In *group (b)* if the teacher has a tenure (yes, no), how long they have been in their teaching job position, whether or not they have attended the post-graduation course aimed at providing training for teaching (ISS) (yes, no), years in their teaching role, years in teaching in the same school, if they give private classes (yes, no) or if they do other work (yes, no). Finally, *group (c)* contains information on the type of school where they teach (primary, lower middle and upper middle) and the size of the city where the school is located (large or small municipality).

Table 2. Pearson correlation coefficients

	TRAINICT	*COMMITMENT*	PROFCOMMUN	ICTPERSUSE	SCHCLIMATE	INNOVTEACH	ICTTEACHUSE	LIMUSE	ICTTIMEUSE	ICTTEACHPERC
TRAINICT	1									
COMMITMENT	*0.5011*	*1*								
PROFCOMMUN	0.039	*0.0741*	1							
ICTPERSUSE	0.2158	*0.2663*	0.0247	1						
SCHCLIMATE	-0.022	*-0.0238*	0.1728	-0.0934	1					
INNOVTEACH	0.1112	*0.1083*	0.4374	0.0329	0.1925	1				
ICTTEACHUSE	0.2554	*0.3358*	0.1344	0.4467	-0.0702	0.2189	1			
LIMUSE	0.2379	*0.2324*	0.1937	0.2942	0.0074	0.2979	0.6181	1		
ICTTIMEUSE	0.2868	*0.3265*	0.0099	0.8066	-0.07	0.142	0.5891	0.4043	1	
ICTTEACHPERC	0.2061	*0.2117*	0.0969	0.2624	-0.0662	0.212	0.4016	0.4335	0.3164	1

For COMMITMENT (ordinal variable) we have reported the Spearman coefficient

In a first step, we highlight the main empirical evidence between covariates and each of the ten dimensions. Covariates were inserted among the predictors by a forward selection procedure designed to maximize the results in terms of a 'goodness of fit' model (adjusted-R^2).

With respect to their *training in ICT*, it appears that parents' level of education, the teaching experience, doing extra-school work activities, and whether they are engaged even occasionally in private classes account for, approximately, 16.5% of the total variability in the individual values. It should be noted that the only variable that seems to have a negative effect on the indicator is for those engaged in other work activities outside the school.

Moreover, results point out that (on average) the expected value of the indicator that measures the training in ICT for a teacher with characteristics that positively affect his attitude to ICT training (namely, teachers coming from families with at least one parent with a secondary education level or higher, having security of tenure for 40 years, giving private classes but not doing other work activities outside the school) is 0.40 (remember that the index takes values in the range -3 and +3) while the same value for a teacher who has an opposite (negative) profile with respect to the same covariates (namely, those from families with no education, no security of tenure, those not involved in private teaching work, involved in other activities) is -1,85.

The regression analysis concerning *commitment* shows that gender, civil status and the total number of years spent working as a teacher with tenure account for the 11.4% of the overall variability in the individual values of the indicator. Results highlight that for teachers who have a positive profile of individual characteristics (man, separated / divorced and in service for 40 years) the expected value of the indicator (which has a mean = 1.73 and standard deviation = 0.86) is about 2,458 whereas for a teacher who has an opposite profile (woman, unmarried and without tenure) it is 1.20.

If in the same model we consider the distinction between teachers with and without tenure, it emerges that the latter have a lower average expected value of the indicator (-0.66) compared with teachers with tenure (controlling for the remaining covariates).

Innovation in teaching seems, on average, to be associated only with the type of school, a variable that explains approximately 13% of the observed differences between individual values. The results show that the expected value of innovation in education for a teacher who teaches in primary school is 0.26, in the lower secondary it is -0.026, and finally, in the upper secondary school it is -0.471.

The dimension related to the *sense of belonging to professional community* seems to be on average higher among teachers of primary schools and lower among those of secondary schools not engaged in private classes (in average 0.25 higher). It should be noted that none of the features directly related to the teacher's profile has a significant influence on the expected value of the latent trait, to a significance level of 5%. The analysis also shows that overall both predictors explain just 5% of the variability found among the teachers in the values of the indicator.

Considering the *use of ICT in teaching,* results show that the size of the municipality in which the school is located, the age, the level of education of parents (only for this dimension recoded as 1 = none, 2 = elementary/middle school and higher education, degree=3) and the length of time spent in a teaching position account for around 7% of the differences in the propensity to use ICT in teaching. We highlight that the value of the latent trait is on average significantly lower in small towns than in big ones (-0.37).

On average, it decreases with the age of the teacher (with differences in the latent trait of about 0.27 between two teachers who have a distance of 10 years), and increases with years of teaching (if the length of teaching experience increases by 10 years, the value of the indicator varies by about 0.16). If we consider the difference between teachers with and without a tenure, leaving the other characteristics constant, the results of the analysis show that the former have, on average, a value of the latent trait 0.46 points higher than the latter. To summarise, together these variables explain just about 7% of the differences in individual values of the indicator.

The intensity in the *IWB use's* latent trait is on average lower among teachers who teach in schools located in small municipalities (-0.29) compared to larger ones, and is lower in lower secondary or high secondary schools than in the primaries (-0.15 and -0.27 respectively). Considering the characteristics of teachers, the expected value of the indicator increases with the seniority of their role (the indicator value changes by 0.11 between two teachers who have 10 years of difference in service) and decreases with the increase in age (the expected change in the indicator is -0.28 if the age increases by 10 years).

With respect to the *time spent using ICT,* an analysis of the relationship between the indicator and the characteristics of respondents shows that the type of municipality along with gender, age, marital status, the level of parents education, the length of service in the position and whether of not they are engaged in private work, explain about 15% of the variability observed in the values of the time spent by teachers on ICT. Teachers who work in schools located in small towns (-0.30), higher in age (an increase in age of 10 years implies a decrease in the expected value of 0.36 points) and senior in tenure (as the number of years of service increases by 10 years, the expected value varies about 0.13 points) seem on average to have lower values of the latent trait. It also appears that men have a higher expected average than women (+0.30), as do those engaged in private classes (about 0.39).

Furthermore, we also detected differences related to marital status, with expected values of married and separated/divorced on average higher than those of singles. Comparing the values of the indicator for an individual with characteristics that are "positively" related with the latent trait (school located in a large municipality, man, 45 years-old, 15 years in the position, who does private work, separated/divorced, middle school for parents' education) and one with features that show negative associations (school located in a small municipality, woman, 45 years-old, 0 years in the position, who does no private work, single, low educational level of parents), the values of the latent trait are respectively 1.39 and -1.326.

With respect to *personal use of ICT*, it emerges that the level of education of parents (categories primary, middle and high have been merged), the length of service in the position, and also whether or not engaged occasionally in private classes, account for about 16% of the total variability in the values of the index. It should be highlighted that this indicator is negatively associated with age and positively with the length of the service and the level of education of the parents. Finally, also with respect to this dimension, teachers who do additional outside school work tend to have lower expected values (-0.48) on average than the others, while divorced and separated teachers have higher average expected values.

The *perception of ICT usefulness for teaching* is worst among the teachers in the primary sector. With regard to the characteristics of teachers, the expected value is on average higher for teachers who work outside of school. The characteristics considered in the model explain only 5% of the total variability in the values of the index.

With regard to the *perception of the school climate* results shows that the differences in the type of school, in the parents' educational level (categories primary, middle and high have been merged) and whether involved in other working activities explain about 9.5% of the variability. Teachers who have a worse perception of the school climate (lower on average) come from families where at least one parent has completed the tertiary education level (-0.54 compared to those whose parents have no qualifications) and who teach in lower (-0.15) and higher secondary (-0.49) schools rather than in the primaries. Furthermore, those who are not engaged in private classes have a higher expected value (+0.27) in this index (table, 3, Appendix d).

Conclusions

The use of ICT in education is an important asset in the European Commission’s strategy to ensure the effectiveness of European education systems and the competitiveness of the European economy. In 2010, the European Commission adopted a new Digital Agenda for Europe (European Commission, 2010) that reaffirms and fine-tunes a number of challenges for the years to come. The objective of the Agenda is to maximise the social and economic potential of ICT. This can only be achieved through the development of high level ICT skills, including digital and media literacy. All European countries are developing national strategies to foster the use of ICT in different areas including a specific strategy devoted to education. In many cases, these strategies aim to provide the necessary ICT skills to pupils (in particular literacy skills) as well as provide ICT training for teachers. Another defining feature is the provision of up-to-date technology and infrastructure in schools. The target groups for the measures in all countries are teachers/trainers and the activities focus on primary and secondary school education. Nowadays, the problem of the measurement of innovation and its effects have become a central issue for international and national agencies. This paper has had the essentially practical goal of presenting and discussing the application of IRT as a methodology apt to measure “latent traits” and to construct indicators of teaching innovation with ICT. By analysing data gathered with an *ad hoc* survey we have explored issues related to the “propensity to innovation” in teaching and ICT use.

It is important to underline here that the concept of “propensity” has to be regarded as a theoretical construct and not as an individual distinctive cognitive feature or psychological attribute. It refers to the probability that a set of actions and representations are associated with practices that involve different levels of use of technological devices. In our hypothesis, their potential use in teaching may be associated with professional and personal habits acquired in the course of personal practice, such as the outcome of organizational learning processes, and / or the result of a positive perception of the use of ICT in teaching (often produced by previous phases of professional and technological socialization). In this way, "innovation" may be viewed in different dimensions (individual, professional, organizational) that are explored to determine their effectiveness and to measure their correlation.

Using data collected from a sample of teachers that filled in the questionnaire, nine series of measurements were built up using IRT models in different domains pertaining to ICT use in schools. The IRT methodology proved to be a suitable research tool in the framework of assessing propensity or attitudes in different domains pertaining to use of the ICT in schools. It provided us with the following significant advantages and enabled us: (i) to inform about the statistical properties of the set of items used to score each domain; (ii) to avoid arbitrary choices in scaling categories and merging item responses in a single score; (iii) to asses the reliability of the indicators for measuring teachers' propensities with respect to the domains of interest and for respondents with different latent trait values. Five specific dimensions were obtained with respect to digital teaching innovation, while the other five dimensions are related to the perception of the school climate, to the school context (commitment and sense of belonging to professional community) and with the use of ICT for other aims (personal use of ICT and training on ICT). From the analysis we observe a strong positive correlation between ICT use for teaching and the use of the electronic whiteboard (or LIM), the time spent on ICT and the perception of ICT usefulness for teaching. At the same time whiteboard use is also strongly (positively) correlated with the last two indexes (ICTTIMEUSE and ICTTEACHPERC). Regarding the other five dimensions (which refer to facets unrelated to digital teaching innovation), ICT training and institutional commitment have a middle positive correlation with four indexes related to ICT and digital teaching innovation, except for the INNOVTEACH index, that is correlated positively with the sense of belonging to community (PROFCOMMUN). The personal use of ICT is strongly positively correlated with the time spent in ICT activities, while a medium correlation exists with ICT use for teaching. Finally, regarding the effect of some chosen teachers/school characteristics regression analysis, results have proved that while socio-demographic characteristics of respondents and school characteristics do affect the five dimensions of digital teaching innovation, characteristics related to teachers' training professional path have no effects on the five dimensions of digital teaching innovation.

Thus, five of the ten dimensions analysed above may be considered as components of the "latent trait" we have called "propensity to innovation". Assuming probabilistic models, we may identify the profile of teachers characterised by different values obtained in the five dimensions of the innovation analysed (For a substantive analyses of these results see Pitzalis et al., 2016).

The empirical analysis pointed out that professional training, the sense of belonging to a professional community, the personal use of ICT and institutional positions held within the school -especially if related to ICT - affect the propensity for digital learning. In conclusion, these factors affect – more than others – educational innovation. Moreover, the analysis has brought to light the importance of the socio-demographic characteristics of the teacher, which although not directly affecting digital educational innovation, does indirectly influence it.

This article was written as part of a research project funded by the Autonomous Region of Sardinia, L.R. 7/2007 (Annualità 2011, CRP 49311 - European Social Fund). Title of the project: *La Rivoluzione digitale nella scuola sarda. Caratteristiche strutturali del sistema, culture professionali, organizzative e didattiche di fronte alla sfida dell'innovazione*. Principal investigator: Prof. Marco Pitzalis, (CIRD-REC: University of Cagliari and University of Sassari).

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Appendix A

Questionnaire item description

In this section the following tables resume the relevant information about the different questionnaire items used to scale the dimension investigated: item content, its label (helpful for reading the figures provided in Appendix B) and its correspondent scale of measurement.

TRAINICT

Item	*Label*	*Scale*
ICT training: basic courses	d190_1_1	dichotomous
ICT training: whiteboard (LIM) basic courses	d190_1_2	dichotomous
ICT training: ICT advanced use (PC, Internet, LIM)	d190_1_3	dichotomous
ICT training: European Computer Driving License	d190_1_4	dichotomous
ICT training: ICT for teaching	d190_1_5	dichotomous
Time spent in training	d190_5	polytomous
Partecipation in ICT projects: none	1rd200_1	dichotomous
Partecipation in ICT projects: M@rte	d200_2	dichotomous
Partecipation in ICT projects: Campus	d200_3	dichotomous
Partecipation in ICT projects: Semid@s (Scuola Digitale)	d200_6	dichotomous
Partecipation in ICT projects: Cl@ssi 2.0	d200_7	dichotomous
Partecipation in ICT projects: Digiscuola	d200_8	dichotomous
Preparation of teaching tools during training	rd190_3	dichotomous
Experience with students during training	rd190_4	dichotomous

ICTPERSUSE

Item	Label	*Item scale*
Technologies available outside school: computer	rd270_02	dichotomous
Technologies available outside school: laptop	rd270_03	dichotomous
Technologies available outside school: tablet	rd270_04	dichotomous
Technologies available outside school: smartphone	rd270_05	dichotomous
Technologies available outside school: USB memory card	rd270_06	dichotomous
Activities and frequency internet use: for school	rd280_11	polytomous
Activities and frequency internet use: for amusement	rd280_12	polytomous
Activities and frequency internet use: for online discussions, communities and virtual spaces	rd280_13	polytomous
Activities and frequency internet use: for update a web site or blog	rd280_14	polytomous
Activities and frequency internet use: to update knowledge	rd280_15	polytomous

PROFCOMMUN

Item	*Label*	*Item scale*
School activities (frequency): to attend teacher meetings to discuss school vision and school goals	d220_01	polytomous
School activities (frequency): to guarantee common criteria to assess students' achievement	d220_02	polytomous
School activities (frequency): training activities for learning	d220_03	polytomous
School activities (frequency): to observe students of other teachers and prepare useful feedbacks	d220_04	polytomous
School activities (frequency): to exchange teaching tools with other teachers	d220_05	polytomous

SCHCLIMATE

Item	*Label*	*Item scale*
Teachers' low expectations of students	d330_01	Polytomous
Student absenteeism	d330_02	Polytomous
Poor student-teacher relations	d330_03	Polytomous
Disruption of classes by students	d330_04	Polytomous
Teachers not meeting individual students' needs	d330_05	Polytomous
Teacher absenteeism	d330_06	Polytomous
Students skipping classes	d330_07	Polytomous
Students lacking respect for teachers	d330_08	Polytomous
Staff resisting ch'ange	d330_09	Polytomous
Teachers being too strict with students	d330_10	Polytomous
Students intimidating or bullying other students	d330_11	Polytomous
Students not being encouraged to achieve their full potential	d330_12	Polytomous
Early school leaving	d330_13	Polytomous
Drug or alcool use	d330_14	polytomous

INNOVTEACH

Item	*Label*	*Item scale*
I explicitly state learning goals.	d210_01	polytomous
I review with the students the homework they have prepared.	d210_02	polytomous
At the beginning of the lesson I present a short summary of the previous lesson.	d210_03	polytomous
I check my students' exercise books.	d210_04	polytomous
I check, by asking questions, whether or not the subject matter has been understood.	d210_05	polytomous
Students work in small groups to come up with a joint solution to a problem or task.	d210_07	polytomous
Students work in small groups to come up with a joint solution to a problem or task.	d210_08	polytomous
I give different work to the students that have difficulties learning and/or to those who can advance faster.	d210_09	polytomous
I ask my students to suggest or to help plan classroom activities or topics.	d210_10	polytomous
Students work in groups based upon their abilities.	d210_11	polytomous
I ask my students to write an essay in which they are expected to explain their thinking or reasoning at some length.	d210_12	polytomous
Students hold a debate and argue for a particular point of view which may not be their own.	d210_13	polytomous

ICTTEACHUSE

Item	*Label*	*Item scale*
Time spent with computer during school lessons (weekly): with internet connection	rd240_1_1	polytomous
Time spent with computer during school lessons (weekly): without internet connection	rd240_1_2	polytomous
Availability of technologies in school: internet connection	rd240_2	dichotomous
Availability of technologies in school: printer	rd240_3	dichotomous
Availability of technologies in school: whiteboard	rd240_4	dichotomous
Activities with students (frequency): researches with internet	rd240_31	polytomous
Activities with students (frequency): upload and download materials on school website	rd240_32	polytomous
Activities with students (frequency): exercises with specific softwares (word, except, etc)	rd240_33	polytomous
Activities with students (frequency): use of CD-ROM and/or textbooks platforms	rd240_34	polytomous
Teaching activities outside school: email with students	rd250_01	dichotomous
Teaching activities outside school: texts with software	rd250_02	dichotomous
Teaching activities outside school: to modify digital texts	rd250_03	dichotomous
Teaching activities outside school: to prepare exercises with excel	rd250_04	dichotomous
Teaching activities outside school: presentations	rd250_05	dichotomous
Teaching activities outside school: download/install software for teaching	rd250_06	dichotomous
Teaching activities outside school: download internet materials for school	rd250_07	dichotomous
Learning Management System use for teaching	rd253	dichotomous

LIMUSE

Item	*Label*	*Item scale*
Whiteboard use with internet connection	d210_01	dichotomous
Tools used for whiteboard activities: available on-line	d210_02	dichotomous
Tools used for whiteboard activities: software and other materials provided by school	d210_03	dichotomous
Tools used for whiteboard activities: software and other tools provided by the publishing house	d210_04	dichotomous
Tools used for whiteboard activities: multimedia self-produced or produced by other colleagues	d210_05	dichotomous
Whiteboard use (frequency) for: work group with students	d210_06	polytomous
Whiteboard use (frequency) for: students’ presentation	d210_08	polytomous
Whiteboard use (frequency) for: to do homework in class	d210_09	polytomous
Whiteboard use (frequency) for: exploration with students	d210_10	polytomous
Whiteboard use (frequency) for: video or listen to digital audio	d210_11	polytomous
Whiteboard use (frequency) for: to assess students’ work	d210_12	polytomous
Whiteboard use (frequency) for: explain or illustrate concepts by writing from a blank page and saving the lesson	d210_13	polytomous

ICTTIMEUSE

Item	*Label*	*Item scale*
Teaching activities outside school: email with students	rd250_01	dichotomous
Teaching activities outside school: texts with software	rd250_02	dichotomous
Teaching activities outside school: to modify digital texts	rd250_03	dichotomous
Teaching activities outside school: to prepare exercises with excel	rd250_04	dichotomous
Teaching activities outside school: presentations	rd250_05	dichotomous
Teaching activities outside school: download/install software for teaching	rd250_06	dichotomous
Teaching activities outside school: download internet materials for school	rd250_07	dichotomous
Activities and frequency internet use: for school	rd280_11	polytomous
Activities and frequency internet use: for amusement	rd280_12	polytomous
Activities and frequency internet use: for online discussions, communities and virtual spaces	rd280_13	polytomous
Activities and frequency internet use: for update a web site or blog	rd280_14	polytomous
Activities and frequency internet use: for update	rd280_15	polytomous

ICTTEACHPERC

Item	*Label*	*Item scale*
Agreement with the following statements on the ICT diffusion for teaching: ICT not change teaching practices	d295_01	polytomous
Agreement with the following statements on the ICT diffusion for teaching: ICT are an obstacle between students and teachers	d295_02	polytomous
Agreement with the following statements on the ICT diffusion for teaching: ICT are not very important	d295_03	polytomous
Agreement with the following statements on the ICT diffusion for teaching: ICT don't facilitate the labour market access	d295_04	polytomous
Agreement with the following statements on the ICT diffusion for teaching: ICT are not necessary for teachers	d295_05	polytomous
Agreement with the following statements: with whiteboard students are more interested at lesson	rd320_01	polytomous
Agreement with the following statements: with whiteboard students are more autonomous	rd320_02	polytomous
Agreement with the following statements: with whiteboard students collaborate	rd320_03	polytomous
Agreement with the following statements: with whiteboard understand better the lesson	rd320_04	polytomous
Agreement with the following statements: with whiteboard students develop transversal competencies	rd320_05	polytomous
Agreement with the following statements: with whiteboard teaching is easier	rd320_06	polytomous
Agreement with the following statements: whiteboard promotes interdisciplinary	rd320_07	polytomous
Agreement with the following statements: whiteboard promotes teacher collaboration	rd320_08	polytomous

Appendix B

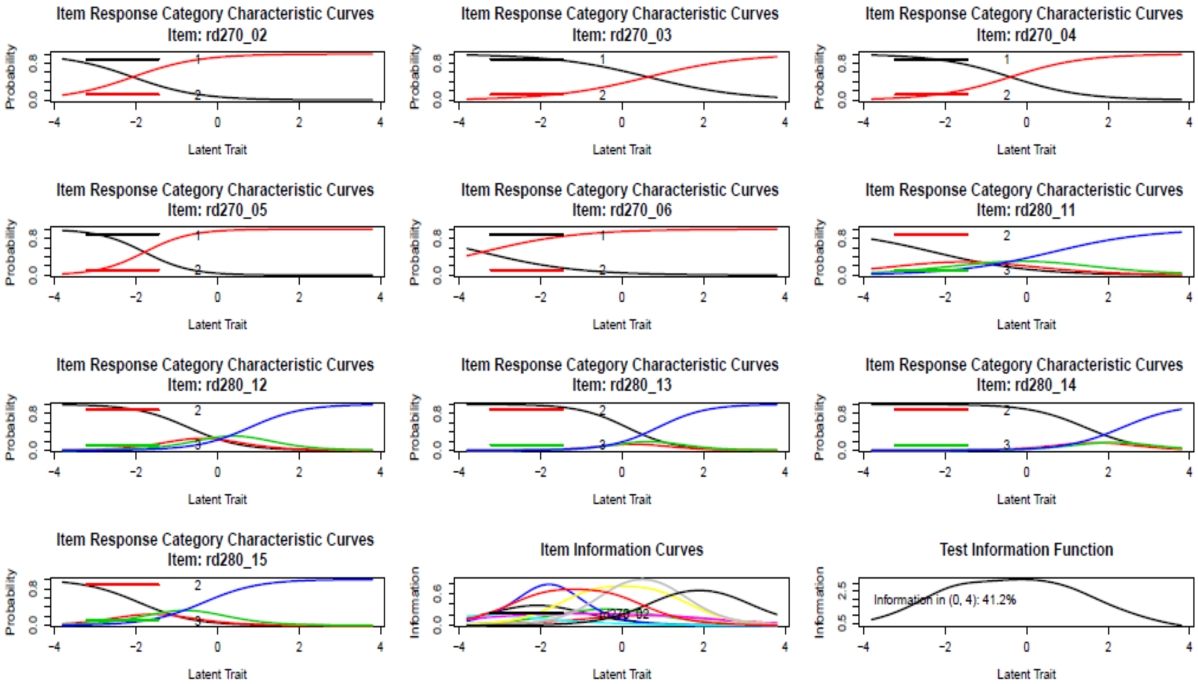
Scaling the considered latent traits via IRT models
In the following, we present the main evidences which arose using IRT models for the analysis of the ten dimensions by briefly describing the characteristics of each scale.

B.1 – Dimension 1: TRAINICT
IRT results on Dimension 1 – TRAINICT have been reported in the Section *Empirical results*.

B.2 – Dimension 2: COMMITMENT
This index has been built considering two items of the questionnaire and it assumes value 0 if teacher has none institutional commitment, 1 if teacher has an administrative commitment and 2 if it is in ICT field.

B.3 – Dimension 3: ICTPERSUSE
High values of the index correspond to higher intensities of use of ICT in teaching. The scale consists of 10 items, 5 dichotomous and 5 polytomous. Figure A01 shows that the dichotomous items are mainly informative on low and medium segments of the latent trait, as shown by the location of the item parameters. The threshold values of the categories of polytomous items vary between -2.269 and 2.357. Polytomous items show a polarization of the responses in the two extreme categories "*never*" versus "*every day*"; in particular, the categories "twice a month" and "twice a week" arise as redundant. The TIF shows a slight positive skewness, indicating a higher accuracy of the scale in the measurement of negative values of the latent trait.

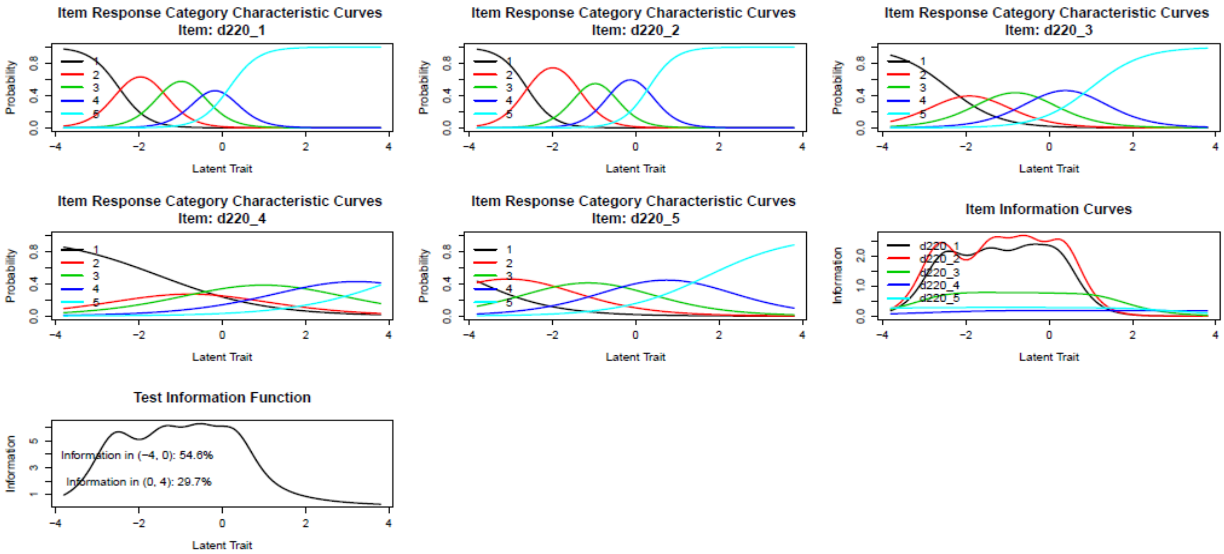
Figure A01: Item Response Category Characteristic Curves, ICTPERSUSE



B.4 – Dimension 4: PROFCOMMUN

Higher values of the index correspond to higher sense of belonging to professional community. The scale consists of 5 polytomous items. The items with the highest discriminatory power (namely, *to attend meetings with other teachers* (d220_01), *to share common criteria to assess students' achievement* (d220_02) and *to participate in professional training activities for learning* (d220_03) are also the ones perceived as "*easier*". For the three items the threshold parameter of the category "*always*" falls within one standard deviation from the mean. On the contrary, the two items which have the lowest discriminatory power, are also those that result as "*the most difficult*", as it is highlighted by the values of the threshold parameters that define the category "*always"* (respectively equal to 4.40 and 1.73) and the form of the ICC and their IIF. The shape of the TIF (Figure A02) shows that the scale has a low reliability for positive values of the latent trait whereas it shows a quite constant accuracy in the negative range.

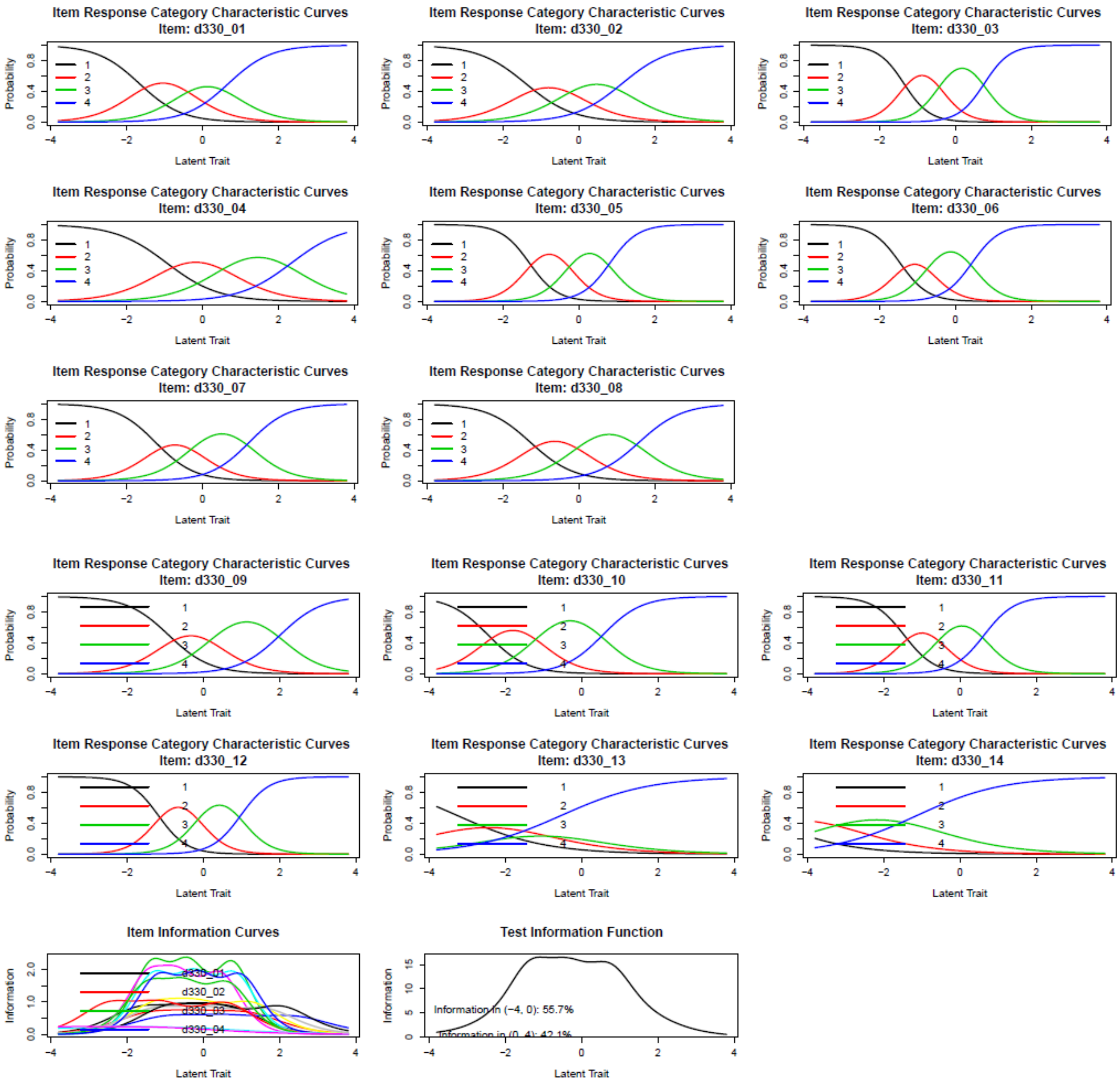
Figure A02: Item Response Category Characteristic Curves, PROFCOMMUN



B.5 – Dimension 5: SCHCLIMATE

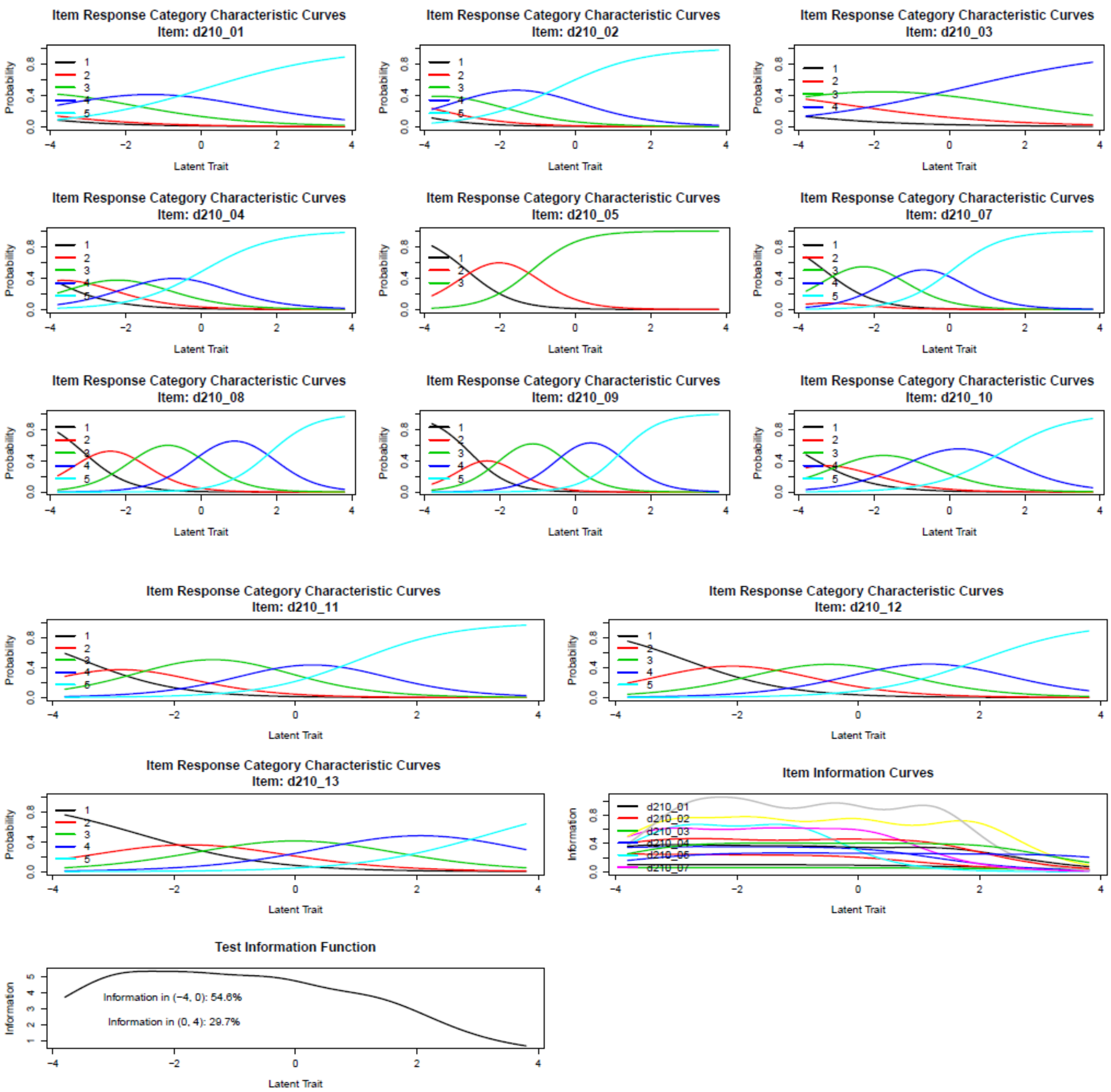
High values of the index correspond to positive perceptions of school climate. The scale consists of 14 polytomous items. Figure A03 shows that the threshold values of the categories are equally distributed along the latent trait [min=-5.315, max=2.012]. The items which show the greatest discriminatory power are *teachers not meeting individual students' needs* (d330_05), *teachers' absenteeism* (d330_06) and *poor student-teacher relations* (d330_03). The shape of the TIF shows that the test information is almost constant from medium low to medium high values of the latent trait.

Figure A03: Item Response Category Characteristic Curves, SCHCLIMATE



The scale consists of twelve polytomous items that define the classroom teaching practices. The first five items refer to activities related to *traditional teaching*. These items have threshold category parameters located in the low segment of the latent trait and are characterized by a low discriminatory power (λj range from 0.466 of itemto 1.076). The other three items refer to *student orientation* teaching practises have the highest discriminatory power (between 1.477 and 1.892). Finally, the last four items refer to the *advanced teaching activities.* The ICCs (Figure A04) show that it is required to a teacher a level of latent trait at least one standard deviation above average (between 1.027 and 3.183) to choose the "*always*" response category. It means that a teacher needs to have an aptitude for teaching innovation very high to answer "*often*" or "*always*" to the actions described by the last items; these turn out to be also those with the lowest discriminatory power among the items which account for the advanced tasks in teaching. The shape of the TIF indicates that the scale of measurement is less accurate for individual values of the attitude to teaching innovation above the average: about 54.6% of the test information is contained in the range [0, -4].

Figure A04: Item Response Category Characteristic Curves, innovteach



B.7 – Dimension 7: ICTTEACHUSE

Higher values of the index correspond to a higher use of ICT in teaching. The scale consists of 11 dichotomous items and 6 polytomous with four response categories. The values of the item-threshold parameters have a range of variation along nearly all the continuum [-3.210, +2.135]. All polytomous items have a medium-high discrimination power, (see Figure A05). The greatest contribution to the TIF is provided by the IIF of the item which provides information on *time spent with computer during school lessons* (rd240_1_1). The TIF shows that the reliability of the test decreases going from the average towards medium-high and medium-low levels of the latent trait.

Figure A05: Item Response Category Characteristic Curves, ictteachuse

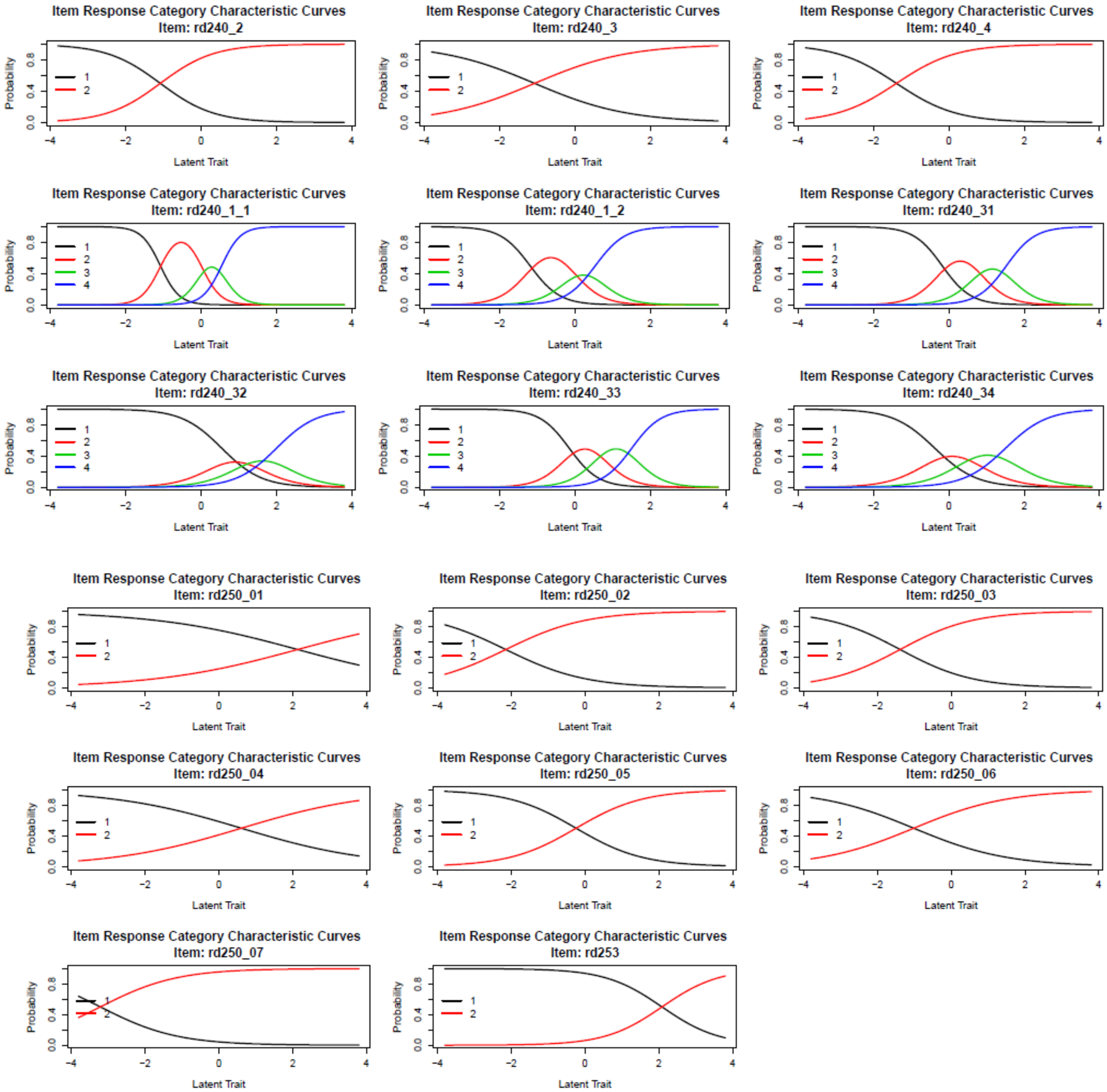
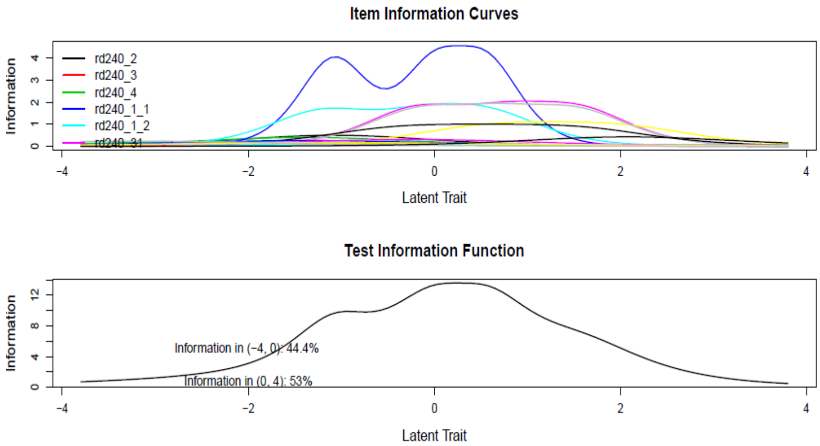


Figure A05: Item Response Category Characteristic Curves, ictteachuse (continues from the previous page)



Higher values of the index correspond to higher intensities of use of whiteboard (LIM). The scale consists of five dichotomous items and seven polytomous (with five response categories). The values of the threshold parameters are mainly located along the medium and positive part of the latent trait, as it is shown by their range of variation [-0.636, 1.863]. For polytomous items, some response categories in the negative part of the latent trait are redundant (as for example "*rarely*" does not identify a segment of the latent trait different from "*never*"). The asymmetric negative TIF (Figure A06) shows that the information provided by the individual parameters sharply decreases in the negative part of the latent trait, highlighting that medium-low and low values of the latent trait are poorly measured

Figure A06: Item Response Category Characteristic Curves, LIMUSE

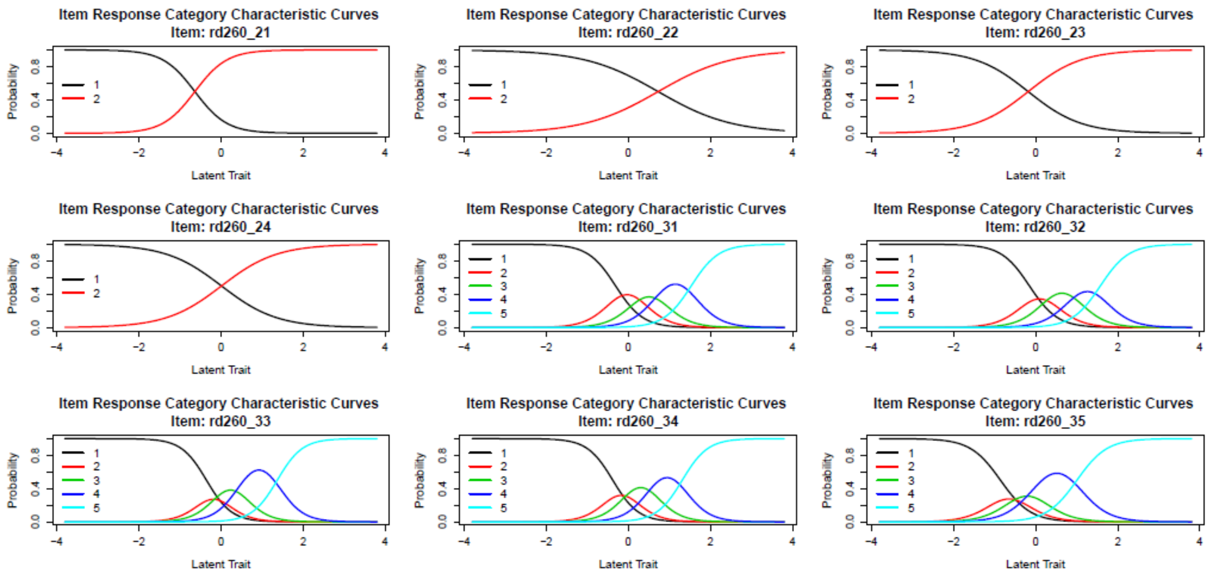
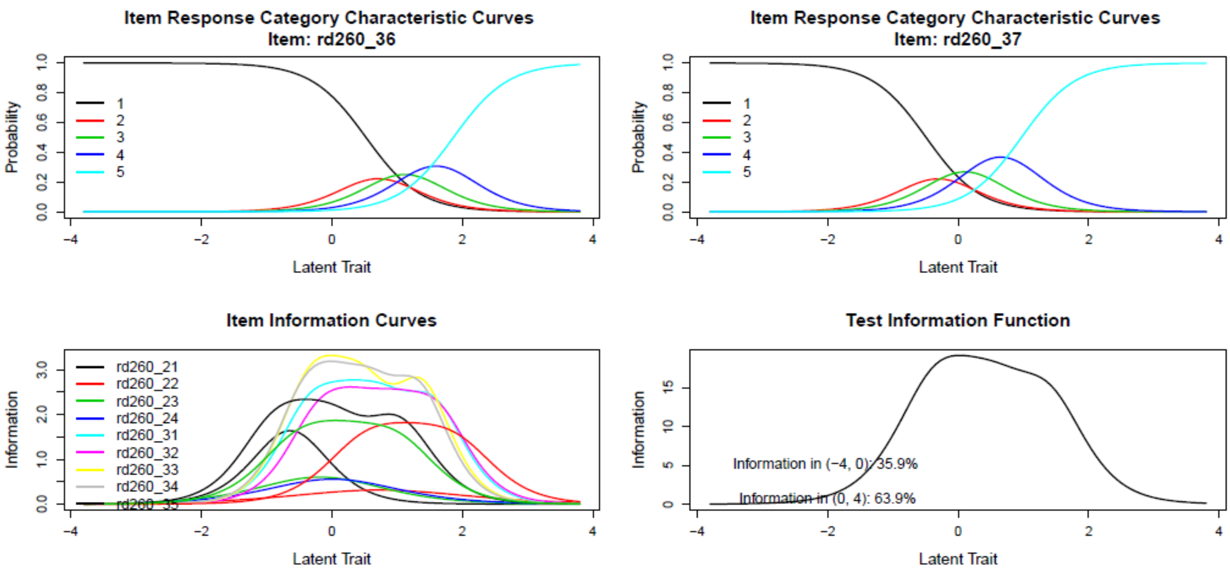


Figure A06: Item Response Category Characteristic Curves, LIMUSE *(continues from the previous page)*



The scale consists of seven dichotomous and five polytomous items (with four response categories). The ICC shows that the position of threshold parameters for dichotomous items vary between -2.008 (rd250_07: *software and other materials for teaching*) and 1.284 (rd250_01: *email with students*), while the threshold parameters of the categories of polytomous items show a polarization of the responses in the two opposite categories "*never*" versus "*every day*". Figure A07 shows that the central categories "*twice a month*" and *"twice a week*" are redundant because their informative power overlaps with the e extreme categories. The discriminatory power of items varies from medium (0.921) to high (2.804). The positive skewed shape of the TIF shows that the function has a peak only for medium-low levels of the latent trait (around at -1.5) and then sharply decreases on both sides for lower latent trait values.

Figure A07: Item Response Category Characteristic Curves, ICTTIMEUSE

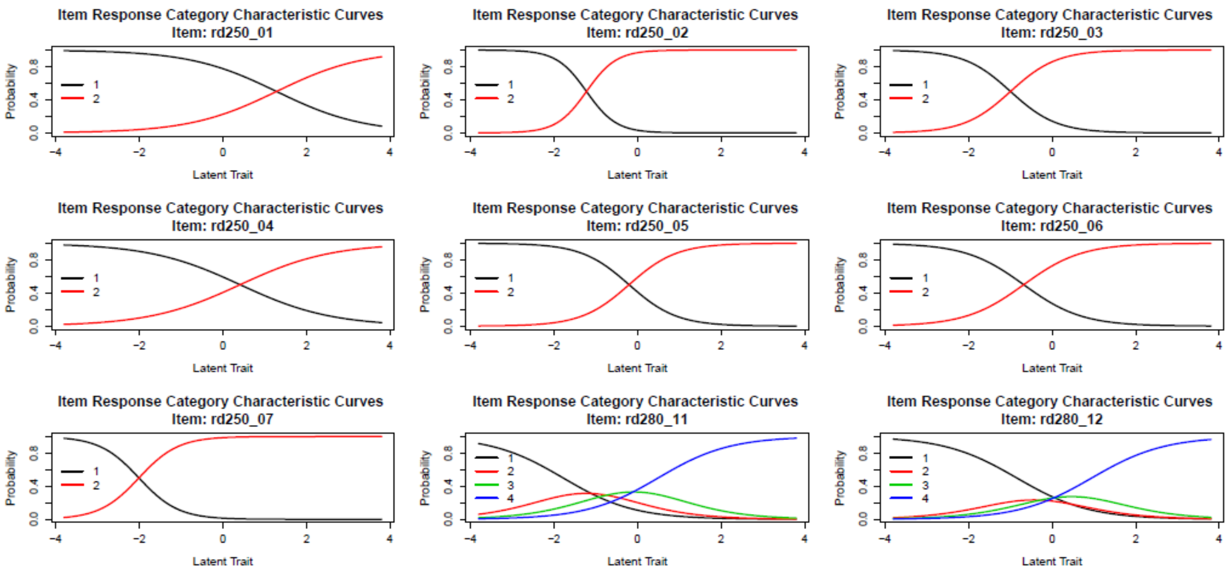
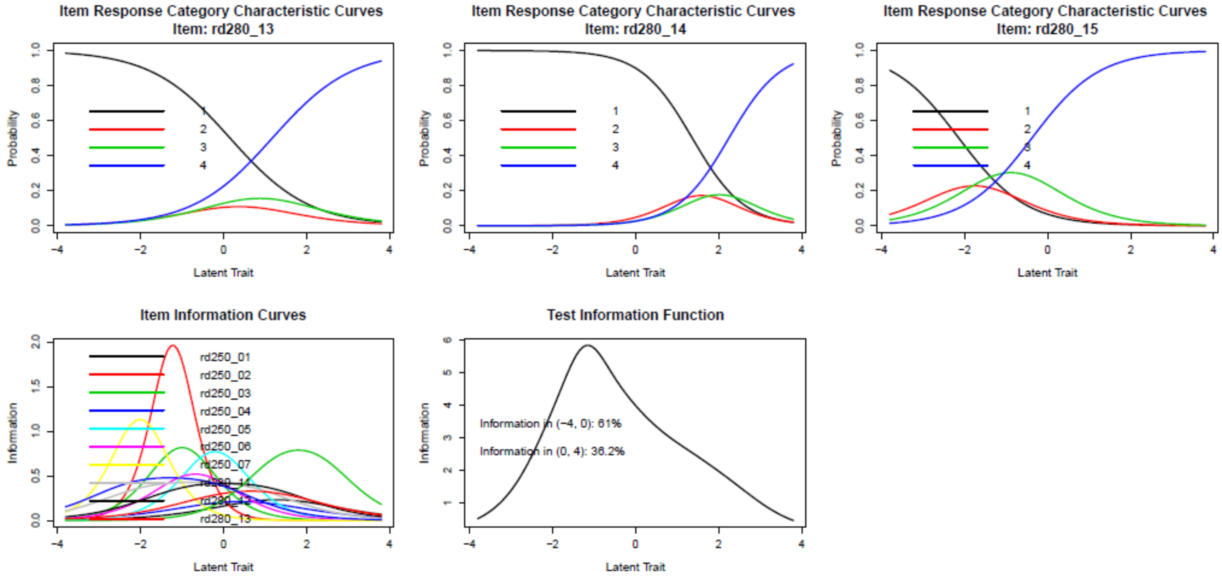


Figure A07: Item Response Category Characteristic Curves, ICTTIMEUSE *(continues from the previous page)*



The scale consists of thirteen polytomous items (with four response categories). Figure A08 shows that the threshold values of the categories assume values ranging from -5.677 (d295_01: *ICT not change teaching practises*) to +1.821 (rd320_08: *whiteboard promote teaching cooperation*); furthermore, the threshold value of the response category ("*enough*") is placed always in the negative part of the latent trait. The discriminatory power of items varies from medium (1.020) to high (4.425). The positive skewness of TIF shows that scale has a low accuracy for values of the latent trait greater than about 0.5.

Figure A08: Item Response Category Characteristic Curves, ICTTEACHPERC

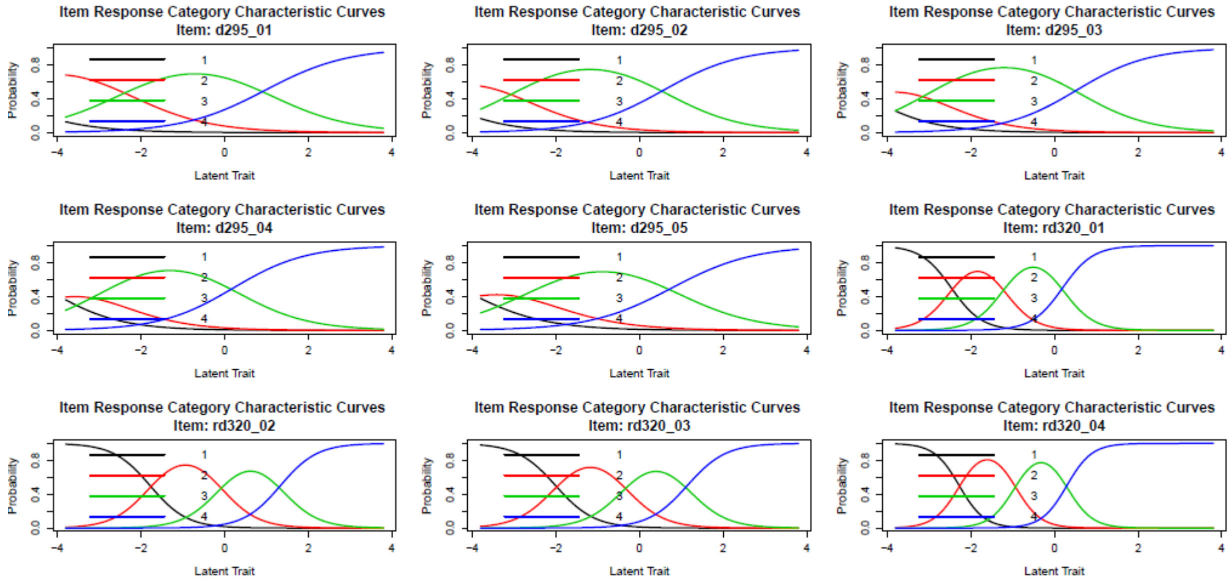
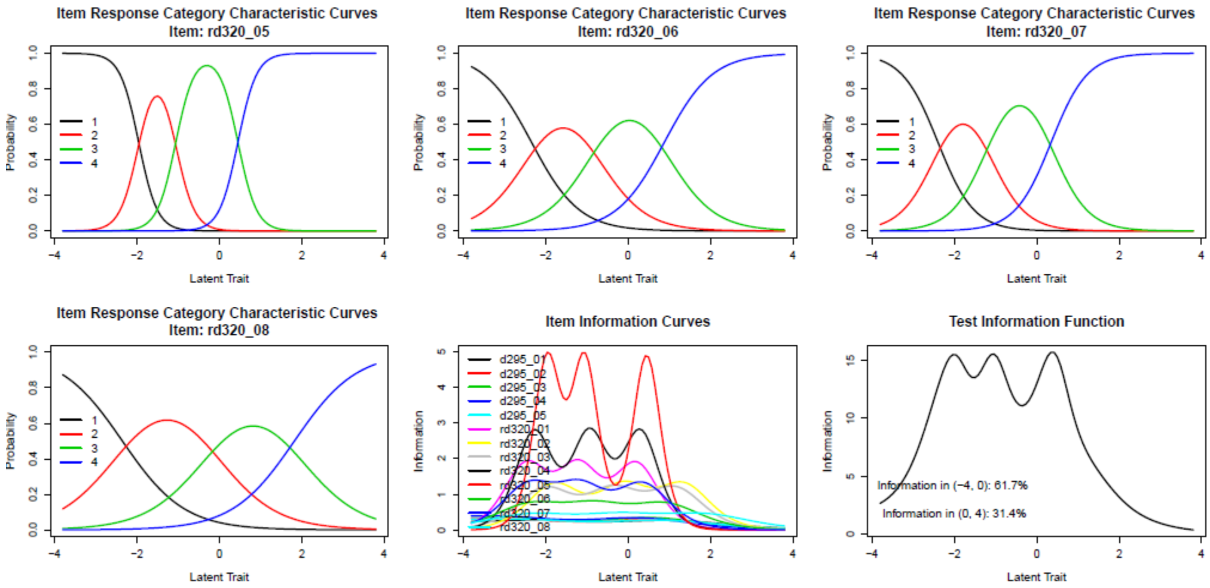


Figure A08: Item Response Category Characteristic Curves, ICTTEACHPERC *(continues from the previous page)*



Appendix C - *Table 1. Dimensions (Latent Traits) of teaching innovation considered in the questionnaire*

Dimensions	*Label*	*Meaning*	*Items questionnaire*	*#item*	*α*
1. Training in ICT	TRAINICT	Higher values of the index indicate higher intensity of ICT training	Tipologies of training courses (5 items); time spent in training (1 item); participation in technological innovation projects in school (6 items); ICT training courses addressed to digital teaching tools (1 item); during ICT training courses experiences with students (1 item).	14	0.81
2. School commitment	COMMITMENT		none commitment	3	---
			administrative commitment		
			ICT administrative commitment		
3. Personal use of ICT	ICTPERSUSE	Higher values of the index indicate higher intensity of ICT personal use	ICT technologies available outside school as pc, tablet, and so on (5 items); for which activities internet is used and time spent (5 items)	10	0.7
4. Sense of belonging to professional community	PROFCOMMUN	Higher values of the index indicate higher sense of belonging to professional community	Time spent to in school activities (5 items)	5	0.76
5. Perception of school climate	SCHCLIMATE	Higher values of the index indicate a positive perception of school climate	How much factors (absenteeism, bullying, and so on) hinder the achievement of student (14 items, only for middle and secondary schools early school leaving and drug use have been considered)	14	0.91
6. Teaching innovation	INNOVTEACH	Higher values of the index indicate higher intensity in teaching innovation	How often do each of the following activities happen in this target class throughout the school year? This is a TALIS item and it refer on the tipology of activity done by teachers: structuring, student orientation and enhanced (12 item)	12	0.76
7. ICT use in teaching	ICTTEACHUSE	Higher values of the index indicate higher use of ICT in teaching	Time spent for lessons using computer (2 items); which tecnologie are available (computer, tablet, and so on) in school (3 items); time spent for some activities (download teaching tools, and so on) with students (4 items); teaching activities outside school (7 items); Learning Management System use (1 item)	17	0.78
8. LIM use	LIMUSE	Higher values of the index indicate higher LIM use for teaching	LIM use with internet connection (1 item); teaching materials used for the activities with LIM (software, video, and so on) (4 items); how often LiM is used for some activities (group work, to explain lesson, and so on) (7 items)	12	0.91
9. Time spent for ICT in teaching	ICTTIMEUSE	Higher values of the index indicate higher time spent for ICT in teaching	How often teacher has spent time for some activities (such as email, exercises with excel, and so on) (7 items); for wich acvities and how often teachers use internet (such as for schools, etc.) (5 items)	12	0.85
10. Usefulness ICT use for teaching	ICTTEACHPERC	Higher values of the index indicate higher perception of ICT usefunness in teaching	Agreement on specific statement regarding the ICT (5 items) and LIM usefulness (8 items)	13	0.9

Table 3. Regression analysis results. How the assessed latent traits relate with relevant covariates

	TrainICT		**Commitment**		**ICTpersuse**		**Profcommun**		**Schclimate**	
	R2=0,1650		*R2=0,1154*		*R2=0,1397*		*R2=0,0557*		*R2=0,0950*	
	Adj R2=0,1502		*Adj R2=0,1002*		*Adj R2=0,1343*		*Adj R2=0,0455*		*Adj R2=0,0815*	
Group A covariates										
Gender (male)	-0.002	0.990	0.184	0,081	0.254	0,024	0.000	0.970	-0.009	0.670
Age	0.009	0.337	0.002	0.354	-0,033	0,000	0.001	0.317	0.045	0.017
Marital Status (married/cohabitant)	-0.007	0.997	0.216	0,051	0,110	0,341	-0.001	0.977	-0.035	0.677
Marital Status (widower)	0.040	0.899	0.133	0,646	0,030	0,922	0.004	0.879	0.200	0.579
Marital Status (separated / divorced)	0.064	0.757	0.333	0,049	0.574	0,001	0.006	0.737	0.320	0.437
Children (no)	-0.009	0.932	0.000	0.124	-0.123	0.442	-0.001	0.912	-0.045	0.612
Highest qualification held by their parents (primary school)	0.477	0.064	-0.231	0.995			0.048	0.454		
Highest qualification held by their parents (middle)	0.476	0,070	0.235	0.540	0.666	0,011	0.048	0.214	-0.353	0.228
Highest qualification held by their parents (high)	0.502	0.053	-1.231	0.123			0.050	0.238		
Highest qualification held by their parents (gratuated)			0.001	0.412	0.838	0,004	0.000	-0.020	-0.542	0,070
Group B covariates										
Lenght of the role	0.028	0,000	0.019	0,000	0.011	0,040	0.166	0.652	-0.030	0.235
Tenure (no)	-0.003	0.220	0.140	0.652	-0.754	0.562	-0.230	0.210	-0.380	0.101
SSIS (no)	-0.038	0.804	-1.457	0.210	0.156	0.147	0.001	0.112	0.010	0.235
TenureTime	0.001	0.223	0.111	0.112	0.002	0.235	-0.221	0.785	0.000	0.478
TenureTimeSchool	0.000	0.658	0.201	0.785	0.000	0.124	0.000	0.472	-3.010	0.331
Private lecturer (no)	-0.301	0.023	0.452	0.234	-0.478	0,000	0.256	0,076	0.271	0,078
Other work activities (no)	0,320	0.022	0.401	0.125						
Group C covariates										
School (middle)	0.037	0.797	0.231	0.725	0.222	0.159	-0.043	0,739	-0.152	0,272
School (high)	-0.154	0.233	0.888	0.622	0.000	0.550	-0,380	0,000	-0.492	0,000
Size of municipalities (small)	0.124	0.295	0.901	0.102	-0.250	0,016	0.009	0.845	0.001	0.236
Constant	-1.534	0,000	1.197	0,000	1.105	0,024	-0.136	0,355	0.322	0,321

	Innovteach		**ICTteachuse**		**Limuse**		**ICTtimeuse**		**Ictteachperc**	
	R2=0,1307		*R2=0,0692*		*R2=0,0699*		*R2=0,1447*		*R2=0,0494*	
	Adj R2=0,1266		*Adj R2=0,0535*		*Adj R2=0,0475*		*Adj R2=0,1108*		*Adj R2=0,0381*	
Group A covariates										
Gender (male)	0.093	0.627	0.009	0.158	0.002	0.852	0,240	0,042	0.133	0.196
Age	-0.010	0.185	-0.027	0,010	-0.028	0,005	-0.036	0,000	0.000	0.214
Marital Status (married/cohabitant)	-0.127	0.277	-0.017	0.289	0.451	0.238	0.361	0,013	-0.008	0.225
Marital Status (widower)	0.003	0.760	-0.218	0.228	-0.258	0.159	0.483	0,138	0.259	0.268
Marital Status (separated / divorced)	0.000	0.209	0.006	0.228	-0.185	0.478	0.643	0,001	0.000	0.110
Children (no)	-0.241	0.100	0.000	0.741	0.236	0.235	0.224	0,045	0.222	0.287
Highest qualification held by their parents (primary school)	0.221	0.258	0,630	0,033	0.575	0,050	0.594	0,031	0.675	0,029
Highest qualification held by their parents (middle)	0.000	0.700			0.565	0,061	0.725	0,011		
Highest qualification held by their parents (high)	0.123	0.597			0.547	0,070	0.548	0,054		
Highest qualification held by their parents (gratuated)	-0.513	0.886	0.657	0,050	0.003	0.294	0.677	0,027	0.676	0,051
Group B covariates										
Lenght of the role	-0.147	0.547	0.016	0,020	0.011	0,080	0,013	0,017	0.063	0.186
Tenure (no)	0.006	0.328	-0.038	0.238	-0.059	0.983	0.158	0.124	0.000	0.204
SSIS (no)	0.129	0.197	-0.026	0.107	0.002	0.258	0.002	0.109	-0.004	0.215
TenureTime	-0.261	0.680	0.013	0.590	0.052	0.923	-0.168	0.214	0.122	0.258
TenureTimeSchool	0.201	0.129	0.000	0.039	-0.104	0.147	0.238	0.118	0.000	0.100
Private lecturer (no)	-0.020	0.024	0.004	-0.066	0.080	0.111	-0.389	0,006	0.104	0.277
Other work activities (no)	0.103	0.178	0.003	0.088	-0.008	0.284	0.096	0.590	0.387	0,030
Group C covariates										
School (middle)	-0.287	0,027	0.112	0.852	-0.153	0,277	0.000	0.296	-0.232	0,032
School (high)	-0.732	0,000	-0.235	0.147	-0.265	0,031	0.025	0.227		
Size of municipalities (small)	-0.254	0.840	-0.381	0,002	-0.292	0,017	-0.306	0,005	0.256	0.214
Constant	0.262	0,000	0.628	0,283	0.781	0,148	0.923	0,081	-0,670	0,071

Note: in parenthesis the comparison category