

Internet use and academic performance: an interval approach

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Abstract

As children spend more and more time on electronic devices and social networks, there is a growing concern about the influence that these activities may have on their development and social well-being. In this context, the present research is aimed at analysing the influence that Internet use may have on 6th grade primary school students' academic performance in Spain. In order to do so, we have employed a methodological approach that combines econometric and interval multiobjective programming techniques, which has let us identify the traits and Internet use patterns that allow students to maximise their academic performance in terms of scores in four competences. Our results show that, while daily use of the Internet to listen to music or search for information about other topics of interest can favour the maximization of educational outcomes, the use of social networks should be limited as much as possible to avoid hindering the educational process.

Keywords: Internet use; academic performance; econometrics; interval multiobjective programming.

JEL Codes: O30, C01.

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1. Introduction

The Internet has become an indispensable tool, particularly for young people. For those who have been surrounded by digital technology since birth, it is not only an information tool, but a major innovation that has conditioned how they spend their leisure time and engage in non-leisure activities. The Internet has been fundamental in society's development; it created a new dimension for digital natives (Prensky, 2001) and has also made it possible to digitise social and paperwork structures that were traditionally "physical" by promoting "virtual mobility" and allowing certain daily activities to be carried out through telework, telehealth and e-learning (Mouratidis & Papagiannakis, 2021).

In this context, the Internet has not only enabled young people around the world to stay in touch with each other, but has also provided them with new learning opportunities, as it is an endless source of information that can speed up the educational process. It allows the creation of "educational environments" that complement the traditional system and fill educational gaps that may be left by face-to-face education. The Internet can even promote an active and independent type of learning adapted to students' characteristics and their own learning pace (O'Flaherty & Phillips, 2015).

In addition to learning, the Internet is a means of entertainment and communication (Zhang et al., 2018) that has enabled young people around the world to develop and nurture relationships while strengthening their sense of community (Pendry & Salvatore, 2015) and social well-being (Castellacci & Tveito, 2018; Alivernini et al., 2019). Furthermore, using different mobile devices from an early age enables the acquisition of so-called digital skills, such as the ability to search for and evaluate information (Van Deursen & Van Dijk, 2008), which can be extremely useful when writing reports or completing assignments (Pagani et al., 2016).

The Internet has become indispensable in teenagers' lives, but its excessive or inappropriate use also has undesirable consequences for young people, especially if we consider that they are more likely to develop a certain degree of Internet addiction than adults (Ko et al., 2012; Fineberg et al., 2018). Excessive use can lead to withdrawal and weaker social skills as well as mental health and family problems (Twenge, 2017; Song et al., 2019; O'Day & Heimberg, 2021). Besides, such dependence can negatively interfere with the educational process and consequently reduce academic performance (Sengupta et al., 2018; Kates et al., 2018; Wammes et al., 2019; Azizi et al., 2019; Koca & Berk, 2019).

Given the relevance of the Internet in our lives, it seems reasonable to question whether its use from an early age can negatively affect a person's psycho-emotional educational and professional development and, specially, if we take into account that late childhood and adolescence are critical stages in human life, as teenagers are supposed not only to develop educational and career goals, but also to ask themselves who they are and who they want to be (Verhoeven et al., 2019).

Therefore, the aim of our study is to identify the profile of students who are able to maximise their academic performance in reading, mathematics, science and English given the different ways in which they can use the Internet. That said, we focus on Spain,

where 91.4% of households had a fixed or mobile broadband Internet connection and 92.9% (INE, 2019) of children aged 10-15 use it in 2019, with the average time spent on the Internet being 3 or more hours per day in 2019 (Qustodio, 2019). Particularly, within Spain, we will use a recent database from the Spanish region of the Canary Islands which collected the census of primary school students in 6th grade in 2018-2019.

We have to bear in mind that, according to the latest Programme for International Student Assessment (PISA) report (2018), the Canary Islands are at the bottom of the Spanish educational ranking. For instance, Canarian students scored 19 points below the OECD average in science and 13 points below Spain (MEPF, 2018). In this sense, given the increase in both poor academic results and Internet use by the younger generations, in our study we seek to analyse the influence that Internet use can have on academic performance. To do so, we will make use of interval multiobjective programming, specifically the algorithm proposed in Henriques et al. (2019). This methodology has been used in applications to analyse workers' well-being (Henriques et al., 2020; Henriques et al., 2021) and in the educational context (Prieto-Latorre et al., 2021).

In short, this study aims to enrich the existing literature in, at least, three aspects. Firstly, it assesses how social networks (and additionally WhatsApp) influence on students' academic performance in different cognitive domains in late childhood, while studies usually focus on secondary school and university students. Secondly, we provide up-to-date evidence for Spain, to the extent that previous literature is limited and the databases used are outdated. Thirdly, by using interval multiobjective programming, we offer a potentially useful tool in the design of educational policies and parental guidance.

The article is structured as follows. First, we provide a brief review of the relevant literature on the influence of Internet use on academic performance. Then, we present the main characteristics of the dataset. Sections 4 and 5 describe the methodology employed and the results obtained. Finally, we discuss and present the main findings, including implications for socio-economic policies.

2. Literature review

The digital dependency and the effect it may have on young people's academic performance and personal development has sparked an increased interest among researchers. Specifically, some studies have shown how using the Internet can improve academic performance (Zhu et al., 2011; Gil, 2012; Chen et al., 2014; Naqshbandi et al., 2017; Çebi & Güyer 2020; Hou et al., 2021). On the one hand, Chen et al. (2014) analysed the relationship between Internet information seeking, academic performance and academic self-efficacy, with the latter being the mediator between the first two. The authors distinguished between educational and leisure-oriented Internet use, concluding that both types had a positive impact on twelfth-grade students' academic self-efficacy, indirectly improving their academic performance. On the other hand, Hou et al. (2021) examined the impact that the Chinese social network, WeChat, may have on university students' academic performance. The authors concluded that the impact of using WeChat was largely due to students' self-control, with the effect of sharing information through the application being positive when students had high self-control.

Likewise, researchers have found a positive relationship between ICT use and academic performance (Mo et al., 2014; Cabras & Tena, 2016; Gubbels et al., 2020; Lei et al., 2021). In particular, Cabras and Tena (2016), using data provided by PISA 2012, found a causal effect of ICT use on Spanish students' mathematics performance, with the effect being stronger for lower-income students. Recently, Gubbels et al. (2020) showed that moderate ICT use was positively related to the reading achievement of 15-year-old

Dutch students, with a negative impact when ICT was overused. Similarly, Machin et al. (2007) highlight that the increase of ICT investment at schools in England caused a positive impact on reading competence and science, but it had no significant influence in mathematics, while Villafuerte and Romero (2017) found that watching videos and using social networks help to improve English skills, as motivation and engagement facilitate English learning, both in writing and listening skills. This result is opposed to most empirical evidence, which usually finds a negative effect of social networks on educational attainment (see meta-analysis by Liu et al., 2017).

However, far from reaching the same conclusion, other studies have found a negative relationship between Internet/ICT use and academic performance (Karpinski et al., 2013; Vigdor et al., 2014; Junco, 2015; Michikyan et al., 2015; Kim et al., 2017; Sengupta et al., 2018; Hsiao et al., 2017; Azizi et al., 2019; Koca & Berk, 2019; Chang et al., 2019). Particularly, Kim et al. (2017) considered confounding factors such as gender, drug use or parental education level, and found that using the Internet for general purposes was negatively correlated with higher school performance, in contrast to when the Internet was used for study.

Finally, some studies point to the lack of significant effect of Internet and ICT on educational outcomes (Woessmann & Fuchs, 2004; Leuven et al., 2007; Mbaeze et al., 2010; Spiezia, 2011; Raines, 2012; Fairlie & Robinson, 2013; Cristia et al., 2017).

The influence that the Internet has on the teaching-learning process may depend on the type of analysis conducted, the potential existence of selection bias (Bulman & Fairlie, 2016), how it is used and whether it is more or less academically oriented (Gil, 2012; Torres-Díaz et al., 2016; Kim et al., 2017; Lau, 2017; Chang et al., 2019). In particular, while online information seeking tools and word processing are associated with higher academic performance in 15-year-old students (Gil, 2012), video games or streaming entertainment hinder the educational process (Rideout et al., 2010; Lopez-Agudo & Marcenaro-Gutierrez, 2020).

In this regard, it seems that the problem lies in excessive or inappropriate use of the Internet (Zhou et al., 2020) resulting in situations where users are unable to control the time they spend on online activities and neglect their daily activities (Wąsiński & Tomczyk, 2015). This “addiction”, which some studies refer to as “Internet use disorder” (Sha et al., 2019; Peterka-Bonetta et al., 2019), can lead to socioemotional problems among young people (Pontes et al., 2015), as well as negatively affect their academic performance (Flisher, 2010; Siciliano et al., 2015; Berte et al., 2021) by reducing academic engagement and increasing disaffection with learning activities (Karpinski et al., 2013; Zhang et al., 2018; Feng et al., 2019).

Focusing on Spain, the studies that have analysed this issue are limited (García-Martín & Cantón-Mayo, 2019; Fernández-Gutiérrez et al. 2020; Gómez-Fernández & Mediavilla, 2021). For instance, García-Martín and Cantón-Mayo (2019) assessed how different types of Internet use might affect academic skills, concluding that each type of Internet use was associated with different cognitive domains. Fernández-Gutiérrez et al. (2020) employ PISA data from three waves (2009, 2012 and 2015) to evaluate the use of ICT at secondary school, finding significant effects in students’ outcomes in science, but not in reading and mathematics. Particularly relevant is the study carried out by Prieto-Latorre et al. (2021), in which they analysed the effect that Internet use may have on school grades (content-based knowledge) and test scores (competences) of a cohort of 8th

grade students in 2011-2012⁵. The authors concluded that using the internet academically and for hobbies should be prioritised over continued use of social networks.

In any case, the evidence in Spain is still scarce and further up-to-date research is needed, as the use of the Internet and new technologies is increasing among young people.

3. Data and institutional background

In recent years, the Spanish education system has adopted a formative assessment model in line with European standards that aims to promote lifelong learning and to move away from an exam-centred educational culture. To implement this formative assessment scheme, in addition to a continuous assessment throughout the academic year, Spanish students take an individual assessment test at the end of each educational stage. Specifically, for primary education, Spanish students take the test at the end of 3rd (LOMCE, art. 20.3; BOE, 2013) and 6th grades (LOMCE, art. 21; BOE, 2013). These tests are designed to assess students' numeracy skills, as well as their oral and written comprehension skills, in order to provide them with individualised attention according to their needs and to prevent them from failing at a later stage of their education.

In this study we have used the data collected by the Canarian Agency for University Quality and Educational Assessment. Specifically, as mentioned above, we have used data from the cohort of 6th grade students in 2018-2019 (in the Autonomous Community of the Canary Islands). In total, our sample collects data from 13,296 students who completed tests in reading, mathematics, science and English. In addition, to avoid losing observations, we have introduced a set of missing flag variables.

In the database under scrutiny, to facilitate comparison with other research studies and between different measures of educational performance, the variables regarding test scores in the different competences have been standardised (through statistical normalisation) to have mean 0 and standard deviation 1 and, consequently, the results can be interpreted as effect sizes. Along with educational competences, by having both a student questionnaire and a parent questionnaire, we have information about parents' educational level, income and occupation, among other variables. Moreover, to capture the students' socio-economic level, the Canarian Agency provides us with an indicator of socio-economic and cultural status (ESCS). This index, which is a continuous variable, has also been standardised to facilitate comparisons.

Since our goal is to analyse how Internet use influences academic performance, this analysis is mainly based on the information collected by the student questionnaire. Concretely, we have based our analysis on the following question:

“How often do you use the Internet for the following activities?”

- a) Searching for information for your studies (Google, Wikipedia, etc.).
- b) Searching for information about games or playing games.
- c) Searching for information about sports.
- d) Searching for information about music or movies (YouTube, Spotify, etc.).
- e) Searching for information on other topics that interest you.
- f) Communicating with other people (WhatsApp, Telegram, Hangout, etc.).
- g) For using social networks (Facebook, Twitter, Instagram, Musically, etc.).

For these 7 Internet-related variables, the answer is one of the following options: “never or almost never”, “once or twice a month”, “once or twice a week”, “every day or

⁵ The database used dates from around 10 years ago, which limits the results obtained considerably to the extent that the Internet use in 2011 has nothing to do with internet use today.

almost every day”. Descriptive statistics regarding these variables are shown in Table A1 (Appendix). We can observe that 6th grade students mainly use the Internet to communicate with others through applications such as WhatsApp, with 40% of students using it every day. This appears to be consistent with new trends, as the younger generation represents the new wave of users of these applications which can be broadly considered as social networks. Similarly, 32.9% of students use applications such as YouTube or Spotify on a daily basis, while they use the Internet for other topics of interest and to play games once or twice a week (36.1% and 24.1%, respectively). This underlines the aim of our analysis, as younger students tend to use the Internet more for non-academic purposes.

Since WhatsApp or Telegram can be considered social networks, we only include the variables related to social network use as a category that encompasses not only Facebook or Instagram, but also other communication channels. This will help us to avoid multicollinearity problems. However, as we will show below, the estimates corresponding to the model including the variables related to WhatsApp use have been run as a robustness check.

4. Methodology

The main goal of our analysis is to explore the influence that Internet use during late childhood may have on students’ academic performance. In doing so, we aim to provide a student profile that combines both academic and non-academic Internet use to maximise academic achievement. To this end, we will combine econometric analysis with multi-objective programming techniques.

The econometric analysis is based on the estimation by ordinary least squares (OLS) of different regression models in which academic performance is regressed on a set of variables. In these variables we include both a set of control variables and those relating to Internet use. Therefore, our base model would be defined as:

$$Z_k(i) = \hat{\beta}_0(i) + \hat{\beta}_{1k}x_1(i) + \hat{\beta}_{2k}x_2(i) + \hat{\beta}_{3k}x_3(i) + \dots + \hat{\beta}_{23k}x_{23}(i) + \varepsilon_k(i) \quad (1)$$

where Z is the standardised academic performance, i is the student, $k = 1,2,3,4$ represents reading, mathematics, science and English, respectively; x_1 to x_4 represent student characteristics; x_5 is a school characteristic; x_6 to x_{23} indicate Internet use (see Table A2, Appendix); ε_k is the error term; $\hat{\beta}_j$ represents estimated regression coefficients for the $j = 1, \dots, 23$ variables. Since this is a point estimate of the influence that each independent variable has on the dependent variable, there is a margin of error and, therefore, we have estimated the lower and upper bounds of the estimated coefficients at the 99% confidence level as follows:

$$[\hat{\beta}^L, \hat{\beta}^U] = [\hat{\beta} - t_{n-k-1, \frac{\alpha}{2}} SE(\hat{\beta}), \hat{\beta} + t_{n-k-1, \frac{\alpha}{2}} SE(\hat{\beta})] \quad (2)$$

where $\hat{\beta}$ is the estimated average coefficient; SE is the standard error; n is the number of observations; k is the number of conditioning variables; α is the significance level and t are the probability values of the t-distribution.

Table 1 shows the lower and upper bounds of estimated coefficients for each of the educational outcomes, i.e. reading, mathematics, science and English⁶. Those coefficients that are not statistically significant, at least at 10%, are shown as “0”.

⁶ Alternatively, Table 1 estimations have been replicated adding school fixed-effects and results are pretty similar. These results are presented in Table A3 (Appendix).

-Insert Table 1 here-

The results obtained show that females perform better than males in reading and English, but perform worse in mathematics. Specifically, girls obtain on average 0.27 standard deviations (SD) and 0.19 SD more in reading and English, respectively, than boys, while their mathematics performance drops by 0.08 SD. Far from being surprising, these findings are consistent with the evidence collected in the literature. On the one hand, females tend to perform better in reading; the Progress in International Reading Literacy Study (PIRLS) 2016 showed that, in 48 of the 50 participating countries, female students' reading achievement was higher than boys' and this female dominance has persisted since this assessment was implemented (Mullis et al., 2016). This gender gap in favour of females can be the result of certain gender stereotypes attributing greater mathematical ability to males (Spencer et al., 1999; Cvencek et al., 2011; Plante et al., 2013; Spencer et al., 2016). The corollary of this is that girls tend to have a higher linguistic self-concept than boys (Wigfield et al., 1997; Jacobs et al., 2002; Heyder et al., 2017) and to value reading highly, which favours their academic performance in this competence. On the other hand, females' higher achievement in English is closely linked to reading skills (Grabe, 2010; Oxford, 2011), as developed skills in interpreting texts and processing information enable females to learn a foreign language more quickly (Wightman, 2020).

Similarly, we find that students' socio-economic status is positively associated with their academic performance. This relationship has been strongly supported by the literature (Martins & Veiga, 2010; Hanushek & Woessmann, 2011; Cedeño et al., 2016; von Stumm, 2017; Kim et al., 2019; Liu et al., 2020) and is explained by the fact that students from disadvantaged backgrounds are constrained by their economic resources and cannot access tutoring and other educational resources that help to improve their educational outcomes (Crosnoe & Cooper 2010; Lareau, 2011). In contrast, the proportion of poor students in school has a negative influence on academic performance. Children from poor socio-economic backgrounds are more likely to develop behavioural problems (Piotrowska et al., 2015; Hendriks et al., 2020; Peverill et al., 2021); this can negatively affect classroom climate and academic performance via peer effects (Busching & Krahé, 2020; Jerrim et al., 2021).

Regarding Internet use, we observe that using the Internet to study and complete school tasks positively correlates with academic performance in all four subjects. In contrast, using the Internet to play video games is negatively related to reading performance. This negative influence goes from 0.05 SD, on average, when the frequency of use is once or twice a month, to 0.10 SD, on average, when it is used every day. This pattern seems to be in line with previous literature (Lopez-Agudo & Marcenaro-Gutierrez, 2020).

Similarly, using the Internet to search for information on sports is negatively related to reading, mathematics, science and English performance, with the influence also being greater as the frequency of use increases. In contrast, using apps like YouTube or Spotify seems to have a positive influence on academic performance. However, the average influence in mathematics is lower than in the other disciplines. For example, daily use of these apps is positively related to mathematics performance (0.12 SD), while the association is 0.18 SD and 0.16 SD in science and English, respectively. Since using music with lyrics or certain genres can be more distracting (Avila et al., 2012; Perham & Currie, 2014) the level of concentration required for mathematics tasks may not be achieved.

Meanwhile, using social networks has a negative influence on academic performance, with the greater the frequency of use, the greater this correlation. In this sense, its overuse can cause students to adopt less efficient and more superficial study techniques, given a greater number of distractions (Alt, 2018).

Following the econometric analysis, our study is carried out on the basis of interval multiobjective programming. This methodology has been applied because, as we know, there are many factors involved in the educational process that are not always controllable and that can affect students' academic performance. Consequently, results cannot be interpreted as causal effects, but rather as conditional associations. In this context, using interval multiobjective programming models is particularly useful. Interval multiobjective programming and, specifically, the algorithm proposed in Henriques et al. (2019) and applied in Henriques et al. (2020; 2021) will allow us to overcome the uncertainty inherent to the coefficients in multiobjective problems. This methodology, which solves Multiobjective Linear Problems (MOLP), combines the reference-point approach with the concept of interval programming (Oliveira & Antunes, 2009) and allows us to use objective functions that take into account the confidence intervals of the regression coefficients. Therefore, by using this methodological approach, we will be able to analyse the potential trade-offs between different students outcomes while obtaining robust results.

That said, we start from a maximisation problem of educational outcomes subject to constraints:

$$\begin{aligned} \text{Max } Z(x) &= (Z_1(x), Z_2(x), Z_3(x), Z_4(x)) & (3) \\ &\text{subject to } x \in X \end{aligned}$$

where each Z_k stands for:

$$Z_k(x) = [\hat{\beta}_{k0}^L, \hat{\beta}_{k0}^U] + [\hat{\beta}_{k1}^L, \hat{\beta}_{k1}^U]x_1 + [\hat{\beta}_{k2}^L, \hat{\beta}_{k2}^U]x_2 + \dots + [\hat{\beta}_{k23}^L, \hat{\beta}_{k23}^U]x_{23} \quad (4)$$

$Z_k(x)$ are the objective functions to be maximized; $\mathbf{x} = (x_1, \dots, x_n)^T$ is the vector of decision variables; $\mathbf{x} \in X$ is the feasible region; $\hat{\beta}_{kj}^L$ and $\hat{\beta}_{kj}^U$ are the lower and upper bounds of the estimated coefficients, respectively.

In this sense, the estimated coefficients will be given by the correlation coefficients in Table 1 and our objective functions will be defined as follows:

1. Competences in reading.

$$Z_1 = [-0.502, -0.172] + [0.219, 0.33]x_1 + [0.155, 0.211]x_2 + \dots + [-0.191, -0.02]x_{23}$$

2. Competences in mathematics.

$$Z_2 = [0, 0] + [-0.129, -0.03]x_1 + [0.191, 0.246]x_2 + \dots + [0, 0]x_{23}$$

3. Competences in science.

$$Z_3 = [0, 0] + [0, 0]x_1 + [0.207, 0.263]x_2 + \dots + [-0.183, -0.017]x_{23}$$

4. Competences in English.

$$Z_4 = [0, 0] + [0.145, 0.241]x_1 + [0.289, 0.341]x_2 + \dots + [0, 0]x_{23}$$

In order to obtain realistic solutions, a set of technical constraints have been defined for Internet use variables. These constraints will guarantee that the solutions are not simultaneously 1 for all binary variables in a group:

1. Using the Internet to study (Google, Wikipedia, etc.).

$$x_6 + x_7 + x_8 \leq 1 \quad (C1)$$

2. Using the Internet to play games.

$$x_9 + x_{10} + x_{11} \leq 1 \quad (C2)$$

3. Using the Internet to search for information about sports.

$$x_{12} + x_{13} + x_{14} \leq 1 \quad (C3)$$

4. Using the Internet to search for information about music or cinema (YouTube, Spotify, etc.).

$$x_{15} + x_{16} + x_{17} \leq 1 \quad (C4)$$

5. Using the Internet to search for information about hobbies.

$$x_{18} + x_{19} + x_{20} \leq 1 \quad (C5)$$

6. Using social networks (Facebook, Twitter, Instagram, Musically, etc.)

$$x_{21} + x_{22} + x_{23} \leq 1 \quad (C6)$$

Besides the technical constraints, we define another set of constraints reflecting the relationships between those independent variables that have significantly stronger associations. To illustrate the creation of these restrictions, an example is given below using the variables “Proportion of poor students” (x_5) and “Immigrant status” (x_3):

Dependence between the two variables is defined as:

$$x_5 = ax_3 + b \quad (5)$$

To incorporate this linear regression into the model, we use 99% confidence intervals for each parameter as follows:

$$a \in [a^L, a^U] = [0.011, 0.064], \text{ and } b \in [b^L, b^U] = [0.210, 0.260]$$

which implies:

$$a^L x_3 + b^L \leq x_5 \leq a^U x_3 + b^U \quad (6)$$

This expression can be broken down into two inequalities:

$$a^L x_3 - x_5 \leq -b^L \quad (7)$$

$$-a^U x_3 + x_5 \leq b^U \quad (8)$$

By following this procedure, we can obtain the set of constraints:

7. Relationship between proportion of poor students (1st quartile ESCS) and students’ ESCS.

$$-0.091x_2 - x_5 \leq -0.224 \quad (C7)$$

$$0.070x_2 + x_5 \leq 0.260 \quad (C8)$$

8. Relationship between proportion of poor students (1st quartile ESCS) and immigrant status.

$$0.011x_3 - x_5 \leq -0.210 \quad (C9)$$

$$-0.064x_3 + x_5 \leq 0.257 \quad (C10)$$

9. Relationship between proportion of poor students (1st quartile ESCS) and repeater.

$$0.072x_4 - x_5 \leq -0.211 \quad (C11)$$

$$-0.131x_4 + x_5 \leq 0.257 \quad (C12)$$

10. Relationship between students' ESCS and immigrant status.

$$-0.261x_3 - x_2 \leq 0.014 \quad (C13)$$

$$0.0814x_3 + x_2 \leq 0.149 \quad (C14)$$

11. Relationship between students' ESCS and repeater.

$$-0.953x_4 - x_2 \leq -0.001 \quad (C15)$$

$$0.705x_4 + x_2 \leq 0.156 \quad (C16)$$

12. Relationship between students' ESCS and using the Internet to find information for study (Google, Wikipedia, etc.).

$$0.052x_6 + 0.001x_7 - 0.018x_8 - x_2 \leq 0 \quad (C17)$$

$$-0.337 - 0.233x_7 - 0.198x_8 + x_2 \leq 0 \quad (C18)$$

13. Relationship between students' ESCS and using the Internet to search for information about other topics.

$$0.046x_{18} + 0.085x_{19} + 0.023x_{20} - x_2 \leq 0 \quad (C19)$$

$$-0.220x_{18} - 0.248x_{19} - 0.181x_{20} + x_2 \leq 0 \quad (C20)$$

14. Relationship between students' ESCS and using social networks (Facebook, Twitter, Instagram, Musically, etc.)

$$-0.338x_{21} - 0.246x_{22} - 0.226x_{23} - x_2 \leq -0.071 \quad (C21)$$

$$0.185x_{21} + 0.102x_{22} + 0.043x_{23} + x_2 \leq 0.247 \quad (C22)$$

Therefore, our multiobjective problem has 23 decision variables (binary and continuous), 4 objective functions and 22 constraints. The type of variables and their bounds (which are considered as constraints of the multiobjective problem) are specified in Table A2 (Appendix).

In order to solve our interval multiobjective problem we must first solve each one of the problems for the objective functions individually. In this way, we will obtain the individual optimal values (Chinneck & Ramadan, 2000) and we will be able to check whether there are trade-offs between the four educational competences.

$$\begin{aligned} \text{Max } Z_k^U(\mathbf{x}) &= \sum_j \beta_{kj}^U x_j, & k &= 1, \dots, p, \\ \text{s. t. : } \sum_j a_{cj} x_j &\leq b_c, & c &= 1, \dots, m, \\ x_j &\geq 0 & j &= 1, \dots, n. \end{aligned} \quad (9)$$

and

$$\begin{aligned} \text{Max } Z_k^L(\mathbf{x}) &= \sum_j \beta_{kj}^L x_j, & k &= 1, \dots, p, \\ \text{s. t. : } \sum_j a_{cj} x_j &\leq b_c, & c &= 1, \dots, m, \\ x_j &\geq 0 & j &= 1, \dots, n. \end{aligned} \quad (10)$$

where k is the number of objective functions; c is the number of constraints; j is the number of decision variables. Consequently, the optimal solution of our multiobjective problem will be somewhere between the ideal solutions of the upper and lower bounds $Z_k^* = [Z_k^{U*}, Z_k^{L*}]$, where $Z_k^{U*} = Z_k^U(x_k^{U*})$ and $Z_k^{L*} = Z_k^L(x_k^{L*})$.

Then, and to obtain the solution of the interval multiobjective problem, we use the following surrogate scalarizing problem proposed in Henriques et al. (2019):

$$\begin{aligned} \min \quad & v + \rho \sum_k \left(\mu_k^L (Z_k^{L*} - \sum_j \beta_{kj}^L x_j) + \mu_k^U (Z_k^{U*} - \sum_j \beta_{kj}^U x_j) \right) \\ \text{s.t.} \quad & \mu_k^L (Z_k^{L*} - \sum_j \beta_{kj}^L x_j) + \mu_k^U (Z_k^{U*} - \sum_j \beta_{kj}^U x_j) \leq v, \quad k = 1, \dots, p, \\ & \sum_j a_{cj} x_j \leq b_c, \quad c = 1, \dots, m, \\ & x_j \geq 0, \quad j = 1, \dots, n \end{aligned} \quad (11)$$

where the term $\rho > 0$ is an augmentation coefficient that guarantees the uniqueness of the obtained solution; k is the number of objective functions; c is the number of constraints; j is the number of decision variables.

This approach considers the Tchebychev distance to the interval ideal values Z_k^{L*} and Z_k^{U*} , as well as the relevance of each objective function to reach these values through the weights $\mu_k^L, \mu_k^U > 0$ for all $k = 1, \dots, p$. In addition, it provides “possibly” efficient solutions, which implies that the solution will be efficient for a linear combination of the parameters $\bar{\beta}_{kj} \in [\beta_{kj}^L, \beta_{kj}^U]$.

On the other hand, the algorithm proposed in Henriques et al. (2019) assumes that $\mu_k^L + \mu_k^U = 1$ for all $k = 1, \dots, p$, which enables to assign different importance to upper or lower bounds and, therefore, the decision maker (DM) will be able to define the importance of achieving each objective function according to their preferences. However, in our analysis we have considered the same importance for reaching each corresponding ideal solution.

5. Results

5.1. Main Results

First, we have obtained the individual optimal values for each function. To simplify the interpretation of the results, Table 2 shows the optimal values (Z_k^*) for each function instead of the ideal solutions of the upper and lower bounds (Z_k^{L*} and Z_k^{U*}).

-Insert Table 2 here-

The last row of Table 2 shows the optimal values in terms of standardised scores. In this sense, the optimal value for English is higher than for the rest of the subjects, with 0.644 SD, compared to 0.549 and 0.472 SD for science and reading, respectively. Meanwhile, the optimal value in mathematics is 0.339 SD.

Along with the individual optimal values, Table 2 shows the profile of the student that maximises their performance in each one of the competences. As we can see, there is a certain trade-off between the different objective functions. Firstly, female students are the highest achievers in reading and English. In contrast, male students are the ones who maximise their performance in science and mathematics. This is hardly surprising and is consistent with the existing literature, as these are male-dominated fields (Spencer et al., 1999; Spencer et al., 2016).

Regarding students' socio-economic level we observe that, in order to maximise students' academic performance, the ESCS index should not be particularly high, although higher than the sample average value. Specifically, students' socio-economic index should be 0.149 if they want to maximise their performance in reading, mathematics and science, and 0.068 when it comes to English. This is – to some extent – unexpected, as students' socio-economic status is positively related to their academic performance. However, given that students interact with peers from diverse socio-economic backgrounds, it seems that academic achievement is maximised when students from low socio-economic backgrounds are surrounded by a higher proportion of poor students. This proportion of poor students will be 23.6% for reading and 22.11% for English performance. In mathematics and science this proportion will be slightly lower (21.11%).

On the other hand, performance in all four subjects is maximised for those students who are not repeaters, while immigrant students are more likely to maximise their performance in English, which may be explained by their language background.

In terms of the Internet use, we can observe a more marked trade-off between the different objective functions. Specifically, students maximise their mathematics performance by continuously using the Internet to study, while it must be limited for the other academic competences. In addition, Internet use for gaming should be limited to once or twice a month to maximise students' performance in mathematics, science and English, and reduced as much as possible to maximise their reading achievement. In the same vein, using the Internet to search for information on sports should be reduced to zero if students want to maximise their academic performance.

Alike, using the Internet for listening to music or for other hobbies daily contributes to maximise their performance in reading, science and English. In contrast, they should reduce these uses to once or twice a week to perform well in mathematics.

Finally, regarding social networks, we see that students should keep their use to the barest minimum. Given that using social networks can lead to addiction, especially in late childhood and adolescence, students should practically not use them if they want to ensure their academic performance.

Once the individual optimal values have been obtained, we have run the algorithm considering equal importance to reach each objective function and obtain “possibly” efficient solutions, presenting these results in Table 3. This table shows that the range of variation of the achieved value in science is larger (between -0.009 and 0.922 points) than in the other subjects. In contrast, the range of variation in mathematics is the smallest (between -0.115 and 0.602 points), with the maximum value being much smaller than that achieved in the other 3 competences.

-Insert Table 3 here-

As we can see, the profile of the student who maximises her academic performance is female, non-immigrant and has not repeated before 6th grade. Moreover, as in the mono-objective problem, it appears that academic performance is maximised when students from a low socio-economic background are surrounded by a higher proportion of poor students, with students' socio-economic index being 0.149 and the proportion of poor students being 21.13%.

As for Internet use we can observe that, in order to achieve higher academic performance, students should reduce their use of the Internet both for studying and for searching for information about sports or playing video games. In this regard, it is worth noting that, to maximise their academic performance, students should reduce their

Internet use for studying to once or twice a month, which may be the result of multitasking (Junco, 2015; Feng et al., 2019). Since younger students may lack self-control, using the Internet for schoolwork or study may lead to a non-academic use. This could hinder the educational process and encourage procrastination from an early age (Aznar-Díaz et al., 2020).

In contrast, our results show that students can maximise their academic performance by using the Internet daily to listen to music or to search for information on other topics of interest. In this sense, listening to music can improve not only mood, but also arousal levels and, consequently, enhance the performance of certain simple cognitive tasks (Goltz & Sadakata, 2021).

Finally we can observe that, if students want to maximise their academic performance, social networks use should be non-existent. Adolescents and pre-adolescents are heavy users of social networks and their desire to be constantly interacting with others can lead them to misuse their time efficiently and neglect academic work (Qiaolei, 2014).

5.2. Robustness Check

To check the robustness of our results, we have replicated our analysis using the variables that only refer to the use of applications such as Telegram or WhatsApp (see Tables A4⁷, A6 and A7, Appendix).

In this sense, if we look at the results obtained for this new mono-objective problem (Table A6), we can observe that the optimal values for each of the subjects are pretty similar to those obtained in our main model. For example, in reading the optimal value decreases just by 0.09 points in terms of standardised scores. As for the student profile, Table A6 shows a very similar pattern to Table 2. In order to maximise their performance in each one of the subjects, students should reduce their use of the Internet to search for information about sports, as well as to use applications such as WhatsApp. These applications should be used minimally to enhance academic performance.

On the other hand, Table A7 shows the “possibly” efficient solutions. In this sense, we can observe that the student who manages to maximise her academic performance is an immigrant female who has not repeated a grade. Her socio-economic index should be around 0.067, while the proportion of poor students (in the school) should be 22.11%.

Regarding the frequency of Internet use, we observe a pattern of use very similar to the one shown in Table 3. Students should use the Internet as little as possible to search for information about sports, while they can listen to music and search for information about other topics of interest daily without harming their academic achievement. As for the use of applications such as WhatsApp or Telegram, this should be limited to once or twice a week.

In summary, as we have seen through the tables, the individual optimal values and the “possibly” efficient solution are pretty close to the ones obtained in our main model, which shows the consistency of our results.

6. Discussion and conclusions

Throughout this paper we have tried to analyse the influence that using the Internet may have on academic performance. In order to do so, using a database that provides us

⁷ Table A4 (Appendix) estimations have been replicated adding school fixed-effects and results are pretty similar. These results are presented in Table A5 (Appendix).

with information on a cohort of 6th grade students in 2018-2019, we have implemented interval multiobjective programming. With this methodology, we have tried to profile those students who are able to maximise their academic performance evenly – and simultaneously – among different subjects.

In detail, we first carried out an econometric analysis to subsequently proceed with the multiobjective programming. From these estimates we observed how, e.g., using social networks had a negative influence on reading, mathematics, science and English performance, with the negative influence being greater as the frequency of use increased. The results of the interval programming model allow to assert that the profile of the student who manages to maximise her academic performance in all four subjects is a female student who has not repeated, from a medium socio-economic level and who attends a school where the proportion of students from a low socio-economic background is 21.11% (i.e. slightly below the sample average).

In addition, the results show that using the Internet from an early age has its ups and downs. To maximise academic performance, students should use the Internet to study or search for information about sports once or twice a month. Similarly, they should use the Internet to play video games 1 or 2 times a week, while they can daily use applications such as Spotify. In contrast, the use of social networks should be practically zero.

Thus, while the Internet can be helpful for the teaching-learning process, its inappropriate use can prevent students from reaching their best balanced performance. Therefore and, given the possibility that constant use of the Internet and social networks may lead to “addiction” that may affect their academic performance, it is necessary to establish some control. Hence, it would be desirable for both the family and the school to offer students some guidance to encourage them to use the Internet appropriately. In addition to promoting awareness and self-control among students, other measures should also be implemented to control both the content and frequency of use by young people. This would prevent exposure to undesirable content, as well as procrastination, that can ultimately lead young people to adopt unhealthy study techniques.

Besides, schools could find more effective ways of integrating ICT into the educational process by providing students with learning environments that are in line with the needs and trends of the 21st century. In this sense, while getting students to reduce their use of the Internet to play video games or to practically stop using social networks may be beyond the school’s scope of action, balancing academic performance with the ICT used in the classroom can be an objective of the school. In recent years, students’ use of computers and tablets during lessons has become increasingly common. However, in order to make it compatible with good academic performance, it is essential that schools set guidelines and control measures such as e.g. applications that limit students’ access to non-academic content during class time, in order to avoid multitasking problems.

In any case, it should be noted that our study is not free of limitations. First, as mentioned above, we are working with correlational rather than causal econometric estimates, as far as we cannot control for all variables that may affect academic performance. However, by using interval multiobjective programming, we are able to deal with this state of uncertainty. Second, Internet variables are self-reported, which may lead to measurement errors in the model. Third, our results may not be extrapolated to the rest of Spain, to the extent that we are using students’ information from only one Spanish region.

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Appendix

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Table 1. Regression results for the social networks model

Variables	Competences in Reading		Competences in Maths		Competences in Science		Competences in English	
	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound
Female student (Ref.: Male)	0.219	0.33	-0.129	-0.03	0	0	0.145	0.241
Index of ESCS	0.155	0.211	0.191	0.246	0.207	0.263	0.289	0.341
Immigrant status (Ref.: Native)	0	0	0	0	-0.145	0.03	0.078	0.246
Repeater before 6 th grade (Ref: No)	-0.648	-0.391	-0.648	-0.425	-0.535	-0.314	-0.773	-0.556
Proportion of poor students in the school (1 st quartile of the ESCS)	0	0	-0.665	0.03	-0.686	-0.028	-1.145	-0.504
Use of the Internet to search for information for studying (Google, Wikipedia, etc). (Ref.: Never or almost never)								
Every or almost every day	-0.007	0.253	0	0	0	0	0.006	0.236
Once/twice a week	0.077	0.29	0	0	-0.02	0.164	0.033	0.218
Once/twice a month	0.04	0.245	0	0	0.021	0.22	0.068	0.251
Missing flag	0.132	1.142	0.112	1.182	-0.088	0.935	0.04	0.787
Use of the Internet to search for information about games or playing (online games). (Ref.: Never or almost never)								
Every or almost every day	-0.187	-0.022	-0.003	0.147	-0.006	0.152	0.284	0
Once/twice a week	0	0	0.017	0.152	0.019	0.153	0.268	0.111
Once/twice a month	-0.121	0.012	0	0	0	0	0.180	0
Missing flag	0	0	0	0	0	0	0	0
Use of the Internet to search for information about sports (Ref.: Never or almost never)								
Every or almost every day	0	0	-0.229	-0.066	-0.328	-0.177	-0.161	-0.013
Once/twice a week	-0.108	0.022	-0.167	-0.035	-0.231	-0.091	-0.126	0.004
Once/twice a month	0	0	0	0	-0.144	-0.025	0	0
Missing flag	0	0	0	0	0	0	0	0
Use of the Internet to search for information about music or cinema (YouTube, Spotify, etc) (Ref.: Never or almost never)								
Every or almost every day	0.084	0.235	0.041	0.208	0.106	0.263	0.097	0.232
Once/twice a week	0.031	0.174	0.046	0.206	0.06	0.208	0.045	0.179
Once/twice a month	0	0	0.006	0.166	0.028	0.186	-0.012	0.132
Missing flag	0	0	0	0	0	0	0	0
Use the Internet to search for information about other hobbies (Ref: Never or almost never)								
Every or almost every day	0.082	0.245	0.069	0.229	0.121	0.278	0.019	0.178
Once/twice a week	0.042	0.196	0.09	0.236	0.1	0.252	0	0.137
Once/twice a month	0.029	0.179	0.067	0.218	0.076	0.227	0.014	0.157
Missing flag	-0.841	0.128	-0.546	0.102	0	0	-0.731	0.03
Use the Internet for social networks (Facebook, Twitter, Instagram, Musically, etc) (Ref: Never or almost never)								
Every or almost every day	-0.197	-0.063	-0.212	-0.076	-0.273	-0.142	-0.212	-0.081
Once/twice a week	-0.146	-0.006	-0.166	-0.032	-0.229	-0.1	-0.119	0.014
Once/twice a month	-0.191	-0.02	0	0	-0.183	-0.017	0	0
Missing flag	0	0	0	0	0	0	0	0
Constant	-0.502	-0.172	0	0	0	0	0	0
Observations	13,296		13,296		13,296		13,296	
R-squared	0.084		0.103		0.118		0.223	

Notes: Dependent variables: Students' standardised scores in Reading, Mathematics, Science and English.

Estimation method: Ordinary Least Squares (OLS). Standard errors are clustered at school level.

Significance: Variables are significant at least at 10%. In case they are not significant, the value "0" is displayed.

Source: Authors' own calculations.

Table 2. Mono-objective problem. Ideal solutions and individual optimal values for the social networks model

		Competences in Reading	Competences in Maths	Competences in Science	Competences in English
Variables	Notation	$x_{k=1}^*$	$x_{k=2}^*$	$x_{k=3}^*$	$x_{k=4}^*$
Female student	x_1	1	0	0	1
Index of ESCS	x_2	0.149	0.149	0.149	0.0676
Immigrant status	x_3	0	0	0	1
Repeater before 6 th grade	x_4	0	0	0	0
Proportion of poor students in the school (1 st quartile of the ESCS)	x_5	0.236	0.2113	0.2113	0.2211
Internet for studying: every or almost every day	x_6	0	1	0	0
Internet for studying: Once/twice a week	x_7	1	0	0	0
Internet for studying: Once/twice. a month	x_8	0	0	1	1
Internet for gaming: every or almost every day	x_9	0	0	0	0
Internet for gaming: Once/twice a week	x_{10}	0	1	1	1
Internet for gaming: Once/twice a month	x_{11}	0	0	0	0
Internet for sports: every or almost every day	x_{12}	0	0	0	0
Internet for sports: Once/twice a week	x_{13}	0	0	0	0
Internet for sports: Once/twice a month	x_{14}	0	0	0	0
Internet for music: every or almost every day	x_{15}	1	0	1	1
Internet for music: Once/twice a week	x_{16}	0	1	0	0
Internet for music: Once/twice a month	x_{17}	0	0	0	0
Internet for other hobbies: every or almost every day	x_{18}	1	0	1	1
Internet for other hobbies: Once/twice a week	x_{19}	0	1	0	0
Internet for other hobbies: Once/twice a month	x_{20}	0	0	0	0
Internet for social networks: every or almost every day	x_{21}	0	0	0	0
Internet for social networks: Once/twice a week	x_{22}	0	0	0	0
Internet for social networks: Once/twice a month	x_{23}	0	0	0	1
Optimal values		$Z_{k=1}^*$	$Z_{k=2}^*$	$Z_{k=3}^*$	$Z_{k=4}^*$
Standardised scores		0.472	0.339	0.549	0.664

Source: Authors' own calculation.

Table 3. Multiobjective interval problem. Possibly efficient solution achieved values for the social networks model

Variables	Notation	Solution
Female student	x_1	1
Index of ESCS	x_2	0.149
Immigrant status	x_3	0
Repeater before 6 th grade	x_4	0
Proportion of poor students in the school (1 st quartile of the ESCS)	x_5	0.2113
Internet for studying: every or almost every day	x_6	0
Internet for studying: Once/twice a week	x_7	0
Internet for studying: Once/twice. a month	x_8	1
Internet for gaming: every or almost every day	x_9	0
Internet for gaming: Once/twice a week	x_{10}	1
Internet for gaming: Once/twice a month	x_{11}	0
Internet for sports: every or almost every day	x_{12}	0
Internet for sports: Once/twice a week	x_{13}	0
Internet for sports: Once/twice a month	x_{14}	1
Internet for music: every or almost every day	x_{15}	1
Internet for music: Once/twice a week	x_{16}	0
Internet for music: Once/twice a month	x_{17}	0
Internet for other hobbies: every or almost every day	x_{18}	1
Internet for other hobbies: Once/twice a week	x_{19}	0
Internet for other hobbies: Once/twice a month	x_{20}	0
Internet for social networks: every or almost every day	x_{21}	0
Internet for social networks: Once/twice a week	x_{22}	0
Internet for social networks: Once/twice a month	x_{23}	0
Achieved values $Z_k^l(\mathbf{x}) / Z_k^u(\mathbf{x})$		
Competences in Reading ($k = 1$)		-0.054/0.914
Competences in Mathematics ($k = 2$)		-0.115/0.602
Competences in Science ($k = 3$)		-0.009/0.922
Competences in English ($k = 4$)		0.112/0.957

Source: Authors' own calculation.

Table A1. Descriptive statistics

		Mean	S.D.	n
Test scores	Reading	0.046	0.998	13296
	Maths	0.045	0.994	13296
	Science	0.050	0.995	13296
	English	0.070	0.991	13296
Gender	Female	0.500	0.500	13296
	Male	0.500	0.500	13296
Immigrant status	Native	0.878	0.328	13296
	Immigrant (first or second generation)	0.122	0.328	13296
Index of Economic, Social and Cultural Status		0.046	0.994	13296
Repeater	Yes	0.039	0.193	13296
	No	0.961	0.193	13296
School composition	Proportion of poor students in the school (1st quartile of the ESCS)	0.238	0.172	13296
Use of the Internet to search for information for studying (Google, Wikipedia, etc)	Every or almost every day	0.193	0.395	13296
	Once or twice a week	0.452	0.498	13296
	Once or twice a month	0.224	0.417	13296
	Never or almost never	0.056	0.230	13296
	Missing Flags	0.076	0.264	13296
Use of the Internet to search for information about games or playing (online games)	Every or almost every day	0.141	0.348	13296
	Once or twice a week	0.241	0.428	13296
	Once or twice a month	0.207	0.405	13296
	Never or almost never	0.333	0.471	13296
	Missing Flags	0.077	0.267	13296
Use of the Internet to search for information about sports	Every or almost every day	0.122	0.327	13296
	Once or twice a week	0.172	0.377	13296
	Once or twice a month	0.252	0.434	13296
	Never or almost never	0.376	0.484	13296
	Missing Flags	0.077	0.267	13296
Use of the Internet to search for information about music or cinema (YouTube, Spotify, etc)	Every or almost every day	0.329	0.470	13296
	Once or twice a week	0.259	0.438	13296
	Once or twice a month	0.160	0.367	13296
	Never or almost never	0.175	0.380	13296
	Missing Flags	0.077	0.266	13296
Use the Internet to search for information about other hobbies	Every or almost every day	0.233	0.423	13296
	Once or twice a week	0.361	0.480	13296
	Once or twice a month	0.221	0.415	13296
	Never or almost never	0.107	0.309	13296
	Missing Flags	0.078	0.268	13296
Use the Internet to communicate with others (WhatsApp, Telegram, Hangout, etc)	Every or almost every day	0.400	0.490	13296
	Once or twice a week	0.190	0.392	13296
	Once or twice a month	0.080	0.271	13296
	Never or almost never	0.254	0.435	13296
	Missing Flags	0.077	0.266	13296
Use the Internet for social networks (Facebook, Twitter, Instagram, Musically, etc)	Every or almost every day	0.216	0.411	13296
	Once or twice a week	0.167	0.373	13296
	Once or twice a month	0.087	0.282	13296
	Never or almost never	0.453	0.498	13296
	Missing Flags	0.077	0.267	13296

Notes: "S.D." stands for "Standard deviation" and "n" indicates "Observations".

Source: Authors' own calculation.

Table A2. Notation of decision variables

Variables	Notation	Type of variable	Bounds
Female student	x_1	Binary	0 or 1
Index of ESCS	x_2	Continuous	[-3.773, 3.078]
Immigrant status	x_3	Binary	0 or 1
Repeater before 6 th grade	x_4	Binary	0 or 1
Proportion of poor students in the school (1 st quartile of the ESCS)	x_5	Continuous	[0, 0.889]
Use the Internet for studying			
Every or almost every day	x_6	Binary	0 or 1
Once/twice a week	x_7	Binary	0 or 1
Once/twice a month	x_8	Binary	0 or 1
Use of the Internet to search for information about games or playing			
Every or almost every day	x_9	Binary	0 or 1
Once/twice a week	x_{10}	Binary	0 or 1
Once/twice a month	x_{11}	Binary	0 or 1
Use of the Internet to search for information about sports			
Every or almost every day	x_{12}	Binary	0 or 1
Once/twice a week	x_{13}	Binary	0 or 1
Once/twice a month	x_{14}	Binary	0 or 1
Use of the Internet to search for information about music or cinema (YouTube, Spotify, etc)			
Every or almost every day	x_{15}	Binary	0 or 1
Once/twice a week	x_{16}	Binary	0 or 1
Once/twice a month	x_{17}	Binary	0 or 1
Use the Internet to search for information about other hobbies			
Every or almost every day	x_{18}	Binary	0 or 1
Once/twice a week	x_{19}	Binary	0 or 1
Once/twice a month	x_{20}	Binary	0 or 1
Use the Internet for social networks (Facebook, Twitter, Instagram, Musically, etc)			
Every or almost every day	x_{21}	Binary	0 or 1
Once/twice a week	x_{22}	Binary	0 or 1
Once/twice a month	x_{23}	Binary	0 or 1

Source: Authors' own calculation.

Table A3. Regression results for the social networks model with school fixed-effects

Variables	Competences in Reading		Competences in Maths		Competences in Science		Competences in English	
	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound
Female student (Ref.: Male)	0.247	0.332	-0.115	-0.028	0	0	0.153	0.233
Index of ESCS	0.151	0.196	0.190	0.236	0.204	0.250	0.258	0.300
Immigrant status (Ref.: Native)	0	0	-0.003	0.128	0	0	0.181	0.299
Repeater before 6 th grade (Ref: No)	-0.591	-0.388	-0.647	-0.438	-0.551	-0.343	-0.730	-0.541
Use of the Internet to search for information for studying (Google, Wikipedia, etc). (Ref.: Never or almost never)								
Every or almost every day	-0.001	0.190	0	0	0	0	-0.017	0.161
Once/twice a week	0.040	0.215	-0.027	0.153	-0.017	0.162	0.023	0.186
Once/twice a month	0.039	0.221	-0.012	0.175	-0.001	0.185	0.050	0.219
Missing flag	0	0	-0.087	0.996	0	0	0	0
Use of the Internet to search for information about games or playing (online games). (Ref.: Never or almost never)								
Every or almost every day	-0.160	-0.023	0.018	0.159	0.013	0.152	-0.012	0.116
Once/twice a week	-0.095	0.015	0.034	0.147	0.034	0.146	-0.001	0.102
Once/twice a month	-0.108	0.002	0	0	0	0	0	0
Missing flag	0	0	0	0	0	0	0	0
Use of the Internet to search for information about sports (Ref.: Never or almost never)								
Every or almost every day	0	0	-0.219	-0.080	-0.343	-0.205	-0.151	-0.025
Once/twice a week	-0.102	0.015	-0.151	-0.031	-0.228	-0.109	-0.123	-0.014
Once/twice a month	0	0	0	0	-0.137	-0.035	0	0
Missing flag	0	0	0	0	0	0	0	0
Use of the Internet to search for information about music or cinema (YouTube, Spotify, etc) (Ref.: Never or almost never)								
Every or almost every day	0.075	0.205	0.027	0.161	0.091	0.224	0.089	0.210
Once/twice a week	0.032	0.158	0.021	0.151	0.037	0.166	0.031	0.149
Once/twice a month	0	0	-0.016	0.124	0.013	0.151	0	0
Missing flag	0	0	0	0	0	0	0	0
Use the Internet to search for information about other hobbies (Ref: Never or almost never)								
Every or almost every day	0.099	0.249	0.066	0.220	0.134	0.288	0.052	0.192
Once/twice a week	0.080	0.219	0.084	0.228	0.115	0.257	0.037	0.167
Once/twice a month	0.054	0.198	0.057	0.205	0.077	0.224	0.025	0.160
Missing flag	0	0	0	0	0	0	0	0
Use the Internet for social networks (Facebook, Twitter, Instagram, Musically, etc) (Ref: Never or almost never)								
Every or almost every day	-0.182	-0.072	-0.207	-0.095	-0.275	-0.163	-0.194	-0.092
Once/twice a week	-0.121	-0.007	-0.167	-0.050	-0.235	-0.118	-0.123	-0.017
Once/twice a month	-0.170	-0.027	0	0	-0.192	-0.045	0	0
Missing flag	0	0	0	0	0	0	0	0
School fixed-effects	✓	✓	✓	✓	✓	✓	✓	✓
Constant	-0.410	-0.204	-0.203	0.010	-0.219	-0.008	-0.355	-0.163
Observations	13,296		13,296		13,296		13,296	
R-squared	0.090		0.083		0.096		0.151	
Number of schools	477		477		477		477	

Notes: Dependent variables: Students' standardised scores in Reading, Mathematics, Science and English.

Estimation method: Ordinary Least Squares (OLS) with school fixed-effects.

Significance: Variables are significant at least at 10%. In case they are not significant, the value "0" is displayed.

Source: Authors' own calculations.

Table A4. Regression results for the WhatsApp model

Variables	Competences in Reading		Competences in Maths		Competences in Science		Competences in English	
	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound
Female student (Ref.: Male)	0.194	0.303	-0.155	-0.057	-0.091	0.012	0.127	0.222
Index of ESCS	0.161	0.217	0.197	0.251	0.215	0.27	0.293	0.344
Immigrant status (Ref.: Native)	0	0	0	0	-0.147	0.027	0.077	0.245
Repeater before 6 th grade (Ref: No)	-0.657	-0.401	-0.657	-0.433	-0.545	-0.325	-0.78	-0.564
Proportion of poor students in the school (1 st quartile of the ESCS)	0	0	-0.667	0.026	-0.686	-0.03	-1.144	-0.504
Use of the Internet to search for information for studying (Google, Wikipedia, etc). (Ref.: Never or almost never)								
Every or almost every day	-0.006	0.253	0	0	0	0	0.007	0.238
Once/twice a week	0.079	0.291	0	0	-0.016	0.169	0.037	0.223
Once/twice a month	0.041	0.246	0	0	0.027	0.226	0.071	0.254
Missing flag	0.186	1.163	0.213	1.23	0.012	0.987	0.129	0.844
Use of the Internet to search for information about games or playing (online games). (Ref.: Never or almost never)								
Every or almost every day	-0.195	-0.029	-0.013	0.137	-0.014	0.144	0	0
Once/twice a week	0	0	0.014	0.149	0.017	0.15	-0.019	0.11
Once/twice a month	-0.121	0.013	0	0	0	0	0	0
Missing flag	0	0	0	0	0	0	0	0
Use of the Internet to search for information about sports (Ref.: Never or almost never)								
Every or almost every day	0	0	-0.241	-0.078	-0.345	-0.192	-0.17	-0.021
Once/twice a week	-0.113	0.016	-0.171	-0.04	-0.238	-0.099	-0.128	0.003
Once/twice a month	0	0	0	0	-0.148	-0.029	0	0
Missing flag	0	0	-0.58	0.108	0	0	0	0
Use of the Internet to search for information about music or cinema (YouTube, Spotify, etc) (Ref.: Never or almost never)								
Every or almost every day	0.044	0.197	0.001	0.165	0.055	0.211	0.074	0.21
Once/twice a week	0.011	0.154	0.028	0.185	0.036	0.185	0.039	0.173
Once/twice a month	0	0	-0.003	0.157	0.019	0.176	-0.012	0.131
Missing flag	0	0	0	0	0	0	0	0
Use the Internet to search for information about other hobbies (Ref: Never or almost never)								
Every or almost every day	0.07	0.235	0.059	0.219	0.109	0.266	0.014	0.176
Once/twice a week	0.035	0.19	0.085	0.231	0.095	0.247	0.002	0.141
Once/twice a month	0.026	0.176	0.066	0.217	0.074	0.225	0.016	0.16
Missing flag	-0.829	0.121	0	0	0	0	-0.688	0.088
Use the Internet to communicate with others (WhatsApp, Telegram, Hangout, etc) (Ref: Never or almost never)								
Every or almost every day	0	0	0	0	0	0	-0.113	0.013
Once/twice a week	0	0	0	0	0	0	0	0
Once/twice a month	0	0	0	0	-0.19	-0.004	0	0
Missing flag	0	0	-1.524	0.218	-1.167	0.05	-1.275	0.21
Constant	-0.514	-0.182	0	0	0	0	0	0
Observations	13,296		13,296		13,296		13,296	
R-squared	0.082		0.1		0.113		0.221	

Notes: Dependent variables: Students' standardised scores in Reading, Mathematics, Science and English.

Estimation method: Ordinary Least Squares (OLS). Standard errors are clustered at school level.

Significance: Variables are significant at least at 10%. In case they are not significant, the value "0" is displayed.

Source: Authors' own calculations.

Table A5. Regression results for the WhatsApp model with school fixed-effects

Variables	Competences in Reading		Competences in Maths		Competences in Science		Competences in English	
	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound
Female student (Ref.: Male)	0.222	0.306	-0.141	-0.055	-0.072	0.015	0.129	0.207
Index of ESCS	0.156	0.201	0.195	0.241	0.211	0.257	0.263	0.305
Immigrant status (Ref.: Native)	0	0	-0.004	0.127	0	0	0.180	0.299
Repeater before 6 th grade (Ref: No)	-0.599	-0.397	-0.654	-0.445	-0.560	-0.352	-0.737	-0.548
Use of the Internet to search for information for studying (Google, Wikipedia, etc). (Ref.: Never or almost never)								
Every or almost every day	-0.003	0.189	0	0	0	0	-0.018	0.160
Once/twice a week	0.041	0.216	-0.025	0.155	-0.014	0.165	0.025	0.189
Once/twice a month	0.039	0.221	-0.010	0.178	0.004	0.191	0.052	0.222
Missing flag	-0.184	0.873	-0.018	1.071	0	0	0	0
Use of the Internet to search for information about games or playing (online games). (Ref.: Never or almost never)								
Every or almost every day	-0.167	-0.030	0.011	0.153	0.008	0.149	-0.018	0.110
Once/twice a week	-0.097	0.014	0.033	0.147	0.033	0.146	-0.003	0.100
Once/twice a month	-0.108	0.003	0	0	0	0	0	0
Missing flag	0	0	0	0	0	0	0	0
Use of the Internet to search for information about sports (Ref.: Never or almost never)								
Every or almost every day	0	0	-0.231	-0.091	-0.359	-0.220	-0.162	-0.035
Once/twice a week	-0.107	0.009	-0.156	-0.036	-0.235	-0.115	-0.128	-0.019
Once/twice a month	0	0	0	0	-0.142	-0.039	0	0
Missing flag	0	0	0	0	0	0	0	0
Use of the Internet to search for information about music or cinema (YouTube, Spotify, etc) (Ref.: Never or almost never)								
Every or almost every day	0.035	0.166	-0.012	0.123	0.045	0.179	0.053	0.175
Once/twice a week	0.011	0.138	0.003	0.133	0.015	0.145	0.014	0.132
Once/twice a month	0	0	-0.023	0.117	0.004	0.143	0	0
Missing flag	0	0	0	0	0	0	0	0
Use the Internet to search for information about other hobbies (Ref: Never or almost never)								
Every or almost every day	0.088	0.239	0.058	0.213	0.126	0.280	0.043	0.183
Once/twice a week	0.074	0.213	0.081	0.225	0.111	0.254	0.034	0.164
Once/twice a month	0.051	0.195	0.058	0.206	0.076	0.224	0.025	0.159
Missing flag	0	0	0	0	0	0	0	0
Use the Internet to communicate with others (WhatsApp, Telegram, Hangout, etc) (Ref: Never or almost never)								
Every or almost every day	0	0	0	0	-0.121	-0.011	0	0
Once/twice a week	0	0	0	0	-0.109	0.015	-0.018	0.095
Once/twice a month	0	0	0	0	-0.184	-0.022	0	0
Missing flag	0	0	-1.468	0.127	-1.305	0.282	0	0
School fixed-effects	✓	✓	✓	✓	✓	✓	✓	✓
Constant	-0.422	-0.214	-0.214	0.001	-0.220	-0.006	-0.370	-0.175
Observations	13,296		13,296		13,296		13,296	
R-squared	0.088		0.079		0.089		0.148	
Number of schools	477		477		477		477	

Notes: Dependent variables: Students' standardised scores in Reading, Mathematics, Science and English.

Estimation method: Ordinary Least Squares (OLS) with school fixed-effects.

Significance: Variables are significant at least at 10%. In case they are not significant, the value "0" is displayed.

Source: Authors' own calculations.

Table A6. Monoobjective problem. Ideal solutions and individual optimal values for the WhatsApp model

		Competences in Reading	Competences in Maths	Competences in Science	Competences in English
Variables	Notation	$x_{k=1}^*$	$x_{k=2}^*$	$x_{k=3}^*$	$x_{k=4}^*$
Female student	x_1	1	0	0	1
Index of ESCS	x_2	0.149	0.149	0.149	0.0676
Immigrant status	x_3	0	0	0	1
Repeater before 6 th grade	x_4	0	0	0	0
Proportion of poor students in the school (1 st quartile of the ESCS)	x_5	0.2349	0.2113	0.2113	0.2211
Internet for studying: every or almost every day	x_6	0	1	0	0
Internet for studying: Once/twice a week	x_7	1	0	0	0
Internet for studying: Once/twice. a month	x_8	0	0	1	1
Internet for gaming: every or almost every day	x_9	0	0	0	0
Internet for gaming: Once/twice a week	x_{10}	0	1	1	1
Internet for gaming: Once/twice a month	x_{11}	0	0	0	0
Internet for sports: every or almost every day	x_{12}	0	0	0	0
Internet for sports: Once/twice a week	x_{13}	0	0	0	0
Internet for sports: Once/twice a month	x_{14}	0	0	0	1
Internet for music: every or almost every day	x_{15}	1	0	1	1
Internet for music: Once/twice a week	x_{16}	0	1	0	0
Internet for music: Once/twice a month	x_{17}	0	0	0	0
Internet for other hobbies: every or almost every day	x_{18}	1	0	1	1
Internet for other hobbies: Once/twice a week	x_{19}	0	1	0	0
Internet for other hobbies: Once/twice a month	x_{20}	0	0	0	0
Internet for WhatsApp: every or almost every day	x_{21}	0	0	0	0
Internet for WhatsApp: Once/twice a week	x_{22}	0	0	0	0
Internet for WhatsApp: Once/twice a month	x_{23}	0	0	0	1
Optimal values		$Z_{k=1}^*$	$Z_{k=2}^*$	$Z_{k=3}^*$	$Z_{k=4}^*$
Standardised scores		0.386	0.313	0.493	0.618

Source: Authors' own calculation.

Table A7. Multiobjective interval problem. Possibly efficient solution achieved values for the WhatsApp model

Variables	Notation	Solution
Female student	x_1	1
Index of ESCS	x_2	0.0676
Immigrant status	x_3	1
Repeater before 6 th grade	x_4	0
Proportion of poor students in the school (1 st quartile of the ESCS)	x_5	0.2211
Internet for studying: every or almost every day	x_6	0
Internet for studying: Once/twice a week	x_7	0
Internet for studying: Once/twice. a month	x_8	1
Internet for gaming: every or almost every day	x_9	0
Internet for gaming: Once/twice a week	x_{10}	1
Internet for gaming: Once/twice a month	x_{11}	0
Internet for sports: every or almost every day	x_{12}	0
Internet for sports: Once/twice a week	x_{13}	0
Internet for sports: Once/twice a month	x_{14}	0
Internet for music: every or almost every day	x_{15}	1
Internet for music: Once/twice a week	x_{16}	0
Internet for music: Once/twice a month	x_{17}	0
Internet for other hobbies: every or almost every day	x_{18}	1
Internet for other hobbies: Once/twice a week	x_{19}	0
Internet for other hobbies: Once/twice a month	x_{20}	0
Internet for WhatsApp: every or almost every day	x_{21}	0
Internet for WhatsApp: Once/twice a week	x_{22}	1
Internet for WhatsApp: Once/twice a month	x_{23}	0
Achieved values $Z_k^l(\mathbf{x}) / Z_k^u(\mathbf{x})$		
Competences in Reading ($k = 1$)		-0.154/0.814
Competences in Mathematics ($k = 2$)		-0.215/0.499
Competences in Science ($k = 3$)		-0.167/0.904
Competences in English ($k = 4$)		0.111/1.129

Source: Authors' own calculation.