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Improving financial literacy by mitigating behavioural biases. A causal mediation analysis on the effects of behavioural-based financial education.

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Improving financial literacy by mitigating behavioural biases. A causal mediation analysis on the effects of behavioural-based financial education.[1]

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Abstract

Financial illiteracy affects considerably the decision-making of individuals, leading to sub-optimal outcomes and lower financial welfare in the society. Although financial education has been demonstrated to improve financial knowledge, evidence of long-term effects is limited. This could be due to the presence of cognitive biases such as myopia, which have also been linked to poor decision-making. We propose a new behavioural-mediated mechanism of financial education in improving financial literacy not only directly, but also indirectly by increasing awareness of cognitive biases. In a randomized controlled trial among 814 secondary school students in Belgium, we tested the effectiveness of course materials that aim to explicitly mitigate the myopic bias while teaching children about financial matters. The results suggested that the intervention groups had significantly better results for both the financial literacy (up to 0.67 sd) and myopia (up to 0.39 sd) post-test scores in comparison to the control condition that did not receive the materials. Using causal mediation analysis, we showed that the significant indirect effects of behavioural-based courses on financial literacy were mediated by better awareness of myopia, which was not observed in traditional courses.

Keywords. Financial literacy; Financial education; Behavioural finance; Myopic bias; Causal mediation analysis
JEL-classification. G53; G52; G51; D91
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1. Introduction

Many of households' financial problems (e.g., over-indebtedness, high financial fraud, low savings rate) are linked, at least partially, to poor financial decision making. Given the macro-economic implications of these individual actions, we witness growing attention to financial literacy, defined as "a combination of awareness, knowledge, skill, attitude, and behaviour necessary to make sound financial decisions and ultimately achieve individual financial well-being" (OECD/INFE, 2011). This leads to the realization that individuals that lack the necessary abilities, knowledge, skills and behaviours have sub-optimal financial outcomes. For instance, a lower level of financial literacy has been linked to lower diversification of investments (Calvet et al., 2009), and higher indebtedness (Lusardi & Tufano, 2015).

Given the topic's importance, the following question is how to improve financial literacy. Financial education and financial advising are the two key options for a possible solution. Even though financial education was shown to have impressive results to improve financial knowledge, the average effect size on financial behaviour is substantially lower (Kaiser & Menkhoff, 2020). This goes in the direction of Willis (2011), who suggests that no causal chain from financial education to financial literacy was found in the literature, considering no evidence of improvement in the financial outcomes and financial well-being in the society as a consequence of financial education.

The prevalence of behavioural biases may be a barrier to achieving the causal chain from financial education to better financial behaviour, financial literacy, and financial outcomes. The behavioural economics literature shows that behavioural and cognitive biases are linked with worse financial decision-making and outcomes. In particular, DeLiema et al. (2020) has linked higher self-assessment of knowledge with higher incidence to financial fraud. Besides, behavioural biases were found to be prominent even among well-educated people and financial professionals (Baker et al., 2017). García (2013) showed that the effect of financial education can be reduced by the existence of behavioural biases. In turn, Jonsson et al. (2017) indicate that higher degrees of financial literacy is associated with a lower prevalence of behavioural biases. Pitthan & De Witte (2021) suggest that sub-optimal insurance decisions due to biases could be mitigated with financial literacy measures focused on behavioural topics.

One of the behavioural biases that can affect financial outcomes is myopia. This bias is related to the short-sightedness of economic and financial decisions, with myopic-biased people presenting short-time preferences for short-term gains over greater long-term benefits and focusing on their close surroundings[2] in the decision-making process (Maskell & Malmberg, 2007). The myopic bias is also associated with the underestimation of risks (De Donder & Leroux, 2013). The literature has shown evidence of the harmful effects of myopia in insurance (Cremer & Roeder, 2013), investment (Benartzi & Thaler, 1995), and pension-planning (McCaffery, 2013) decisions. Possible policies to mitigate myopia can be centred on sharing publicly the real threats of risky events to combat underestimation of risks (Pitthan & De Witte, 2021) and reducing taxes for long-term decisions such as retirement planning (McCaffery, 2013).

[2] Focus on the close environment in terms of time, geography and relationships. Which leads them to be over-influenced by events that happened recently, information shared through closed ones or by things that happened in their neighbourhood.

This paper adds to the field by suggesting and experimentally evaluating a new behavioral-based financial education method. In particular, in addition to the traditional direct mechanism of financial education, we examine if financial literacy can be indirectly improved by better awareness of the myopic cognitive bias. Using a randomized controlled trial (RCT), 814 secondary school students were distinguished between a control group without financial education classes[3], and three intervention groups: one with a regular class about financial education and two other groups that received a modified version of the class which also teaches students about the myopic bias in addition to financial education. The indirect effects (i.e. average causal mediated effects) were estimated using causal mediation analysis (Imai et al., 2010). The proposed mechanism had an additional causal link to financial literacy since students being more aware of their own mistakes and automated thought processes, made more informed financial decisions.

The main contributions of the paper are twofold. First, the paper endeavours to improve financial literacy with a new financial education mechanism, with course materials centred to increase the awareness of cognitive biases. Although some financial education programs also focus on financial behaviour elements, those programs tend to be scarce and more focused on illustrating what the good behaviour is (Amagir et al., 2018). To the best of our knowledge, no trials incorporated the awareness of cognitive pitfalls or automatic thought processes that individuals may fall caused by behavioural biases as part of financial education programs. Financial education programs still did not show long-run improvements to financial outcomes and financial well-being (Willis, 2011). With this new mechanism, not only the direct effect on financial literacy would be observed, but also the indirect effect, enlarging the total effect, and possibly increasing the strength of the causal link towards better financial well-being. Carpena & Zia (2020) ventured into some of the causal mechanisms of financial education to improve financial decisions mediated by better financial literacy. The focus is mainly on the previous step of the causal chain that is to investigate the mediation effect of better awareness on behavioural biases to improve financial literacy. Second, this is the first paper that uses a financial education program as a RCT-based intervention to mitigate the myopic behavioural bias. The literature applied debiasing techniques to biases such as framing effects (Cheng & Wu, 2010), but it did not yet venture to debias myopia, nor to use financial education programs centred on increasing awareness to behavioural components as a debias technique. From Compen et al. (2022), a few behavioural biases can be persistent enough that smaller interventions (e.g., warning messages) might not be enough to mitigate them, thus, financial education and other more extensive techniques might be more appropriate as a debiasing method.

The results suggest that the treatment groups had significantly better results for both the financial literacy (up to 0.67 standard deviations) and myopia (up to 0.39 standard deviations) post-tests in comparison to the control condition. In addition, a causal mediation analysis supports the hypothesis that behavioural-based courses have significant indirect effects on financial literacy mediated by better awareness of the myopic bias. This was not observed in traditional courses, strengthening the importance of the behavioural-based mechanism of financial education.

[3] At the moment of the intervention financial literacy was not included in the curriculum of secondary education students of that age.

The remaining of the paper is organized as follows. In section 2 we discuss the theoretical framework of financial literacy, myopia and financial education. Section 3 details the experiment design used in the intervention. Section 4 focuses on the methodology used in this study. Section 5 presents the data of our experiment. The results are presented in section 6, while the last section is dedicated to the discussion.

2. Behavioural-based financial education

A novel mechanism is proposed to improve the financial literacy: behavioural-based financial education. This mechanism not only has the direct effect of financial education on financial literacy but also an indirect effect mediated through the mitigation of behavioural biases. In addition to traditional content, this would be achieved through behavioural-based financial education aimed to increase the understanding and awareness of cognitive pitfalls, heuristics and thought processes that lead to sub-optimal decisions and outcomes, giving more information about bad outcomes and how they can impact our lives.

Figure 1: Direct acyclic graphs with causal links of financial education mechanisms.

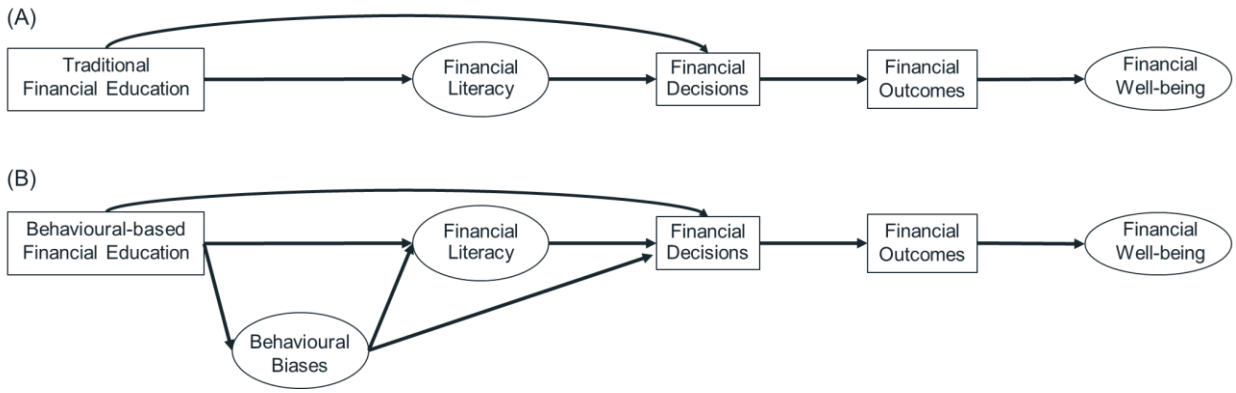


Figure 1 shows Direct Acyclic Graph (DAG)[4] representations of two mechanisms of financial education to improve financial literacy: upper panel 1.A for the traditional financial education path, and lower panel 1.B for the behavioural-based financial education path. The circles represent unobserved or latent variables, squares represent observed variables and arrows represent causal links. As they are not directly observed, financial literacy, behavioural biases and financial well-being are usually estimated by proxy scores. Here we included both the direct effect from traditional financial education to financial decisions (or perceived behaviour) and the indirect effect mediated by better financial literacy, as proposed by the causal model of Carpena & Zia (2020). In the literature, we can observe a causal link of education to financial literacy through the better proxy scores of financial knowledge and financial

[4] Direct Acyclic Graphs (DAG) are graphical representation of causal links with no cyclical or simultaneity relationships. For details of DAGs and their use in causal inference, please refer to Cunningham (2021).

behaviour (Kaiser & Menkhoff, 2020), but the main critique is that this might not be enough to improve actual financial decisions (or observed financial behaviour), financial outcomes and subjective financial well-being (Willis, 2011), thus the causal chain of Figure 1.A would be broken. Our hypothesized mechanism of behavioural-based financial education (Figure 1.B) has two additional indirect effects to improve financial literacy and financial decisions, both mediated by a smaller prevalence of behavioural biases.

In the analysis, it is tested if an educational intervention can mitigate myopic bias and if this mitigation can act as a mediated indirect effect to improve financial literacy. Financial illiteracy and myopic bias are two factors that can influence financial decision-making through a wide range of mechanisms, detailed in Appendix A. They are based on different influences to one's decision-making, with the exception of short-term preference which is present at both. Still, many financial outcomes which resulted from their different mechanisms are similar, among others we note lower insurance intake (Cremer & Roeder, 2013), and lower pension planning (McCaffery, 2013).

3. Experimental Design and Test Constructs

An experiment was organised that took place among 14 to 18-year-old students in Dutch-speaking secondary schools in Belgium's Flemish region to examine the efficiency of behavioural financial education courses in mitigating myopic bias and improving financial literacy, both directly and indirectly. The Flemish education system includes education organised by the Flemish community itself, by municipal and provincial authorities or by private organizations, which accounts for the main part of schools and is usually run by catholic private institutions. Secondary education is organised in three cycles of two years and includes both general education schools, technical education, arts education and vocational education. As part of the increased relevance of financial education, financial literacy-related learning objectives have begun to be included into the curricula of Flemish schools beginning September 2019 (De Witte et al., 2020). At the moment of the intervention, only students in the first cycle of secondary education have financial literacy as a compulsory element in the curriculum.

The main intervention of this experiment is in the format of a financial computer-assisted game called "*Life Path"*, developed by experienced teachers in the research team. Financial education courses were seen to be effective when applied to computer-assisted environments (Iterbeke et al., 2021). Hence, instead of presenting the course material in a traditional teacher-led classroom format, it is based on an online interactive platform. Students learn about financial concepts and products of investments, insurance, pensions and savings with the help of articles, games, questions, feedback and videos, being presented with close to real life examples and having to face financial decisions, centred mainly at two of the four OECD/INFE's (2015) core competencies for financial literacy (i.e., planning & managing; and risk & reward).

The experiment consists of four different experimental conditions, a control group (without any sort of intervention and financial literacy courses), and three treatment groups that received interventions in the format of the game. The first treatment group ('Treatment Traditional Financial Education' from here on) received the basic version of the material, with only financial education components, and without learning about behavioural biases. The second treatment group ('Treatment Myopia 1') received the basic

version of the game, and additional content related to the underestimation of risks observed in individuals with myopic bias. Finally, the third treatment ('Treatment Myopia 2') received all the materials from 'Treatment Traditional Education' and 'Treatment Myopia 1', with in addition materials to increase awareness of the short-term preference from myopic individuals. Although awareness of risk underestimation and different types of risks (i.e., in the material of treatment Myopia 1) can help to improve bad decisions that underweight the chance of bad outcomes happening (e.g., De Donder & Leroux, 2013), it still cannot help with decisions related with investments or intertemporal preferences (i.e., in treatment Myopia 2's content), by this the two contents are included. Both treatments Myopia 1 and 2 are referred to jointly in the remainder of the paper as the behavioural-based financial education treatments. Table 1 summarizes the main differences across the experimental conditions. Few examples of the course material are presented in Appendix B.

Table 1: Schematic representation of the experimental conditions

	Control	**Treatment Trad. Fin. Educ.**	**Treatment Myopia 1**	**Treatment Myopia 1**
Traditional financial education course about insurance, pensions and investments	No	Yes	Yes	Yes
Behavioural-based materials about underestimation of risks	No	No	Yes	Yes
Behavioural-based materials about short-term preferences	No	No	No	Yes

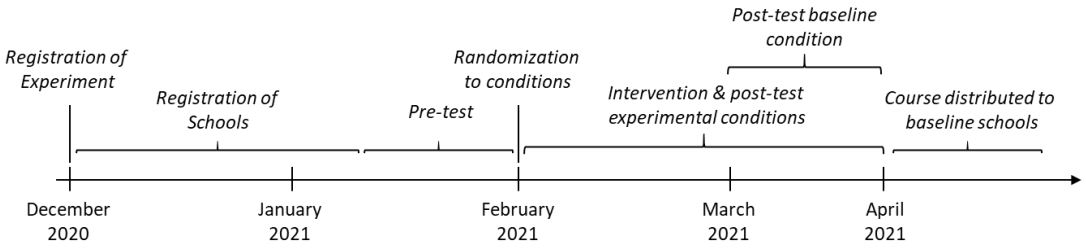
The experiment is randomized at the school level to mitigate intra-school contamination and externality issues. In the empirical analysis, we cluster the standard errors at the school level to account for potential peer effects within schools. The evaluation of the students was based on pre and post-tests. The tests had socio-economic characteristics (e.g., age, sex, language spoke at home); proxy for economic status (e.g., travel frequency in 2019 – before the covid-19 pandemic); financial independence (e.g., who pays mobile phone bills, if received allowance); and previous academic scores (e.g., Dutch and math).

In the empirical analyses, we rely on two outcome variables. First, the financial literacy outcomes were divided into financial knowledge (comprising questions on numeracy and knowledge of financial concepts and products), financial attitude (with questions about financial habits, perspectives and opinions related to different financial matters and types of situations) and financial behaviour (with most likely financial decisions under hypothetical situations) which was measured by including questions presented at Maldonado et al. (2019) and OECD/INFE (2011). As the second outcome variable, the myopic bias score was measured with questions inspired by Jacobs & Matthews (2012), as well as novel questions to reflect other components of myopia (underestimation of risks, short-time preference and level of awareness to important matters). Answers that showed a high myopic bias got a score of 1, and 0 otherwise (i.e., higher score in the test related to undesired higher myopia).

From the questions, pre-test and post-test scores were constructed by appraising all the questions related to each outcome variable using item response theory, Cronbach's alpha, factor analysis and point-biserial correlation. The detail of the questions' consistency analysis is presented in Appendix C. Based on this, all test constructs have sufficient internal validity and reliability based on the scores. Pre and post-test scores were standardized by the mean and standard deviation of the pre-test ones.

The timeline of the experiment is presented in Figure 1. After the RCT pre-registry, from December 2020 until mid-January 2021, an open call (which could easily be shared with the whole Flemish education network to achieve a representative sample) was sent to secondary schools' teachers, offering the chance to receive the newly developed course materials of financial education. This open call also presented the consent form to participate in this experiment. In January, students of the registered schools completed the pre-test. To reduce the attrition, the experimental conditions were randomized only after the completion of pre-tests, with schools' inclusion in the experiment and the randomization itself being conditional on the completion of the pre-tests by the students. From February until Easter, schools from the intervention groups received the course material, with an expected duration of about 4 hours. Teachers could divide the course from 1 to 4 study sessions and fix the dates that could best fit in the school schedule. Considering the Covid-19 situation in Belgium, the course and the tests could be done either online (via distance learning) or at the school (we control for this in the analysis), which would depend on the decision of the teacher and the current sanitary rules in place at the moment. After completion of the materials, students from the intervention groups answered the post-test. In parallel to this, students of the control condition answered the post-test without completing the course material. There was no intervention between the two tests performed by the control students, but after the experiment ended (i.e., after Easter), schools in the control condition received the course content after answering both tests, without leaving any schools behind for ethical reasons.

Figure 2: Timeline of the experiment.



4. Methodology

Our identification strategy is based on assigning students to experimental groups randomly, which overcomes the selection problem and makes the interventions independent of potential outcomes. Since all students assigned to treatment groups that filled the inclusion criteria received the treatment (and all control students did not receive any intervention), their average treatment effects (ATE) were measured using the following OLS equation:

$$(1) \qquad y_{i,s}^{1} = \alpha + \beta_1 Trad_s + \beta_2 Myop\ 1_s + \beta_3 Myop\ 2_s + \beta_4 y_{i,s}^{0} + \sum \beta'_5 S_s + \sum \beta'_6 P_i + \epsilon_{i,s}$$

where $y_{i,s}^{1}$ denotes the post-treatment outcome variable (i.e., myopia or financial literacy) for the student i of school s, with the treatments being indicated by additive binary variables. $Trad_s$ identifies schools that received the treatment Traditional Financial Education (i.e., treatment group 1), $Myop\ 1_s$ the treatment Myopia 1 (i.e., focus on underestimation of risks) and $Myop\ 2_s$ only accounts for the Myopia 2 treatment group (i.e., focus on underestimation of risk and short-term preferences). This separate setting allows us to evaluate the total effect of each of the different treatments. Besides the treatment variables,

$y^0_{i,s}$ controls for the pre-test results of all outcome variables; S_s identifies observed school characteristics (e.g., province, student track and if catholic); P_i are observed pupil characteristics (e.g., age, sex, school grades, financial independence, language spoken at home, number of siblings, education of the mother, where the material was followed and travel frequency); while $\epsilon_{1,i,s}$ is the robust clustered error term at school level for equation (1). Additionally, we propose the following equation with interaction to test the incremental effect of each additional content from the different treatment arms:

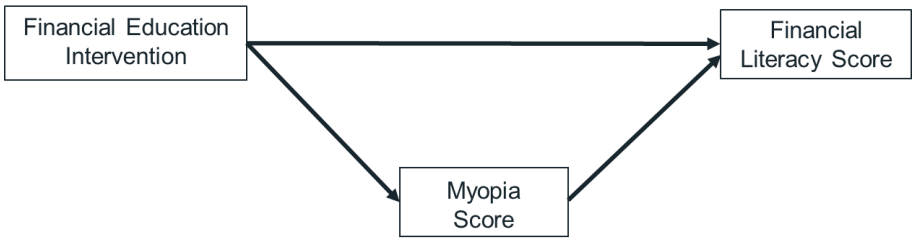
$$(2)\ y^1_{i,s} = \alpha + \beta_7 Trad_s * Myop\ 1_s * Myop\ 2_s + \beta_8 Myop\ 1_s * Myop\ 2_s + \beta_9 Myop\ 2_s + \beta_{10} y^0_{i,s} + \sum \beta'_{11} S_s + \sum \beta'_{12} P_i + \epsilon_{2,i,s}$$

Here $Trad_s * Myop\ 1_s * Myop\ 2_s$ measures the effect of receiving the content from the traditional financial education (present in all treatment groups), $Myop\ 1_s * Myop\ 2_s$ measures the marginal effect to receive content about underestimation of risks (present in Myopia 1 and 2 groups) in addition to the traditional content, while $Myop\ 2_s$ measures the incremental effect of receiving material about short term preference in addition to underestimation of risks.

Although we apply RCT design, sample attrition caused a few imbalances in the sample across experimental conditions (see Section 5). Therefore, we use two models as robustness analysis, to account for sample imbalances and attrition. First, we apply Lee's (2009) bounds, which is done by trimming the full sample by how much each experimental condition was affected by attrition. We present the lower and upper bounds with 95% confidence intervals. Lee bounds assume monotonicity of the sample (i.e. no attrition among defiers), which is not observed in our sample: we have full compliance of the treatment (i.e. schools that answered the pre-test applied the course materials among their students), but students of those schools could have dropped out of the evaluations (either of the pre or post-test), as seen in Appendix E.

Second, we use Mahalanobis-distance matching to control for sample imbalances and to approximate counterfactuals of treatment units closer to more similar observations. In line with Iacus et al. (2011), we use Mahalanobis Distance Matching (MDM), which still approaches a fully blocked randomized experiment (as for the Coarsened Exact Matching (CEM)), but without reducing greatly the sample size during the matching procedure.

Figure 3: Direct acyclic graph of the estimated financial education mechanisms.



In addition, we also analyse the hypothesized financial education mechanism discussed in Section 2: its possible indirect effect on financial literacy mediated by the reduction of the myopic bias. In Figure 3 we see a Direct Acyclic Graph (DAG) representation of this tested relationship. All variables are observed

(test scores are used as proxies to the latent variables financial literacy and myopia), thus they are all represented by squares in this DAG. Instead of testing all three experimental conditions separately, we tested the indirect mechanism for the traditional financial education (when no components to increase awareness to behavioural biases was presented) and for the behavioural-based financial education (related with both treatments Myopia 1 and 2 groups).

In Appendix D we show an overview of causal mediation analysis, the methods used to test the identification assumptions, and detail of the models tested in the paper as seen in equations (3) and (4) below:

(3) $$M_i^1(d, X) = \alpha + \beta_{13} d_s + \beta_{14} X_{i,s} + \epsilon_{3,i,s}$$

(4) $$y_{i,s}^1(d, M, X) = \alpha + \beta_{15} d_s + \beta_{16} M_i^1 + \beta_{17} X_{i,s} + \epsilon_{4,i,s}$$

where, in addition to $y_{i,s}^1$ (i.e., our main outcome variable, here financial literacy), d is the treatment status, M_i is the average value of the mediator variable (the post-test score of myopic bias) for individual i, X is the set of all confounders (pre-treatment scores and characteristics at school and pupil levels), while $\epsilon_{3,i,s}$ and $\epsilon_{4,i,s}$ are the errors. For identification, the sequential ignorability assumptions require statistical independency (i) of the treatment status with the mediation and outcome variables (which arises from RCT's random assignment); and (ii) of the mediation and outcome variable (strong assumption and hard to test, as argued in Appendix D.

5. Data

The final sample comprised of 814 students[5] from 42 schools. The results from Appendix E suggest that the schools participating in the experiment are representative of all Flemish general education schools, yielding confidence in the external validity of the results.

Panel A in Table 2 shows the school characteristics of our sample, while Panel B shows the student characteristics. For both panels, the proportions are shown across experimental groups, and the values are compared with the control group, checking if the figures are significantly different by using t-tests. Due to randomization at the school level, even though the randomization was performed by school characteristics' strata, we observe imbalances in student and school characteristics. Performing Wilks lambda multivariate analysis for homogeneity across the four experimental groups, we observe an F-statistic of 26.74 for Panel A and 6.37 for Panel B, rejecting the equality of the groups at 0.01% significance. Therefore, to account for the sample imbalances, the characteristics are included as covariates in the econometric specifications tested. In addition, we applied matching models, to compare matched treated and control observations, and Lee's (2009) bounds, to trim the sample with attrition in a consistent way across experimental conditions. The results indicate that our main findings are not driven by imbalances.

Panels C and D of Table 2 present the pre and post-test scores. As far as pre-test scores, myopic bias and financial literacy scores (i.e., the main outcome variables) are fairly balanced across all experimental conditions, with multinomial F-test yielding 0.73, not rejecting equality among the different

[5] For a detectable effect-size of 0.15 with the sample of 814 and significance level of 1%, a power of more than 95% was entailed in a post-hoc analysis. In Appendix E we detail the attrition from the sample, and its relationship with the experimental conditions.

treatment arms. As such, the pre-test scores will also be controlled in our models to account for those imbalances, and to control the pre-existing abilities and knowledge of students.

Table 2: Characteristics and test scores across experimental groups.

	Control	**Treatment Trad. Educ.**	*p-value*	**Treatment Myopia 1**	*p-value*	**Treatment Myopia 2**	*p-value*
Panel A: School characteristics							
Number of schools	6	10		13		14	
Number of students	92	118		239		365	
Type of school (catholic)	79.35%	77.97%	0.81	87.03%	0.08	80.00%	0.89
Student track (academic)	96.74%	39.83%	0.00***	82.43%	0.00***	84.66%	0.00**
Panel B: Student characteristics							
Gender (male)	57.61%	40.68%	0.01*	48.96%	0.16	46.58%	0.06
Age (years)	15.70	16.86	0.00***	16.22	0.00***	16.65	0.00***
Language:							
Dutch	81.52%	76.27%	0.69	95.40%	0.00***	82.74%	0.78
Other languages	18.48%	23.73%	0.36	4.60%	0.00***	17.26%	0.78
Grade in Dutch:							
Below 50	7.61%	0.80%	0.01*	2.51%	0.03*	1.10%	0.00***
Between 50 and 70	51.09%	60.17%	0.19	39.33%	0.05	62.19%	0.05
Above 70	41.30%	38.98%	0.73	58.16%	0.00**	36.71%	0.42
Grade in Math:							
Below 50	9.78%	10.17%	0.93	5.02%	0.11	4.66%	0.06
Between 50 and 70	59.78%	48.31%	0.10	43.10%	0.01**	58.08%	0.77
Above 70	30.43%	41.53%	0.10	51.88%	0.00***	37.26%	0.22
Financial independency degree	30.98%	36.02%	0.16	32.01%	0.76	33.56%	0.43
Frequent travel (2 or more)	50.00%	40.68%	0.18	46.44%	0.56	50.14%	0.88
Siblings (2 or more)	52.17%	48.31%	0.58	32.64%	0.00**	45.48%	0.25
Where was course followed?							
At home	34.78%	32.20%	0.70	46.03%	0.06	41.37%	0.25
At school	3.26%	22.03%	0.00***	8.79%	0.08	24.93%	0.00
Mixed	10.87%	34.75%	0.00***	19.25%	0.07	31.23%	0.00
Low educated mother	41.30%	56.78%	0.03*	41.42%	0.98	38.63%	0.64
Panel C: Pre-test scores							
Financial literacy	-0.07	-0.06	0.96	0.01	0.48	0.03	0.40
Myopic bias	0.17	0.01	0.23	-0.06	0.07	-0.01	0.12
Panel D: Post-test scores							
Financial literacy	0.40	0.68	0.10	0.72	0.03*	1.02	0.00***
Myopic bias	-0.30	-0.48	0.19	-0.83	0.00***	-0.73	0.00***

Note. Mean values for each of the experimental groups in the columns, with p-values being derived from t-tests of mean-differences between each of the treatment arms (i.e. Traditional Financial Education, Myopia 1 and Myopia 2) in comparison with the control group. Where course was followed answer does not reach 100% since first surveys did not include this question.

The effect of the treatment variables is observed for the post test scores. All treatment groups have significantly positive differences in financial literacy scores when compared with the control post-test scores, with those differences being fairly similar across the groups. For the myopic score, all treatment groups decreased the level of myopia, but this difference was slightly greater for the myopia treatments. The multinomial F-test for this panel was 8.08, which rejects the equality among groups at 0.01% significance.

6. Results

This section presents the main results of the paper. The first subsection discusses the Average Treatment Effect (ATE) of the course materials on educational, financial literacy and behavioural outcomes. Next, heterogeneity analysis is presented. Finally, mediation analysis is used to test the hypothesis of the additional behavioural-based financial education mechanism to improve financial literacy mediated in the experiment by better awareness of the myopic bias.

6.1 Treatment effect estimations across experimental conditions

Table 3 Panel A presents the ATE of the intervention using financial literacy post-test score as an outcome. The estimated ATEs were significant for all the treatment variables for both the OLS (column 1) and Mahalanobis Distance Matching (MDM) (column 2) specifications. Starting with the OLS results, traditional financial education ATE was 0.33 standard deviations (sd), which was greater than treatment Myopia 1's total effect of 0.17 sd and smaller than that of Myopia 2's (0.51 sd). Although the ATEs had different magnitudes, all effects were significant at 5%, but only treatment Myopia 2 effect was significant at 0.01%. Regarding MDM estimates, the pattern was similar with slightly higher effect sizes: traditional financial education had 0.49 sd, while treatment Myopia 1 and 2 had respectively 0.33 and 0.67 sd. The results suggested that all treatment groups improved considerably their initial level of financial literacy. The additional content received by treatment Myopia 1 (i.e. underestimation of risks) did not seem to improve the strength of the treatment effect, on the contrary, it led to a smaller value, which showed that knowing about different types and sizes of risks may not improve the financial literacy as much. As other core concepts included in the traditional course. The largest effect sizes were found for the treatment Myopia 2 group (i.e., which in addition to the traditional course and the underestimation of risks, also included content about short-term preferences), indicating that behavioural components can be beneficial to improve financial literacy. Course components with behavioural applications of short-term preference to pensions, insurance and investments can be a reason behind the larger ATEs for the case of the treatment Myopia 2 group.

For the Lee bounds, considering the difference of the attrition rates between control and treatment groups, the trimming proportion for the treatment Myopia 1 was the greatest, at 17%, with treatment Myopia 2 at 16% and treatment Traditional Financial Education at 2%. Although some treatment effects were outside the point-estimate bounds, all effects were still inside the 95% confidence interval. The results suggest that the effect sizes are valid in attrition-balanced samples since no treatment effects estimated were outside the confidence intervals.

Table 3: Estimated ATEs and Lee bounds.

Specification	OLS	Mahalanobis Matching	Lower Bound	Upper Bound	Trimming proportion
Panel A: Financial literacy post-test score as outcome					
Treatment	0.343*	0.494**	-0.279	0.501	2.2%
Trad. Fin. Educ.	(0.150)	(0.153)	[-1.169, 0.611]	[-0.368, 1.370]	
Treatment	0.165*	0.333**	-0.816	0.102	16.8%
Myopia 1	(0.081)	(0.101)	[-1.589, -0.043]	[-0.479, 0.682]	
Treatment	0.512***	0.667***	-0.371	0.666	15.7%
Myopia 2	(0.085)	(0.083)	[-0.869, 0.127]	[0.007, 1.325]	
N	814	814			
R^2	0.361	0.442			
F	117.7	578.2			
Panel B: Myopia post-test score as outcome					
Treatment	-0.243*	-0.254**	-0.071	0.052	2.2%
Trad. Fin. Educ.	(0.094)	(0.086)	[-0.525, 0.387]	[-0.525, 0.623]	
Treatment	-0.387***	-0.393***	-0.364	0.275	16.8%
Myopia 1	(0.073)	(0.069)	[-0.667, -0.061]	[-0.040, 0.590]	
Treatment	-0.359***	-0.390***	-0.286	0.809	15.7%
Myopia 2	(0.084)	(0.063)	[-0.628, -0.101]	[-0.061, 0.447]	
N	814	814			
R^2	0.211	0.258			
F	65.87	109.1			

Note. Lower and upper bounds coefficients are the Lee's (2009) bounds estimations for the required trimming rate in comparison with control conditions. Numbers in brackets are the 95% confidence intervals. The estimations for OLS and Mahalanobis Distance Matching are the estimated coefficients in terms of standard deviations of the outcome variable. Clustered standard errors in parentheses. * $p \leq .05$ ** $p \leq .01$ *** $p \leq .001$. Estimation controls for all pre-test observed characteristics presented at table 2.

The results for myopia score as an outcome variable are presented in table 3 panel B. Here negative ATEs represent mitigation of the myopic bias. In the OLS column, we see that the ATEs were -0.24, -0.39 and -0.36 sd to the traditional financial education, Myopia 1 and Myopia 2 respectively. Here the pattern is also maintained for the MDM results, -0.25, -0.39 and -0.39 sd for the three aforementioned groups. For both treatments Myopia 1 and 2 the effect sizes were large and significant at 0.1% level. Although with a smaller size, the effect for the traditional course (i.e., treatment Traditional Financial Education) was also significant (at 5% level for OLS and 1% for MDM), which suggested that regular financial education courses could also help with behavioural biases to a certain extent. This result might be linked with the short-term preference overlapping in the definition of both concepts; thus a few components of myopia could be improved while students learnt about financial concepts and products. As in the case of the previous table, all ATEs were inside the Lee bounds confidence intervals. The effect-size magnitude for both treatment Myopia 1 and 2 was similar, which points in the direction of relatively greater importance to the underestimation of risks to improve myopia than short-term preference.

The question remains on how the effect sizes is compared with each other. Table 4 presents the results of estimating Equation (2) using the MDM approach to test incremental effects. With financial literacy as the outcome variable, the ATE to receive any form of treatment was 0.50 sd, while the underestimation of risk content decreased the total effect size by 0.16 sd (although this difference was not statistically significant). The marginal effect to receive the extra content of short-term preferences in addition to underestimation of risks was 0.33 sd, which was significant at 5%. Although the underestimation of risks seems to be of no difference to improve financial literacy, this cannot be said to short-term preferences which might be a good addition to financial education courses curricula. Moving

to myopia as the dependent variable, receiving any of the treatments incurred a myopic score which was 0.25 sd lower. Although receiving the myopia content increased the total effect size to reduce myopia, this surprisingly did not have a statistically significant difference with respect to the traditional content. The Traditional Financial Education content seemed to be effective to decrease myopia, with content about myopia having a detectable difference only to improve financial literacy. Additionally, in Appendix F tables 3 and 4 replicate the results using the course knowledge as the outcome variable, which evaluates the learning outcomes of the course.

Table 4: Estimated incremental ATEs

Specification	Fin. Literacy	Myopia
Traditional Content (Trad. + Myopia I & II)	0.495**	-0.252**
	(0.155)	(0.089)
Myopia I Content (Myopia I & II)	-0.163	-0.139
	(0.149)	(0.104)
Myopia II Content (Myopia II only)	0.333**	0.002
	(0.110)	(0.082)
N	814	814
R^2	0.442	0.212
F	575.3	64.75

Note. The values are the estimated MDM coefficients in terms of standard deviations of the outcome variable. Clustered standard errors in parentheses. * $p \leq .05$ ** $p \leq .01$ *** $p \leq .001$. Estimation controls for all pre-test observed characteristics presented at table 2.

6.2 Heterogeneity analysis

Table 5 Panel A presents the sub-group heterogeneity analysis for the top (75th percentile) and bottom (25th percentile) performers in financial literacy. As far as the pre-test score sub-groups, students with the lowest financial literacy showed the highest effect sizes, which were significant differences of the ATEs from higher financial literacy students for the treatment Myopia 1 and 2 groups, which contributes to the argument that financial education courses can help financial illiterate students. Although the incremental difference was not analysed here (i.e., comparing the effects from the table horizontally), the different magnitude of the effects across different treatments can be compared. Considering the lowest quartile of financial literacy, Traditional Financial Education and Myopia 1 had very similar levels of treatment effect, while Myopia 2 had a considerable higher ATE. In the high financial literacy case, the pattern is similar to what was observed in table 3, with the size of Myopia 1's ATE being the lowest and Myopia 2's effect being the highest (but still similar to Traditional Financial Education effect-size).

Older students also showed higher effect sizes, which was significantly different for the case of the treatment Traditional Financial Education coefficient. This supports the idea that older students could get the most of financial education courses, since they already have more contact with financial matters, seeing thus the importance of the topic. Considering the horizontal comparison, while treatment Myopia 2 still has the highest effect size to both younger and older students, Traditional Financial Education had the lowest ATE for younger students while the lowest observed ATE for older students was from treatment

Myopia 1. Besides, for younger students, both Traditional Financial Education and Myopia 1 ATEs were not significant.

Table 5: Heterogeneity analysis – financial literacy post-test score as outcome.

	Treatment Trad. Fin. Educ.	Treatment Myopia 1	Treatment Myopia 2	N
Panel A: Financial literacy post-test score as outcome				
Financial literacy				
Low (25th percentile)	0.981***	0.930***	1.361***	206
	(0.246)	(0.146)	(0.118)	
High (75th percentile)	0.425*	0.263*	0.468***	215
	(0.179)	(0.103)	(0.100)	
p-value (difference)	0.092	0.001	0.000	
Age				
14-16	0.002	0.159	0.478***	408
	(0.155)	(0.169)	(0.120)	
17-18	0.596***	0.321*	0.722***	406
	(0.145)	(0.136)	(0.165)	
p-value (difference)	0.005	0.418	0.210	
Sex				
Male	0.443	0.145	0.576***	388
	(0.246)	(0.154)	(0.121)	
Female	0.528*	0.517***	0.730***	426
	(0.212)	(0.083)	(0.109)	
p-value (difference)	0.821	0.026	0.443	
Panel B: Myopia post-test score as outcome				
Myopia				
Low (25th percentile)	-0.394*	-0.367**	-0.190	241
	(0.189)	(0.108)	(0.150)	
High (75th percentile)	-0.213	-0.406**	-0.500**	330
	(0.220)	(0.220)	(0.220)	
p-value (difference)	0.592	0.855	0.276	
Age				
14-16	-0.053	-0.242**	-0.249	408
	(0.182)	(0.092)	(0.157)	
17-18	-0.384*	-0.598***	-0.473***	406
	(0.195)	(0.154)	(0.097)	
p-value (difference)	0.241	0.034	0.150	
Sex				
Male	-0.303	-0.366**	-0.447***	388
	(0.227)	(0.112)	(0.067)	
Female	-0.199	-0.339**	-0.252	426
	(0.238)	(0.106)	(0.132)	
p-value (difference)	0.804	0.871	0.291	

Note. The estimations come from Mahalanobis Distance Matching using sub-groups, the estimated coefficients are in terms of standard deviations of the outcome variable. The p-values presented correspond to the estimated Wald test for the difference between the coefficients. Clustered standard errors in parentheses. * $p \leq .05$ ** $p \leq .01$ *** $p \leq .001$. Estimation controls for all pre-test observed characteristics presented at table 2 (except when specific sub-group tested).

In terms of gender, we see that, on average, females receive a greater impact from financial education courses than males, being significantly different for the treatment Myopia 1 group. This can be

an effect of a lower financial literacy observed among girls in the literature[6], and by this, they have more to profit from such courses. We see that the ranking pattern of the ATE's order of magnitude is similar to table 3 ranking for both genders. Here all the effect sizes for females are quite similar (above 0.50 sd) and significative at 5%, while the ATEs of Traditional Financial Education and Myopia 1 were not significant for males.

The heterogeneity analysis for myopia as the outcome is seen in Table 5 panel B. The post-test score of myopia did not show a significant difference between the ATEs for any of the course materials, which suggests that even students with an apparent low prevalence of myopia (i.e. low myopia score) can still benefit from better awareness of this bias. This contributes to the behavioural literature by giving additional evidence that even individuals with a small influence of behavioural biases/ can still benefit from debiasing techniques. From a horizontal comparison, two different magnitude patterns are observed. For students with a low prevalence of myopia, shorter courses (i.e. Traditional Financial Education and Myopia 1) had a more significant treatment impact than the longer course (i.e. Myopia 2). For individuals with high myopia, the effect is inverse, the longest course, treatment Myopia 2, had the greatest effect size to improve myopia.

Compared to the heterogeneity analysis for financial literacy seen in table 5 panel A, older students also showed higher ATEs for myopia on panel B (treatment Myopia 1 had significant differences here). Comparing the effect sizes for the same sub-group, the greatest ATE in both cohorts was the treatment Myopia 1 (which was significant for both young and old students). For older students, all treatment groups showed significant effects, but it was greater for both treatments Myopia 1 and 2.

Regarding sex, no significant difference was observed between male and female students. Horizontally, the longer course Myopia 2 had a greater effect among males, while the Myopia 1 course had the highest ATE for females.

6.3 Mediation analysis

The results of the mediation analysis are presented, which tests if behavioural-based financial education was able to improve financial literacy indirectly using the smaller presence of behavioural biases (in this case myopia). Table 6 Panel A presents the mediation analysis for financial literacy as an outcome variable with myopia as the mediation variable. A significant average causal mediated effect (ACME) was observed in all behavioural based education treatments, being 0.07 (to treatment Myopia 2 and the behavioural based financial education) and 0.11 sd (to treatment Myopia 1), which was not observed in the Traditional Financial Education that had a non-significant indirect effect. This provides evidence in favour of the suggested mechanism, in which behavioural based financial education treatments can improve financial literacy also indirectly by means of a smaller prevalence of behavioural biases. All treatment interventions showed significant total effects (between 0.20 and 0.52 sd's). Although treatment Myopia 1 had a non-significant average direct effect (ADE), it showed the greatest proportion of mediated ATE (53%). In Appendix G we show the sensitivity analysis and exogeneity tests used to check the validity of the sequential ignorability identifying assumptions.

[6] A global evaluation of the financial literacy gender gap can be seen in Hasler & Lusardi (2017). In our sample this was also observed considering our pre-test scores: girls had scores that were 0.26 sd lower in comparison to boys.

Table 6: Mediation analysis for financial literacy post-test as outcome with effect mediated by myopia.

	Treatment Trad. Fin. Educ.	**Treatment Myopia 1**	**Treatment Myopia 2**	**Treatment Beh. Based Fin. Educ. (Myopia 1 + 2)**
Panel A: Financial literacy post-test as outcome				
Average Causal Mediated Effect (ACME)	0.036	0.111***	0.067***	0.073***
	(0.025)	(0.025)	(0.021)	(0.016)
Average Direct Effect (ADE)	0.314**	0.093	0.451***	0.238**
	(0.092)	(0.073)	(0.076)	(0.083)
Average Treatment Effect (ATE)	0.350***	0.203**	0.517***	0.311***
	(0.090)	(0.077)	(0.084)	(0.084)
% of ATE Mediated	10.32%	52.87%	13.02%	23.74%
N	210	331	457	696
R^2	0.438	0.426	0.362	0.345
F	278.74	431.40	193.69	80.78
Panel B: Financial knowledge post-test as outcome				
Average Causal Mediated Effect (ACME)	0.027	0.136***	0.060	0.085***
	(0.024)	(0.033)	(0.035)	(0.027)
Average Direct Effect (ADE)	-0.221	-0.267	0.616	0.251
	(0.282)	(0.230)	(0.283)	(0.307)
Average Treatment Effect (ATE)	-0.195	-0.132	0.676	0.337
	(0.281)	(0.243)	(0.284)	(0.304)
% of ATE Mediated	-4.49%	-30.56%	8.58%	16.73%
N	210	331	457	696
R^2	0.274	0.291	0.175	0.179
F	83.8	54.82	11.01	15.26
Panel C: Financial behaviour post-test as outcome				
Average Causal Mediated Effect (ACME)	0.052	0.121***	0.075***	0.075***
	(0.042)	(0.355)	(0.025)	(0.019)
Average Direct Effect (ADE)	0.682**	0.090	0.099	0.033
	(0.216)	(0.112)	(0.171)	(0.155)
Average Treatment Effect (ATE)	0.735***	0.212	0.174	0.108
	(0.219)	(0.126)	(0.180)	(0.160)
% of ATE Mediated	7.07%	48.15%	23.02%	26.40%
N	210	331	457	696
R^2	0.277	0.233	0.217	0.189
F	650.15	103.83	39.56	40.00
Panel D: Financial attitude post-test as outcome				
Average Causal Mediated Effect (ACME)	0.029	0.075**	0.066**	0.059***
	(0.027)	(0.031)	(0.026)	(0.190)
Average Direct Effect (ADE)	0.510***	0.116	0.629***	0.420***
	(0.146)	(0.138)	(0.109)	(0.113)
Average Treatment Effect (ATE)	0.538***	0.190	0.696***	0.479***
	(0.139)	(0.133)	(0.121)	(0.116)
% of ATE Mediated	5.29%	29.40%	9.55%	12.32%
N	210	331	457	696
R^2	0.291	0.243	0.228	0.212
F	166.38	127.01	332.94	89.29

Note: The results show direct and indirect effects estimated by mediation analysis using the algorithm proposed by Imai et al. (2010). Standard errors obtained by quasi-Bayesian Monte Carlo using Hicks & Tingley (2011) implementation. * $p \leq .05$ ** $p \leq .01$ *** $p \leq .001$. Estimation controls for all pre-test observed characteristics presented at table 2.

In tables 6 Panel B to D the mediation analysis for each of the components of our financial literacy score is presented (i.e. financial knowledge, behaviour and attitude). With the exception of the Myopia 2 treatment in the financial knowledge estimation, all other behavioural based treatments showed significant ACME in all three elements of financial literacy, which was not observed in the Traditional

Financial Education treatment. A possible reason can be linked to short term preference, which is part of the concepts of both financial literacy and myopia. By this, teaching short-term preference would increase financial literacy in a more direct than indirect way (although the direct effect of Myopia 2 was also not significant due to big standard errors, the point estimate was 0.62, with the total effect being mediated by ACME by less than 9%). Moreover, the direct and total effects on financial knowledge seemed to be not significant in all cases.

Interestingly, the only significant total effect on financial behaviour was observed in the Traditional Financial Education treatment. This suggests that, although the myopia treatments showed a significant mediated effect on financial behaviour, the extra effort to increase awareness of myopia made students less aware of situations in which the myopic bias does not play a role.

7. Discussion

This paper presented a novel mechanism to improve financial literacy: a behavioural-based financial education. The suggested mechanism provides both a direct effect of financial education on financial literacy and also an indirect effect mediated through the mitigation of behavioural biases. Behavioural-based financial education is motivated by the growing importance of behavioural bias to financial literacy (García, 2013; Jonsson et al., 2017; Pitthan & De Witte, 2021) and by the lack of causal chain found in the literature from financial education to long-lasting financial literacy improvements and changes in society (Willis, 2011). The mechanism is tested through a randomized controlled trial with a control group and three gradually more exposed treatment groups. Group 1 'Traditional' received the basic version of the material, with only financial education components, and without learning about behavioural biases; Group 'Myopia 1' received additional content related to the underestimation of risks observed in individuals with myopic bias; Group 'Myopia 2' obtained additionally materials to increase awareness of the short-term preference from myopic individuals. The experiment was applied to 814 students in 42 secondary schools in the Flemish region of Belgium. The treatment effects were tested using OLS and Mahalanobis Distance Matching (MDM) regressions, also testing for Lee's (2009) bounds to account for the difference in attrition. To test for the behavioural mechanism of financial education, we used mediation analysis (Imai et al., 2010).

The results indicate that the students who received the treatment had better financial literacy scores while decreasing their previous myopic bias level. Besides, the evidence of the existence of the behavioural-bias mediated mechanism to improve financial literacy is observed, since the courses which received material about the myopic bias had significant indirect effects on financial literacy mediated by the mitigation of myopia, which was not observed in Traditional Financial Education courses. The course material managed to improve the financial literacy score of students, increasing up to 0.67 standard deviations (sd) compared to a control group that did not receive financial literacy courses. Since the largest effects were observed in the treatment group 'Myopia 2', it suggests that course components with behavioural-based applications are beneficial to financial literacy. Further research is needed to detail the effect of courses that teach about behavioural biases in real-life financial decisions.

Moreover, all the treatments had significant effect sizes on myopia test scores, ranging from 0.25 up to 0.39 sd. This gives us evidence that course materials that teach about behavioural biases can be

helpful to increase awareness of the pitfalls caused by those biases and to decrease the hurtful effect of them. All treatment groups managed to increase the knowledge of the course, based on academic learning objectives for financial education. The average treatment effect ranged from 0.54 to 0.84 sd, with treatments that included myopia materials having larger effects. Again, this suggests that course materials with behavioural components might be effective in teaching important learning objectives, such as learning about different financial concepts and products.

The heterogeneity analysis indicates that students with smaller pre-test scores experienced larger effects to financial in comparison to students with high pre-test scores, which was not observed by using myopia as an outcome variable. Older students showed, on average, higher effects using both financial literacy and myopia as an outcome for at least one of the experimental groups. In terms of sex, only for the case of financial literacy did female students experienced larger effect sizes.

The causal mediation analysis supports the hypothesis of an indirect mechanism for financial education mediated by better awareness of behavioural biases. The average causal mediated effect (ACME) to financial literacy mediated by mitigated myopia was significant under a causal counterfactual approach (Imai et al., 2010) for the behavioural-based courses, with estimated effects between 0.07 and 0.11 sd. We have also estimated ACMEs for the different elements of our financial literacy score (i.e. financial knowledge, behaviour and attitude), having for the most part significant coefficients between 0.06 and 0.14 sd. Although the indirect effect sizes were smaller in comparison to the direct effects, they still shed light on the importance of new mechanisms of financial education, which can help to fortify its causal link with financial literacy. The identification of average causal estimates for mediation depends on two assumptions of sequential ignorability, with the RCT only meeting the first assumption. Since the second assumption (i.e., of statistical independency between the mediator and outcome variables) is particularly strong and hardly testable, our mediation analysis results should be taken with caution, even considering our sensitivity analysis and proxy tests for exogeneity. New research is still needed to verify the effect of this and other mechanisms on financial decisions and outcomes, alongside the use of other possible behavioural biases as mediators. Even though not tested in this paper, the mechanism of behavioural-based courses can also have an indirect effect on financial decisions. Since biases are known to affect decision-making negatively (Duxbury, 2015), courses that help to reduce those negative effects could have an additional causal link to better financial decisions, and, with this, better financial outcomes.

The results have important policy implications. First, it was showed that even short financial education programs with computer-assisted elements can be beneficial to reaching learning outcomes, improving financial literacy and behaviour. Second, course materials that include behavioural components applied to financial concepts (e.g., explicitly showing the cognitive pitfalls of automatic thought process students are having) can not only be good to increase awareness of certain behavioural biases but also to indirectly improve financial literacy with this. Additionally, since students with more experience and prior knowledge of financial matters appear to get the most of financial education, programs should be aimed at older students and young adults, with programs being also applied to university students or professionals. Finally, policies that track students' financial outcomes across time can be beneficial to analyse long-lasting effects of financial education programs on future financial decisions and outcomes of students.

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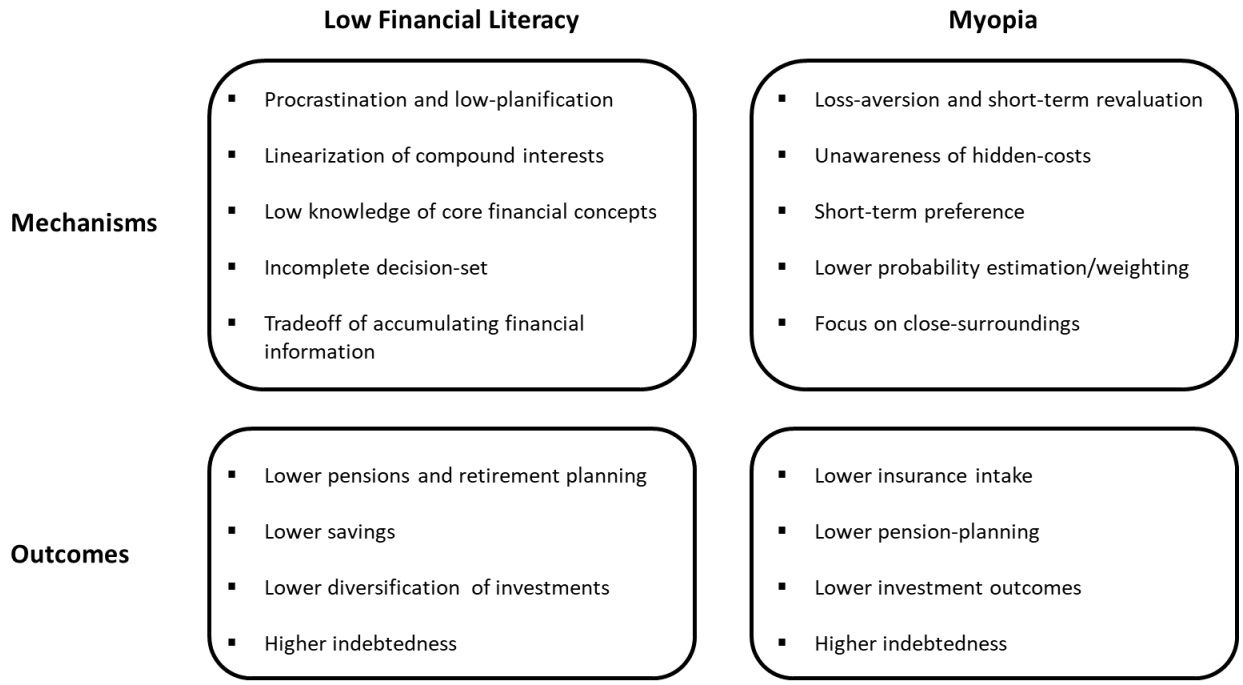
Appendix A: Mechanisms of low financial literacy and myopia.

Figure A1 shows a non-exhaustive overview of the mechanisms and outcomes of low financial literacy and myopia. Among the different mechanisms of financial illiteracy, we can cite the procrastination and low-planification of financial matters without immediate return, which can be linked with the short-term preference of individuals (Lusardi & Mitchell, 2007; Gamst-Klaussen et al., 2019). But sometimes the problem is beyond an individual's temporal preference or procrastination. Song (2020) illustrates this with the linearization of compound interests that many financial illiterate people do, leading them, for instance, to not observe the full possible return of an investment in the long-run. Alongside this problem, low knowledge of core financial concepts (e.g., risks, returns, liquidity, opportunity cost) is another source of sub-optimal decision-making (Pang, 2010), making a comparison of alternatives and maximization of expected value harder. Not only financial concepts can be in the way, but also the growing number and growing complexity of financial products (Lusardi, 2019), which leads financial illiterate individuals to have observed decision set which is incomplete and might lead to worst financial well-being (i.e., they might not know that their optimal financial product exits or they might not understand it properly). Jappelli & Padula (2013) note the high cost financial illiterate individuals put into acquiring new information about financial products and concepts, which also pressures their incomplete decision set to continue to be incomplete.

Figure A1: Overview of mechanisms and outcomes of low financial literacy and myopia.



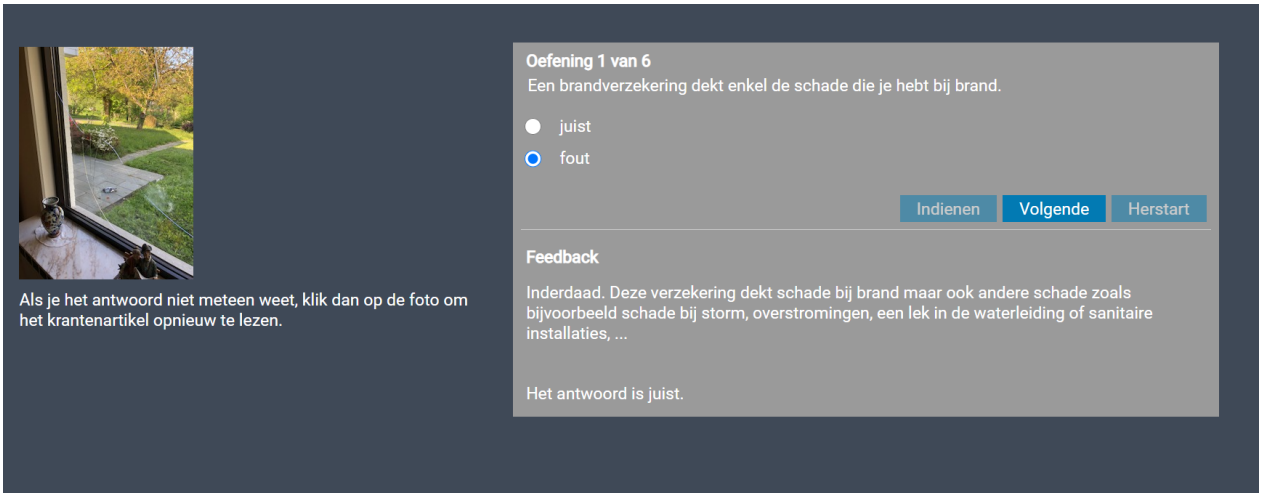
But besides financial illiteracy, behavioural biases can also play an important role in people's decision-making, usually linked with poorer decisions and outcomes (DeLiema et al., 2020). it is also noted the growing importance of biases and heuristics to financial literacy itself, since they can limit the relevance of new financial information (García, 2013); and that even well-educated people or financial professionals can be affected by them (Rzeszutek & Szyszka, 2020). Although higher degrees of financial literacy can be associated with being less affected by biases, Baker et al. (2019) shows that this can depend on the bias, for instance, the mental accounting bias was positively related to higher financial literacy, and few biases such as overconfidence and affection were found to be independent of financial literacy, this would indicate that regular financial literacy measures might not be enough to overcome some biases, which could need more focus on such behavioural aspects.

Among the different behavioural biases, myopia also has particular mechanisms that affect financial decision-making. Benartzi & Thaler (1995) show myopia in the context of loss-aversion and mental accounting: most individuals have an inherent dislike towards losses, which together with the constant revaluation of return performance in the short-run lead individuals to prefer less risky investment alternatives. Myopic individuals tend to be unaware of the hidden costs or "add-on" prices of products, attributing high adjustment costs to see the full price of a particular product (Gabaix & Laibson, 2006). De Donder & Leroux (2013) also link myopia with short-term preference, lower probability estimation (i.e. attribution of lower probability to a particular risk) and lower probability weighting (i.e. in the context of cumulative prospect theory, giving less importance of risk in one's decision-making). The myopia mechanisms are also influenced by proximity, with more importance given to information about one's closed surroundings or received by trusted individuals in one's inner personal circle (Maskell & Malmberg, 2007).

Appendix B: Examples of the course material.

In this section, a few examples of the material received by students are given. In figure 1B, one of the interactive questions of the game is shown that is presented in all treatment groups. Here students are asked (after reading an article about insurance) if fire insurance provides protection only against fire. Upon an answer, the student receives feedback and can re-read the article in case of doubts. The basic version of the course (i.e. with only the Traditional Financial Education materials) later presented games of insurance (travel, health, fire and third-party), pensions (estimation of retirement pensions, decision to save for pension), investments (multiple investment products, game of investment decisions), and a concluding life path game (students were asked to make interactive decisions of insurance, pensions and investments, with different consequences and outcomes).

Figure 1B: Example of interactive question of the Path of Live gamified course material.



Students in the treatment groups that included the behavioural component of myopia (i.e. Treatment Myopia 1 and 2) received additional materials. Figure 2B shows the introduction that students in those two treatment groups received about the myopic bias, explaining the pitfalls of myopia regarding short-term preference, underweighting of risks and unawareness. After this introduction, the Treatment Myopia 1 group did a game about multiple risks, how different they can be, how risks can grow over time and an example with accidents during a ski travel. Besides those games, the Treatment Myopia 2 group also watched videos on the reasons to invest and played games of how different interests work and of risk trade-offs during investments.

Figure 2B: Example of interactive question of the Path of Live gamified course material.

Appendix C: Consistency of questions and construction of scores

This section details the methodological process to check for the consistency of the questions and build the scores used as an outcome variable in this study. The consistency analysis was used as one of the criteria to decide over question selection and scores construction, since our goal was to have short and comprehensive enough tests while maintaining consistency, in order not to increase the attrition (Galesic & Bosnjak, 2009). Item response theory (to check for question difficulty, assuming discrimination constant), Cronbach's alpha (to check for how the score overall consistency changed by the inclusion/exclusion of questions), factor analysis (to analyse the significance of factor loadings of questions for factors with an eigenvalue above 1) and point-biserial correlation (to check individual item consistency in comparison to the score) were used to help in the decision of inclusion or exclusion of questions. Those methods were applied to the pre and post-test scores of myopia and financial literacy.

The consistency analysis of the surveys was not the only factor of the decision to include the variables. The main focus was to build relatively short surveys that could measure a number of different abilities related to each outcome variable. Those different abilities tested in each score survey and the relatively small number of questions could indeed decrease the consistency of the questions but was done to increase the response rate. Galesic & Bosnjak (2009) and Fan & Yan (2010) demonstrate that attrition and drop-out rates can grow by the length of computer-based questionnaires.

C.1. Myopia score

The myopic score's questions aimed to measure different components of the myopic bias, meaning the underestimation of risks (by asking a question about the risk of events, and how this risk could grow over time), short-time preference (with questions over intertemporal decisions) and the unawareness or inattention of important matters (i.e., related to decisions with blurred lines on a contract, or hidden information not presented in the headlines of a marketing campaign). The pre-test score had originally 9 questions, with the post-test having 12.

Figure C1: Item response theory characteristic curves – myopia score questions.

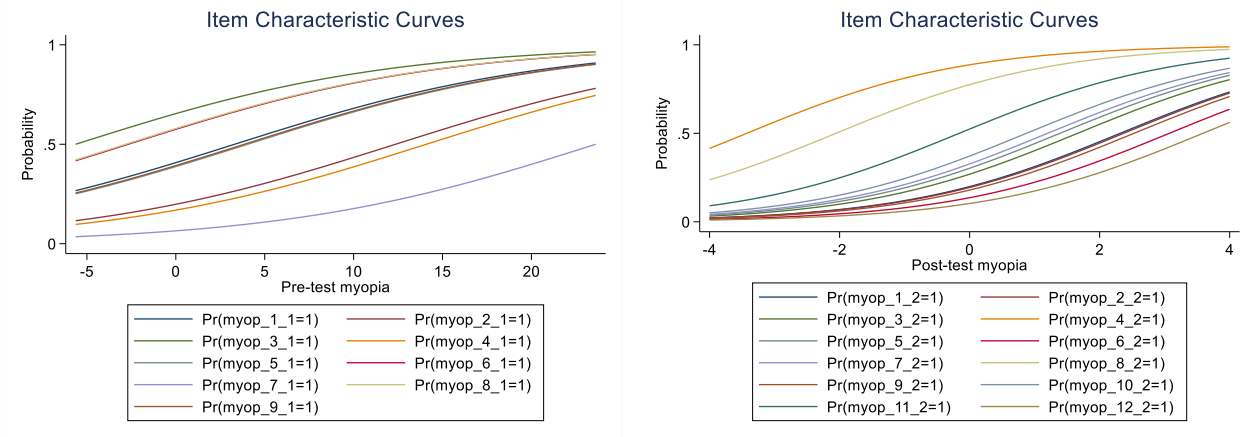


Figure C1 shows the item response theory characteristic curves for the pre and post-test myopia scores. Since having a "right" question in the myopia survey is associated with a higher myopic bias, "easier" questions in terms of item response theory is difficult (i.e., questions when only a few people did not show a myopic behaviour), with the same analogy for the "difficult" questions. For the pre-test questions, 65% showed a myopic behaviour in question 3 (i.e., students made a wrong estimation about the risk of a ski accident), and most students showed no myopic behaviour in question 7 (i.e., students identified a suspicious investment opportunity with blurred lines), question 4 (i.e., what is the risk of a house fire) and question 2 (i.e., on the reasons why not to buy fire insurance), with 7%, 17% and 20% respectively. For the post-test questions, the "easiest" question (i.e., with higher myopic behaviour) was question 4 (i.e., most students would only invest unrealistically small sums of the number to obtain 1200 euros after one year) with 87% of biased answers. On the other hand, questions 12 (i.e., similar to question 7 in pre-test) and 6 (i.e., students estimated well the risk of needing medical help for an accident in the kitchen) had low levels of myopic answers, 12% and 15%.

To evaluate if a factor analysis was appropriate, it was tested if the questions were intercorrelated and checked the sample adequacy with the Kaiser-Meyer-Olkin measure (Kaiser, 1970), which require a value of at least 0.50 (Glorfeld, 1995). All factors with eigenvalues above 1 (Kaiser, 1960), and factor loadings above |0.30| were considered as being important (Hair et al., 1998; Peterson, 2000). For both the pre and post-tests the hypothesis of the non-intercorrelated question was rejected, and the Kaiser-Meyer-Olkin was above the 0.50 cut-off. For the factor analysis, the pre-test questions had 4 factors with eigenvalues above 1, while post-test questions had 5. All the questions had factor loadings above 0.30 in absolute value in at least one factor.

For consistency analysis, point-biserial correlation and Cronbach's alpha[7] was considered. Point-biserial correlation of each question with the whole score found all questions rejecting the null of non-correlation. Considering all questions in the pre-test, Cronbach's alpha was 14%, decreasing with the exclusion of other questions. For the post-test, the original alpha was 0.50% and increased to 53% when questions 4 and 6 were excluded. By the results of the analysis, questions 2 and 7 of the pre-test, besides questions 4 and 6 of the post-test were not considered for the composition of the final scores.

C.2. Financial literacy score

Since financial literacy is a measure that is influenced not only by financial knowledge but by financial attitude and behaviour as well, those three different abilities were tested in the questions. The pre-test had 5 questions of financial knowledge, 3 on financial behaviour and 5 on financial attitude, while the post-test had 6 for financial knowledge, 3 for financial behaviour and 3 for financial attitude.

[7] For the myopia pre-test, question 2 was not answered by all subjects (it was dependent of a certain answer in question 1). By this, the Cronbach's alpha was not identified with the inclusion of question 2, by this it was not included.

Figure C2: Item response theory characteristic curves – financial literacy score questions.

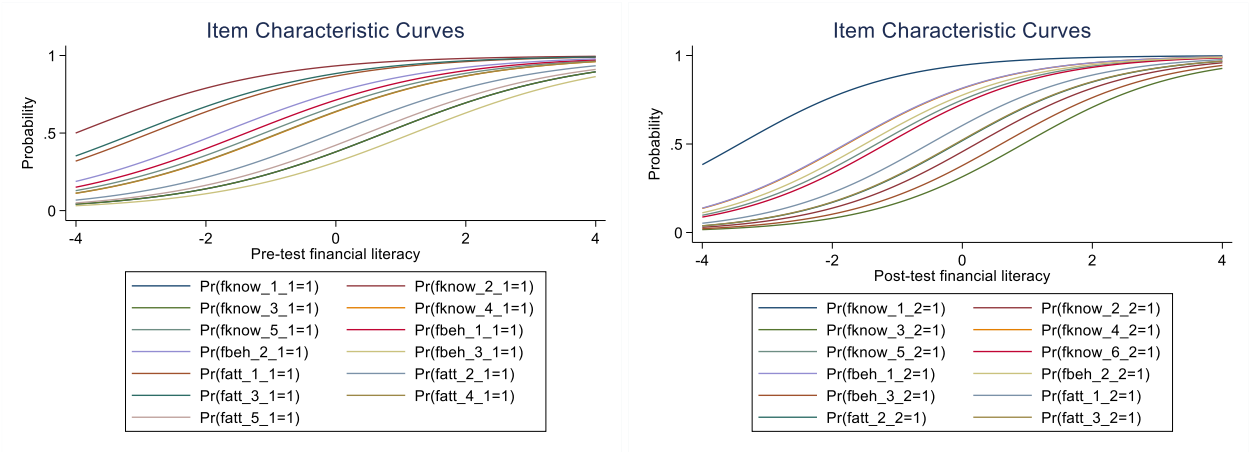


Figure C2 shows the item response characteristic curves for both the pre and post-test questions. Considering the pre-test, most students gave the right answer to the financial knowledge question 2 (i.e. about the interest over a loan), financial attitude question 1 (i.e. if found financial knowledge important) and financial attitude question 3 (i.e. if found important to save part of allowance), with 92%, 85% and 87% correct answers respectively. For the post-tests, only question financial knowledge 1 (i.e. similar to financial question 2 of pre-test) was considerably easier than the others, with 93% right answers.

The hypothesis of the non-intercorrelated question was rejected, with Kaiser-Meyer-Olkin measures above the 0.50 cut-off for both the pre and post-test questions. The pre-test of the financial literacy questions had 5 factors with eigenvalues above 1, while the post-test had 4. All questions had factor loadings above |0.30| for at least one factor.

In the point-biserial correlation analysis, all questions reject the null of non-correlation with the score for both the pre and post-tests. Question financial knowledge 2 of the pre-test and financial knowledge 1 of the post-test, although having rejected the null, had point-biserial correlations below 0.20. By the exclusion of question financial knowledge 2, the Cronbach's alpha of the pre-test increases from 51% to 53%. In the post-test, the alpha is increased from 58% to 59% by the exclusion of financial knowledge question1. The analysis led us to decide for the exclusion of questions financial knowledge 2 in the pre-test and financial knowledge 1 in the post-test for the final scores.

Appendix D: Causal mediation analysis

Although commonly used in the literature, the Baron & Kenny (1986) approach to mediation analysis using the product of coefficients in structured equation models has no causal interpretation without the strong (but usually implicit) assumption of no variation and is not generalized to non-linear forms (Imai et al., 2010). Therefore, the mediation analysis here applied was counterfactual-based (Imai et al., 2010), with recent applications to financial education (Carpena & Zia, 2020). Causal mediation analysis is worried about the division of average treatment effects into direct and indirect components, requiring the fulfilment of two sequential ignorability assumptions for their identification. We define first the average direct effect (ADE):

(5) $$ADE(d) = E[Y_i(d=1), M_i(d)] - E[Y_i(d=0), M_i(d)]$$

Where Y_i is the potential[8] outcome of the financial literacy post-test score, d is the treatment status, and M_i is the potential value of the mediator variable (in our case the post-test score of myopic bias) for individual i. This is evaluated by setting d to either the traditional or behavioural-based financial education in the first outcome term, subtracting the second outcome term when $d = 0$ (i.e. the control condition when no treatment was performed), for the mediator variable d is kept constant. $ADE(d)$ can be though as the effect to Y_i due only to a change in the person's treatment status, holding the potential value of the mediator variable constant. Then, we define the average causal mediation effect (ACME), the indirect effect component:

(6) $$ACME(d) = E[Y_i(d), M_i(d=1)] - E[Y_i(d), M_i(d=0)]$$

Here the expectation is evaluated by holding d constant for the Y outcome, as such $ACME(d)$ will change in value only as a function of the myopic score (i.e. either at its level when one of the treatments was received with $d = 1$, or without treatment when $d = 0$). For the estimation and implementation, we follow the algorithm from Imai et al. (2010) using a parametric form to predict $Y(d, M, X)$ and $M(d, X)$ with standard errors obtained by a quasi-Bayesian Monte Carlo implemented by Hicks & Tingley (2011), where X is the set of all confounders (pre-treatment scores and characteristics at school and pupil levels). Although the counterfactual-based mediation analysis does not set a specific functional form nor has a linearity assumption (e.g. it can be estimated by non-parametric or *logit* models), a linear model is used to help with interpretation and to be comparable with the other results (the same models showed in the methodology section):

(3) $$M_i^1(d, X) = \alpha + \beta_{13} d_s + \beta_{14} X_{i,s} + \epsilon_{3,i,s}$$

(4) $$y_{i,s}^1(d, M, X) = \alpha + \beta_{15} d_s + \beta_{16} M_i^1 + \beta_{17} X_{i,s} + \epsilon_{4,i,s}$$

As noted by Carpena & Zia (2020), $ACME$ can be estimated by $\widehat{\beta_{13}}.\widehat{\beta_{16}}$ and ADE from $\widehat{\beta_{16}}$ following equations (3) and (4) above. Since the counterfactuals are not observed, the sequential ignorability assumptions are needed to identify the average causal effects (Imai et al., 2010). First, it is needed that the treatment assignment must be statistically independent of potential outcomes and potential mediators given observed pre-treatment confounders. Second, the mediator must be statistically

[8] Potential in the terms of counterfactuals, i.e. the value it would have obtained in case of a particular treatment or absence of it.

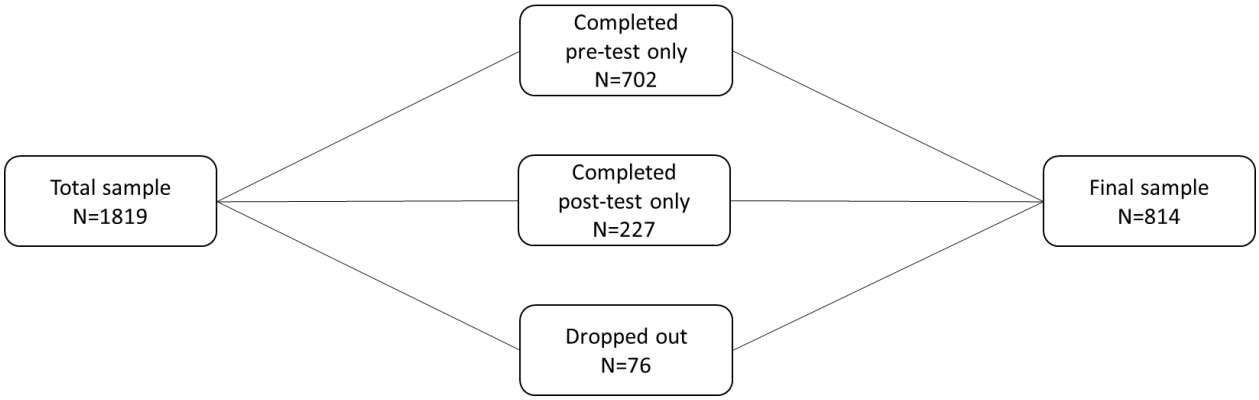
independent of the potential outcome given the treatment assignment and pre-treatment confounders. The two assumptions also imply assumption (iv) from Valeri & Vanderweele (2013), that it is violated if descendant variables of the treatment are included as confounders. From Theorems 2 and 6, together with Corollary 1 of Pearl (2001), the effects can be identifiable with conditional unconfoundedness (i.e. if assumptions are met when controlled by non-descendent covariates). Following Valeri & Vanderweele (2013), the random assignment of treatment conditions can directly satisfy the first assumption. As noted by Imai et al. (2010), the second assumption is particularly strong and not easily testable. This could be easily violated by the presence of non-observed variables that affect both the mediator and the outcome variables, for instance, risk aversion (as in the case of Carpena & Zia, 2020 for financial literacy and behaviour) and time preference could potentially affect both myopia and financial literacy levels. For this, we perform sensitivity analysis of different degrees of the violation of this assumption by assuming different levels of correlation ρ between errors $\epsilon_{3,i,s}$ and $\epsilon_{4,i,s}$ of equations (3) and (4). Besides, to serve as proxy testing[9] of statistical independence we use three methods to test for endogeneity: testing the 0 correlation between the residuals of the estimated myopia and estimated financial literacy in equations (3) and (4) using Z-tests with bootstrapped confidence intervals (Cox, 2008); testing the significance of the residual of the estimated myopia from equation (3) as a variable in the augmented regression for financial literacy in equation (4) (Antonakis et al., 2014); and using the Wooldridge's (1995) endogeneity test in a two-stage least squares estimation with robust standard errors.

[9] Since actual errors are unobserved and we can only estimate the residuals.

Appendix E: Attrition and sample representativeness

In this section, the attrition in the experiment is explored. Figure E1 shows a visualisation of the experiment attrition. From an original sample of 1819 students, different causes led of attrition led to the final sample of 814 students, which was used in the analysis. Of the 1005 observations not used, 929 observations were of students that did not complete one of the tests, with the majority of those coming from students that only completed the pre-test (702). This can be due to the small incentive of teachers to enforce the completion of the post-test after application of the course material on class, since one of the main incentives behind the participation of the schools was to have readily available course materials[10]. Although teachers that successfully enforced completion of the post-tests could win prizes (i.e. complying teachers entered in a raffle to obtain gift cards of well-known magazines in Belgium), this incentive seemed insufficient. The students that completed only the post-test (227) can be linked with teachers which did not manage to enforce all their students to do the pre-test but made a bigger effort during the realization of post-tests. Additionally, 76 students started both pre and post-tests but dropped out in the middle. This can be linked to the length of the surveys or the low incentive of students to finish them, although students could also win prizes (i.e. a raffle to win Netflix and Spotify subscriptions).

Figure E1: Visualisation of attrition



In Table E1 to relate the observed attrition rates across the different experimental conditions, an OLS model was run. This model was fit to observe if attrition is different among the treatment groups. With the coefficients for the treatment Traditional Financial Education and the treatment Myopia 1 and 2 variables being significant at 0.1% level, this gives a hint that there indeed exists differences in attrition between the groups. All treatment groups had similar negative coefficients, suggesting that the three groups had a smaller proportion of attrition in comparison to the control condition. Those differences in attrition are one of the motivations of the methods used in the results section: Mahalanobis Distance Matching and Lee's Bounds (besides the inclusion of control variables with imbalance).

[10] Since financial education is a relatively recent class in Flemish curricula, teachers still struggle to find new materials to apply to their students.

Table E1: OLS model – attrition

Dependent Variable	Attrition
Treatment Trad. Fin. Educ.	-0.324*
	(0.135)
Treatment Myopia 1	-0.348***
	(0.0993)
Treatment Myopia 2	-0.377***
	(0.0866)
Constant	0.813***
	(0.0808)
N	1819
R^2	0.104
F	6.348

To analyse the representativeness of the sample in comparison with Flemish schools, it was compared with the official figures of the Flemish Ministry of Education and Training (2021). The report mentions that 289,000 students were registered in the second and third cycles of regular secondary education, with 72.1% of them studying in private schools (mostly catholic). Relatively to student tracks, 42% of students go to general academic tracks, while 30% go to technical tracks, while the remaining go either to either professional or artistic tracks. Referring to our sample presented in table 2, the numbers are in line with the official figures in terms of the proportion of private schools, but are more concentrated in students of academic tracks.

Appendix F: Estimated effect of the experiment on course knowledge

In this section, tables 3 and 4 results are replicated using the course knowledge as the outcome variable, which evaluates the learning outcomes of the course. It was measured with questions that follow the Flemish secondary education curriculum. Table F1 presents the results for the case of course knowledge as the outcome variable, which measures if students could learn the academic learning goals of the Flemish education system. The ATEs were 0.61, 0.55 and 0.86 sd to the traditional, Myopia 1 and Myopia 2 groups in the case of the OLS column and 0.54, 0.56 and 0.84 sd to the MDM regressions. The results suggest that all different interventions were able to improve the course knowledge of students. The effect sizes were relatively big in Cohen's terms (with the ones for the treatment Myopia 2 being considered large). This can be linked to specific knowledge required by the Flemish education system about financial concepts and products which is studied thoroughly in the courses provided, while students in the control group did not receive anything.

Table F1: Estimated ATEs and Lee bounds – course knowledge as outcome variable.

Specification	OLS	Mahalanobis Matching	Lower Bound	Upper Bound	Trimming proportion
Treatment	0.612**	0.539**	-0.707	0.531	2.2%
Trad. Fin. Educ.	(0.182)	(0.159)	[-1.746, 0.333]	[-0.245, 1.754]	
Treatment	0.549***	0.563***	-1.542	0.284	16.8%
Myopia 1	(0.125)	(0.083)	[-2.414, -0.669]	[-0.466, 1.034]	
Treatment	0.861***	0.840***	-0.781	1.335	15.7%
Myopia 2	(0.156)	(0.141)	[-1.437, -0.126]	[0.573, 2.097]	
N	814	814			
R^2	0.158	0.246	-0.707	0.531	2.2%
F	65.87	65.4			

Note. Lower and upper bounds coefficients are the Lee's (2009) bounds estimations for the required trimming rate in comparison with control conditions. Numbers in brackets are the 95% confidence intervals. The estimations for OLS and Mahalanobis Distance Matching are the estimated coefficients in terms of standard deviations of the outcome variable. Clustered standard errors in parentheses. * $p \leq .05$ ** $p \leq .01$ *** $p \leq .001$. Estimation controls for all pre-test observed characteristics presented at table 2.

In table F2 the estimation of equation (2) using MDM for course knowledge as the outcome variable is presented. It shows that receiving the traditional content improved the score in 0.54 sd, which was not statistically different from the inclusion of other contents. This indicates that all treatment groups managed to increase their awareness of financial concepts and products at a similar level.

Table F2: Estimated incremental ATEs – course knowledge as outcome variable.

Specification	Course Knowledge
Traditional Content (Trad. + Myopia I & II)	0.539**
	(0.159)
Myopia I Content (Myopia I & II)	0.023
	(0.189)
Myopia II Content (Myopia II only)	0.274
	(0.156)
N	814
R^2	0.244
F	57.07

Note. The values are the estimated MDM coefficients in terms of standard deviations of the outcome variable. Clustered standard errors in parentheses. * $p \leq .05$ ** $p \leq .01$ *** $p \leq .001$. Estimation controls for all pre-test observed characteristics presented at table 2.

Appendix G: Sensitivity analysis and exogeneity tests

The identification of the causal effects estimated in section 6.3 requires that the two assumptions of sequential ignorability are filled. Although the random assignment of treatment conditions guarantees that the first assumption of sequential ignorability is met, the second assumption (SI2), which mandates statistical independence between the mediator and outcome variable, is strong and hardly testable. For this reason, in this section 6.4, a sensitivity analysis of different degrees of violation of the hypothesis and a proxy test for exogeneity of the mediator and outcome variables is presented. The sensitivity analysis follows the implementation by Hicks & Tingley (2011), assuming different sizes of the correlation ρ between the errors of equations (4) and (5) testing the impact on the size of the ACME. Although it is not possible to directly test the statistical independence, proxy tests for the exogeneity of the residuals from (4) and (5) is estimated (Cox, 2008; Antonakis et al., 2014; Wooldridge, 1995). This was tested with the behavioural-based financial education treatments (i.e., treatment Myopia 1 and 2 individually and together). Both sensitivity analysis and exogeneity tests were presented using financial literacy as an outcome variable, but separating into its different elements (i.e., financial knowledge, behaviour and attitude) incurred in similar results.

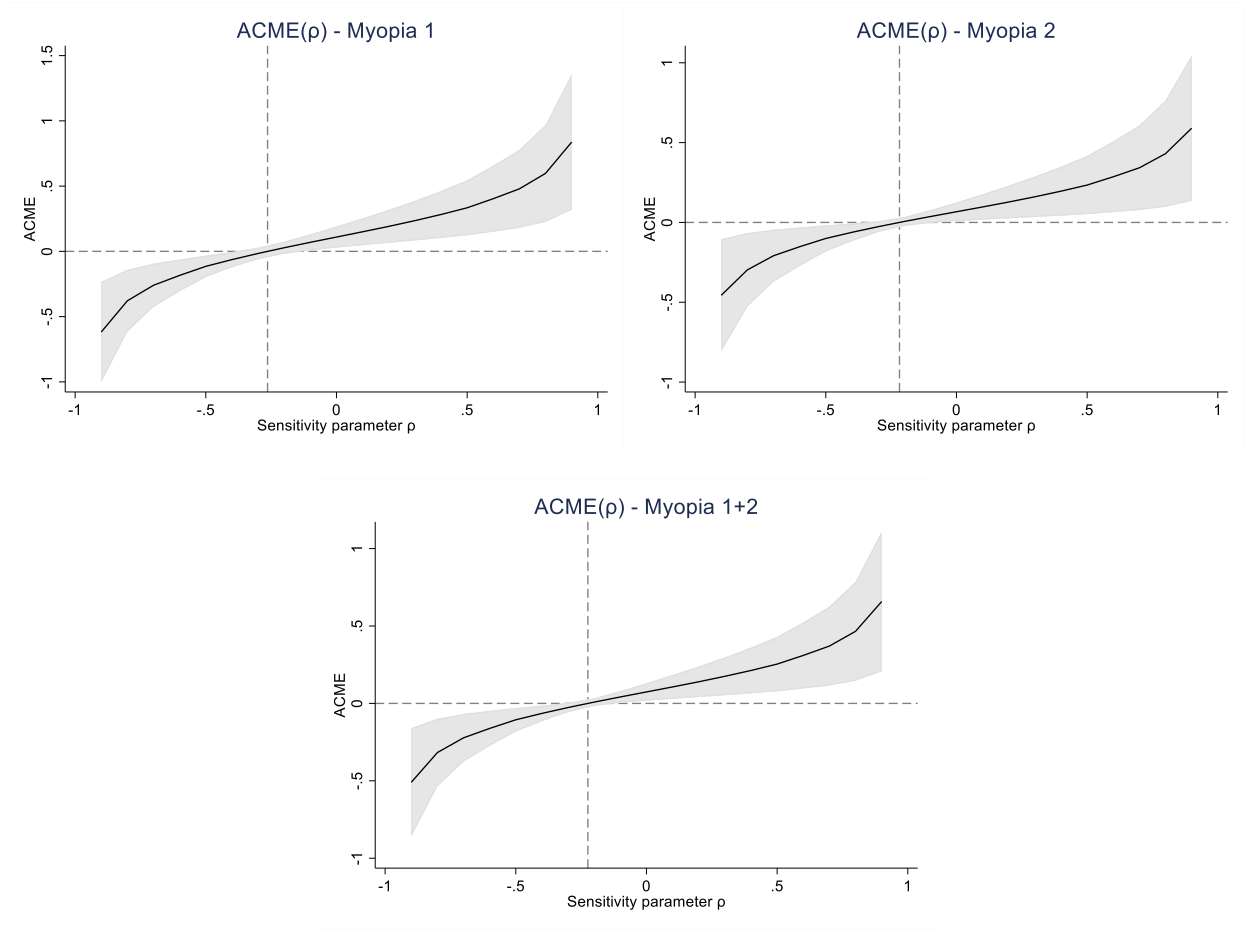
Table G1: Endogeneity tests to check identification of the indirect effect.

	Z-test for correlation between residuals	**Myopia residuals as coefficient in Augmented Regression**	**Wooldridge (1995) Endogeneity test**
Treatment Myopia 1	-0.011	-2.703	1.850
	[-0.080, 0.058]	(4.323)	(p-value = 0.191)
Treatment Myopia 2	-0.035	3.982	2.381
	[-0.103, 0.034]	(13.350)	(p-value = 0.139)
Treatment Myopia 1 + 2	0.003	0.168	0.813
	[-0.065, 0.072]	(4.841)	(p-value = 0.374)

Note: The first column tests the 0 correlation between the residuals of the estimated myopia (equation 3) and estimated financial literacy (equation 4) using Z-tests with bootstrapped confidence intervals at 95% confidence level (Cox, 2008); the next column tests the significance of the residual of the estimated myopia as a variable in the augmented regression for financial literacy (Antonakis et al., 2014), the non-significance of this coefficient in the augmented regression indicates that the unexplained factors of the estimated myopia are not correlated with the unexplained factors of the estimated financial literacy ; the last column refers to the Wooldridge's (1995) endogeneity test in a two stage least squares estimation with robust standard errors, where the first stage is the estimation of myopia and the second stage the estimation of financial literacy.

In figure G1 the sensitivity analysis with different sizes of ρ and respective value of ACME for myopia as a mediator holding everything else constant for financial literacy as the outcome variable is shown. The black line shows the point estimate of ACME for each ρ level, with the grey area representing the 95% confidence interval. The dashed line indicates where in the graph the ACME is equal to zero, which is -0.264, -0.218 and -0.224 for the treatments Myopia 1, Myopia 2 and Myopia 1 together with Myopia 2 respectively. The confidence intervals get larger when the absolute value of ρ gets closer to 1. As noted by the interpretation of Carpena & Zia (2020), the variability of the ACME in figure 5 shows how sensitive our estimates are to changes in ρ. Although the sensitivity analysis has no clear measures to define if SI2 is met, it indicates that our results should be taken carefully.

Figure G1: Sensitivity analysis changing different violation of SI2 assumption for financial literacy as outcome



As a second approach, the estimated proxy exogeneity tests for SI2 are presented, these results can be seen in table G1. In all three tests presented we have a null hypothesis exogeneity between the mediator and the outcome variables. In neither of our three exogeneity tests we reject null. Although the coefficients in the augmented regressions are sizable, since the standard errors are big, they are still insignificant. Although those three tests can suggest the possible exogeneity between the two variables, they are still imperfect measures since the errors are unobservable.

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