Gutenberg School of Management and Economics

& Research Unit “Interdisciplinary Public Policy”

Discussion Paper Series

Teaching Self-Regulation

Daniel Schunk, Eva M. Berger, Henning Hermes, Kirsten Winkel, Ernst Fehr

October 13, 2022

Discussion paper number 2210

Johannes Gutenberg University Mainz
Gutenberg School of Management and Economics
Jakob-Welder-Weg 9
55128 Mainz
Germany
https://wiwi.uni-mainz.de/

Contact details

Daniel Schunk
Chair of Public and Behavioral Economics
Johannes Gutenberg University
Jakob-Welder-Weg 9
55128 Mainz
Germany
daniel.schunk@uni-mainz.de

Eva M. Berger
German Council of Economic Experts
Statistisches Bundesamt
Gustav-Stresemann-Ring 11
65189 Wiesbaden
Germany
eva.berger@uni-mainz.de

Henning Hermes
Düsseldorf Institute for Competition Economics
Heinrich Heine University of Düsseldorf
Universitätsstr. 1
40225 Düsseldorf
Germany
mail@henninghermes.com

Kirsten Winkel
School of Social Sciences
University of Applied Sciences Saarbrücken
Malstatter Straße 17
66117 Saarbrücken
Germany
kirsten.winkel@htwsaar.de

Ernst Fehr
Department of Economics
University of Zurich
Blümlisalpstr. 10
8006 Zürich
Switzerland
ernst.fehr@econ.uzh.ch

Teaching Self-Regulation

Authors: Daniel Schunk[*1†], Eva M. Berger[2†], Henning Hermes[3†], Kirsten Winkel[4†], Ernst Fehr[4]

Affiliations:

[1]Johannes Gutenberg University of Mainz, Mainz, Germany.

[2]German Council of Economic Experts, Wiesbaden, Germany.

[3]Heinrich Heine University of Düsseldorf, Germany.

[4]School of Social Sciences, University of Applied Sciences Saarbrücken, Saarbrücken, Germany.

[5]University of Zurich, Department of Economics, Zurich, Switzerland.

[†]These authors contributed equally to this work.

***Corresponding author**. E-mail: daniel.schunk@uni-mainz.de

Accepted Version
Originally published at:
Schunk, Daniel; Berger, Eva M; Hermes, Henning; Winkel, Kirsten; Fehr, Ernst (2022). Teaching self-regulation. Nature Human Behaviour, 6(12):1680-1690.
DOI: https://doi.org/10.1038/s41562-022-01449-w

Abstract:

Children's self-regulation abilities are key predictors of educational success and other life outcomes such as income and health. However, self-regulation is not a school subject, and knowledge about how to generate lasting improvements in self-regulation and academic achievements with easily scalable, low-cost interventions is still limited. Here we report the results of a randomized controlled field study that integrates a short self-regulation teaching unit based on the concept of mental contrasting with implementation intentions into the school curriculum of first graders. We demonstrate that the treatment increases children's skills in terms of impulse control and self-regulation while also generating lasting improvements in academic skills such as reading and monitoring careless mistakes. Moreover, it has a substantial effect on children's long-term school career by increasing the likelihood of enrolling in an advanced secondary school track three years later. Thus, self-regulation teaching can be integrated into the regular school curriculum at low cost, is easily scalable, and can substantially improve important abilities and children's educational career path.

Introduction

Self-regulation refers to the capacity to regulate attention, emotion, impulses, and behaviour directed at pursuing individually valued goals[1-5]. Children's early self-regulation plays a major role in their school readiness, in their school achievement, and in a range of later life outcomes, such as educational attainment, income and wealth, health, and criminal behaviour[6-13]. In addition, the proliferation of recently developed distance-learning methods greatly increases the demands on children's self-regulation capabilities[14,15] – prompting leading institutions such as the United Nations Educational, Scientific and Cultural Organization to conclude that self-regulation is the key twenty-first-century skill for student success and should thus be primarily promoted[16]. A considerable literature emphasizes that self-regulation and related skills are malleable in children[17-23], especially by use of explicit strategy instruction[24-26], and that influences during early childhood and in younger ages generally play an important role in later skill formation[27-31].

Despite its fundamental importance, self-regulation is not a school subject—such as reading, language, or mathematics—that is directly taught in schools as a regular part of the curriculum. It is at best an implicit part of normal school education that typically lacks a sufficient curricular basis. A key challenge for introducing self-regulation into the curriculum is due to the many other competing demands on scarce teaching time; adding further subjects or replacing valuable teaching time foreseen for other important topics thus entails various direct and indirect costs. Imagine, however, an effective method of teaching self-regulation that does not compete with other uses of teaching time, but which substantially improves learning in other school subjects and thus positively affects children's educational career path. Moreover, suppose that teachers could learn this method in little time by equipping them with appropriate knowledge and materials. Such a method would not only greatly reduce the opportunity cost of improving self-regulation but also enhance the teaching of other school subjects and be easily scalable.

In this article, we propose that a short self-regulation teaching unit consisting of five lessons developed on the basis of mental contrasting with implementation intentions (MCII)" can fit that bill[32-34]. MCII is a metacognitive strategy that addresses goal setting and goal striving as well as overcoming obstacles that prevent individuals from reaching their goals. The general idea underlying MCII is that once individuals set a goal, they imagine the positive consequences of achieving the goal, which enhances goal commitment, but they also contrast the goal with the obstacles that are currently in their way. This constitutes the mental contrasting (MC) part of MCII. Subsequently, MCII requires the identification of concrete behaviours for overcoming the barriers and of forming implementation intentions in the form of "when-then" plans that indicate a concrete self-regulatory action whenever the identified obstacle emerges. This latter part of the strategy—the implementation intention (II) part—is intended to automatize the implementation of behaviours that help overcome the obstacles.

MCII provides a general method for helping individuals achieve desirable goals[32-34]. It has the advantage that it can be applied to a wide range of different goals[35].(MCII shares the property of general applicability to a diverse set of goals with the growth mindset approach[35] and the grit approach[13].) Because these goals can also be directly related to various school subjects, MCII can, in principle, be used to enhance learning in these fields. A potential disadvantage is that it is very hard – and in the opinion of some teachers impossible – to teach the abstract concept of MCII to young children such as first graders. In fact, when we first discussed this concept with the schoolteachers, they were extremely skeptical whether MCII could be applied to first graders because children at that age have very limited abilities to understand general, abstract ideas and their reading and writing abilities are also very limited (for example, they typically do not know all letters of the alphabet yet).

In addition, children at that age are often characterized by limited goal setting skills, patience, attention span, and inhibition skills as well as a lack of perseverance and sense of responsibility for their own learning progress. These limits also constrain them in transferring the method to other tasks and contexts. However, they are at the same time exactly the reason why young children such as first graders would particularly benefit from effective self-regulation strategies.

According to a recent meta study[36], there are no studies where self-regulation based on MCII is taught by the schoolteachers and integrated into the regular school curriculum. Two previous studies recruited sixth- and seventh graders[37] and fifth graders[38], but MCII was provided by trained experts outside of regular classroom teaching in both studies. The first study found that parent-rated self-regulation is higher in treated children two weeks after the intervention. The second study reports that the MCII-treated children have better report card and behavioural grades at the end of the third quarter—during which MCII was implemented—but these effects became small and insignificant in the fourth quarter. Thus, the longer-run effects of MCII on children's academic outcomes and school careers are basically unknown[39] ,and it remains unclear whether MCII can be successfully integrated into the early school curriculum to enhance not only young children's self-regulation skills but also their skills in traditional school subjects such as reading. Here we develop a relatively brief and scalable self-regulation teaching unit based on MCII, delivered by teachers and integrated into the regular school curriculum, and we test whether it can yield sustained benefits in academic outcomes for children in primary school.

To do so, we conducted a randomized field experiment with 572 schoolchildren in 31 first-grade classes in 12 schools in Germany (Supplementary Section 1.1., Supplementary Fig. 1, Supplementary Table 1). In the treatment condition, the children were taught five self-regulation lessons on the basis of MCII. These lessons were spread over five weeks and directly tied to the teaching of skills that are fundamentally important for first graders—practising reading and monitoring own mistakes. The fact that we did not apply MCII to mathematics enables us to examine whether the taught self-regulation skills automatically extend to and improve academic skills in other—untrained—fields as well. The children's regular schoolteachers conducted the self-regulation teaching. It was embedded in everyday classroom activities and introduced to the children as part of their regular curriculum. Therefore, the children perceived it as a natural part of classroom teaching, which makes Hawthorne effects unlikely to occur.

The control group received regular classroom teaching, which consisted of language lessons (reading and writing) and mathematics lessons. Therefore, we can address the question of whether the self-regulation teaching lessons actually yield larger or smaller benefits than using scarce teaching time for the standard curriculum—a question of utmost importance for (educational) policy.

Entire (treatment) classes were taught MCII and the control group classes continued with the standard curriculum, i.e., we randomized at the class level within schools with at least one treatment and one control class per school. This has the advantage that we can control for school fixed effects and that potential within-class peer effects of the self-regulation intervention can play a role. Consider, for example, children who often disturb in class and disrupt their peers. Self-regulation teaching could help improve these children's behavioural control and thus improve their educational performance. In addition, other children in the classroom might also benefit from a quieter classroom environment and thus also improve their educational performance. In essence, our setting allows us to evaluate the total effect of teaching self-regulation in school, including reinforcing peer effects.

In view of the challenges involved in teaching MCII to first graders, we developed five completely scripted school lessons (lasting 50 min each) and a detailed set of materials to address these challenges ((‘Addressing the challenges of teaching MCII to first graders’ in Methods). We

also instructed the teachers in a three-hour workshop how to implement self-regulation teaching in the classroom (Supplementary Section 1.2). Importantly, while teachers were instructed how to conduct the lessons, they were not informed about any specific hypotheses related to the intervention.

To assess the intervention effects, we administered standardized computer-based tests of children's self-regulation abilities as well as their academic abilities in reading and mathematics ('Measuring the effects of self-regulation in teaching' in Methods). The staff that conducted these tests were blind to treatment conditions, and the teachers were neither involved in the tests nor informed about their content nor the test results. In addition, we complemented these tests with teachers' assessments of the children's reading and self-regulation skills. The combination of objective, computer-based tests with teachers' ratings also enables us to check the credibility and validity of the teachers' ratings. To learn about the dynamic effect of the intervention, the outcome evaluations were carried out in four waves extending over the course of more than one year: prior to treatment (t_0), 4–5 weeks after the treatment (t_1), 6 months after treatment (t_2) and 12–13 months after treatment (t_3). All objective tests were adapted to the children's age. Furthermore, in a three-year follow-up, we collected information about the children's secondary school track enrolment. The choice of secondary school track is a high-stakes educational decision in Germany, as it strongly predicts the likelihood of later enrolment at a university/college. It is therefore of direct relevance to adult labour market outcomes. If self-regulation teaching improves key skills, the trained children may have a higher propensity to move into an advanced school track in secondary school (college preparatory, referred to as *Gymnasium* in German).

What should we expect regarding the effects of the self-regulation teaching unit? Effects may not occur directly after the teaching unit because it takes time for the children to internalize the strategy, to apply it repeatedly to different contexts, to learn from the feedback that they receive and to get more proficient in using it. Therefore, we conjectured that the outcome measures in t_1 (assessed 4–5 weeks after the teaching unit) may not yet show clearly visible treatment effects.

In terms of outcome categories, we expected that if MCII teaching generates treatment effects, these effects are more likely to show up in domains to which MCII has been directly applied—reading skills and the ability to find careless mistakes (outcome category 1). We also conjectured that it might enable the children to better inhibit prepotent impulses and improve their self-regulatory classroom behaviours (outcome category 2). This conjecture follows from the fact that MCII represents a self-regulation strategy that requires the children to approach goal implementation in a systematic manner by overcoming obstacles that often come in the form of strong temptations. In contrast, we were considerably more pessimistic about the children's ability to automatically generalize and extend the strategy to other academic subjects or other domains. It is, perhaps, too much to expect first graders to already have the cognitive capacity for abstract thinking and generalization that these automatic extensions to other academic domains require.

With regard to the impact of MCII teaching on children's longer-run school career path, we remained entirely agnostic. In this context, it is important to keep in mind that previous studies on MCII teaching in schoolchildren only reported very short-run effects[37] or effects that vanished in the next school quarter[38]. Thus, showing a sustained effect of the teaching unit after 6 months (t_2) and after 12-13 months (t_3) goes already considerably beyond the previously available evidence. While it is definitely possible that a short-run intervention like ours triggers a process that benefits the children several years after the teaching unit, it is also entirely possible that the benefits deteriorate and vanish.

Results

Randomization and sample balance

The randomization into treatment and control group led to a balanced sample, as documented in tests for differences between treatment and control group conducted by regressing various socio-demographic background variables measured at baseline (t_0) on the treatment dummy (Supplementary Table 2). Similarly, we test for imbalances in our outcome measures before treatment (Supplementary Table 3). Overall, there is no evidence for imbalances between treatment and control group beyond differences caused by chance; moreover, we control for any residual non-significant imbalances in our econometric analyses by controlling for the children's baseline characteristics (see Supplementary Section 1.5 for more details).

Main Results

The following results are based on ordinary least squares regressions that regress the respective outcomes (for example, reading abilities displayed in the reading test) at three different points in time—at t_1 (4–5 weeks after the treatment), t_2 (6 months after the treatment), and t_3 (12–13 months after the treatment) —on a treatment dummy and control variables. As we stratified our randomization on the school level, we include school fixed effects. Doing so removes noise that is due to school facilities or social background differences between schools. To increase the precision of the estimated treatment effect, we also include the respective baseline outcome score (measured before treatment at t_0) in each regression as a control variable (Supplementary Section 1.5). It has been shown that this method provides more precise results than the difference-in-differences estimators that compare the outcome changes from pre- to post-teaching measures between treatment and control groups[40,41]. We allow for interdependence of observations within classrooms by clustering the standard errors at the classroom level, and we also report *P* values that are adjusted for multiple hypothesis testing (Supplementary Section 1.5). In addition, we also estimate our treatment effects using tobit models to account for censored outcome variables; all results are robust to this alternative specification (Supplementary Tables 9 and 10). The results also do not change if we restrict the sample to those observations that are present in all four waves (no attrition sample, Supplementary Tables 11-13). All outcomes are standardized to make treatment effects comparable in size.

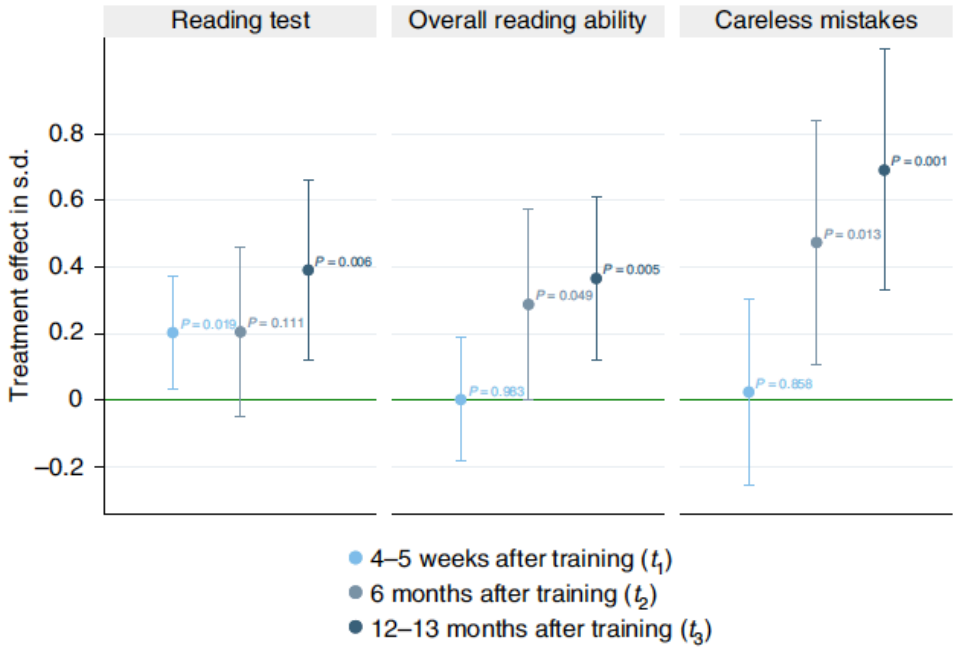


Fig. 1 | The effects of self-regulation teaching on reading and avoiding careless mistakes. The dots show point estimates (as fractions of a standard deviation of the respective outcome) of how MCII teaching changes the outcome indicated in the panel title relative to the control group. Reading test is the score from the reading comprehension test. Overall reading ability indicates the teachers' overall assessment of the children's reading abilities. Careless mistakes shows the teachers' assessment of the children's ability to find careless mistakes. All *P* values refer to two-sided *t*-tests. The bars indicate 95% CI. All estimates are based on least squares models controlling for school fixed effects, pre-treatment outcome scores, and further controls (see Supplementary, Sections 1.5 and Table 4 for more details and *P* values adjusted for multiple hypothesis testing). Standard errors are clustered at the classroom level.

MCII teaching already has a significant effect in t_1 on the reading test (d.f. = 30, $P = 0.020$, effect size = 0.20 s.d., 95% confidence interval (CI) = [0.035; 0.371]; see Fig. 1 and Supplementary Table 4), but this effect is somewhat fragile as indicated by the larger confidence intervals in t_2 (d.f. = 30, $P = 0.111$, effect size = 0.21 s.d., 95% CI = [-0.050; 0.460]). However, the treatment effect in t_3 becomes sizeable and highly significant (d.f. = 30, $P = 0.006$, effect size = 0.39 s.d., 95% CI = [0.122; 0.660]). Although the teachers were blind to all computer-based tests, a similar picture emerges from the teachers' assessment of the children's overall reading abilities. They indicate no treatment effect in t_1 (d.f. = 29, $P = 0.983$, effect size = 0.002 s.d., 95% CI = [-0.184; 0.188]), a treatment effect in t_2 that just passes the 5% significance threshold (d.f. = 29, $P = 0.049$, effect size = 0.29 s.d., 95% CI = [0.001; 0.574]), and again a sizeable and robustly significant effect in t_3 (d.f. = 29, $P = 0.005$, effect size = 0.37 s.d., 95% CI = [0.122; 0.609]). It is reassuring that the teachers' assessments of overall reading ability are quite consistent with the results from the objective reading test, even though the teachers were not involved in the reading test and did not know its results, suggesting that demand effects do not drive teachers' assessments.

Further evidence for the credibility of teachers' assessments is provided by the strong correlation (Spearman's rank correlation, $\rho = 0.78$, $P < 0.001$) between the children's average score in the four objective reading tests (in t_0, t_1, t_2, and t_3) and the teachers' average reading assessment of the children. In addition, we observe that the teachers' ratings in the first assessment after the self-regulation intervention (in t_1) are even more conservative than the results of the objective computer-based reading tests. In the presence of demand effects, one would expect the opposite result, that is,

that the teachers report overly optimistic reading assessments. The teachers' overall assessment of children's ability to find careless mistakes follows a similar time pattern as their assessment of the overall reading ability (Fig. 1): there is no treatment effect in t_1 (d.f. = 29, $P = 0.858$, effect size = 0.02 s.d., 95% CI = [-0.254; 0.303]), but significant and increasing treatment effects in t_2 (d.f. = 29, $P = 0.013$, effect size = 0.47 s.d., 95% CI = [0.107; 0.841]) and t_3 (d.f. = 29, $P = 0.001$, effect size = 0.69 s.d., 95% CI = [0.329; 1.053]).

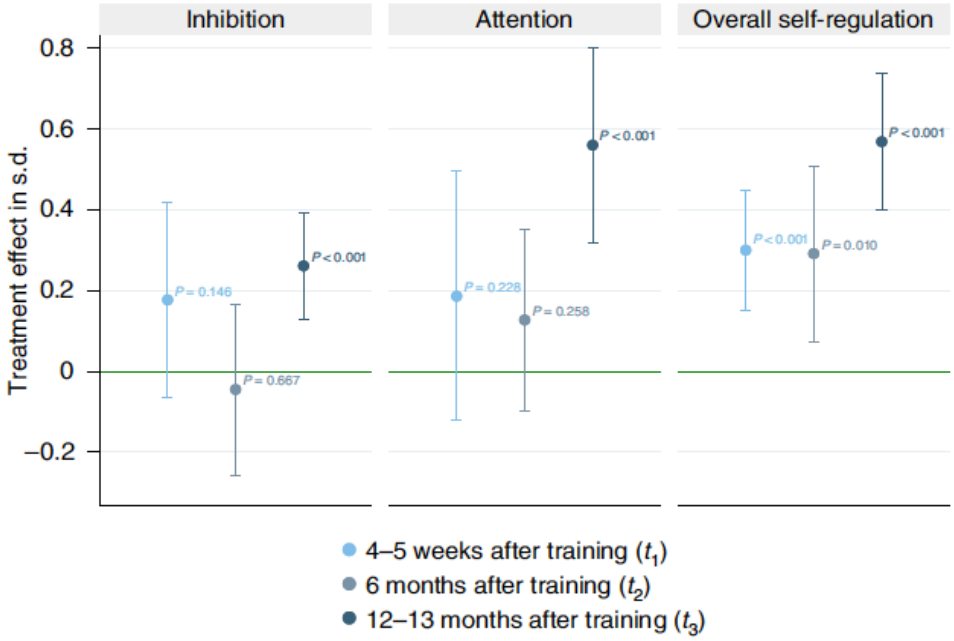


Fig. 2 | The effects of self-regulation teaching on inhibition, attention and overall self-regulation. The dots show point estimates (as fractions of a standard deviation of the respective outcome) of how MCII teaching changes the outcome indicated in the panel title relative to the control group. Inhibition measures the children's ability to inhibit prepotent impulses (by the negatively signed commission errors) in the go/no-go task, Attention indicates the ability to respond properly to the stimuli that require an action (measured by the negatively signed omission errors) in the go/no-go task. Overall self-regulation indicates the children's assessment of their everyday self-regulation behaviours in the classroom by the teachers. All *P* values refer to two-sided *t*-tests. The bars indicate 95% CI. All estimates are based on least squares models controlling for school fixed effects, pre-treatment outcome scores, and further controls (see Supplementary Section 1.5 and Supplementary Table 5 for more details and *P* values adjusted for multiple hypothesis testing). Standard errors are clustered at the classroom level.

The above-reported effect sizes are quite substantial as it has been pointed out that "in real-world settings, a fifth of a standard deviation (0.2 SD) is a large effect"[43]. This assessment is supported by 'the best evidence synthesis' literature[43], which suggests the use of empirical benchmarks from high-quality field research on education instead of benchmarking on the basis of laboratory studies[44,45]. A comparison of our results with the control group's scores provides another intuitive benchmark for assessing the effect size. For example, if we compare the treatment effect on the reading score in t_3 with the distribution of the control group's reading scores, we find that the effect size of 0.39 s.d. moves the median child's reading score in the control group from the 50th to the 75th percentile. For the careless mistakes' outcome, the treatment effect is very similar in size, moving the median control group child again from the 50th to the 75th percentile. Thus, taken together, these results suggest that the application of five lessons of MCII teaching to reading and

finding careless mistakes causes significant and sizeable outcome improvements one year later in these domains.

How does MCII teaching affect the ability to inhibit prepotent impulses ("inhibition"), the ability to attend and quickly respond to stimuli that require an action ("attention"), and overall self-regulation ability as assessed by teachers (outcome category 2)? We find a significantly positive treatment effect (Fig. 2 and Supplementary Table 5) on inhibition (measured by the negatively signed commission errors in the go/no-go task; d.f. = 30, $P < 0.001$, effect size = 0.26 s.d., 95% CI = [0.128; 0.393]) and attention (measured by the negatively signed omission errors in this task; d.f. = 30, $P < 0.001$, effect size = 0.56 s.d., 95% CI = [0.317; 0.801]) 12–13 months after the treatment (t_3). Interestingly, as with the measures in outcome category 1, the effects are weaker and non-significant 4–5 weeks after the teaching unit (in t_1), suggesting that the teaching needs time to come to fruition.

The teachers' assessments of the children's overall self-regulation behaviour in the classroom show a roughly similar time pattern: the treatment effect is significant and largest after 12–13 months (d.f. = 29, $P < 0.0001$, effect size = 0.57 s.d., 95% CI = [0.400; 0.735]) and similar in size to the effect on attention, yet the treatment effects in the previous waves (t_1 and t_2) are already significant due to smaller standard errors (t_1, d.f. = 29, $P < 0.001$, effect size = 0.30 s.d., 95% CI = [0.152; 0.447]; t_2, d.f. = 29, $P = 0.010$, effect size = 0.29 s.d., 95% CI = [0.074; 0.508]) and slightly larger effect sizes compared to the inhibition and attention outcome. Thus, both the results from standardized computer-based tests and the findings from teachers' ratings suggest that the treatment improved the children's self-regulation abilities. In addition, we also collected parent ratings of their children's self-regulation six months after the training (in t_2). However, the parents' response rate was, unfortunately, considerably lower (63%) compared to the teachers' response rate (92%). The parent ratings also suffer from several other problems adding noise to the measurement (Supplementary Section 1.4 and Supplementary Table 15). Albeit these problems may prevent us from finding significant results, if the parent ratings point in the same direction as the other self-regulation measures, they complete the overall picture. We indeed find that parent-assessed self-regulation skills are higher in the treatment group but the effect is not statistically significant (d.f. = 30, $P = 0.144$, effect size = 0.13 s.d., 95% CI = [-0.047; 0.306]; see also Supplementary Section 1.4 and Supplementary Table 15). Nevertheless, by pointing in the same direction, they are consistent with the other results on self-regulation.

To what extent does MCII teaching spill over to an academic domain that was not targeted by the teaching unit or leads to an increase in stamina in a tedious letter detection task? We address these questions with two outcome measures—children's mathematics skills (measured by arithmetic and geometry tests) and the letter discrimination task that requires stamina and frustration tolerance (Supplementary Section 1.4). Here we find that MCII teaching has basically no impact at all on these outcomes (Supplementary Fig. 14 and Supplementary Table 6). Moreover, there is no time trend across all outcome evaluation waves: the treatment effect for these outcomes is always close to zero, suggesting that first graders do not automatically generalize the MCII teaching to new academic domains or to tedious tasks that require stamina and high frustration tolerance.

Does teacher quality or experience affect the treatment effect? This question is relevant, as more experienced teachers are typically better at educating children[46] and therefore might also have been better in teaching MCII. However, the fact that we developed detailed and fully scripted lessons for teaching MCII made it easy for the teachers to teach and apply MCII, and this may have mitigated effects of teacher experience on the treatment effect. Indeed, if we control for teacher experience (Supplementary Table 8), we find that classes with teachers with a below-median

experience do not show a significantly lower treatment effect. In addition, we also do not find heterogeneous treatment effects for demographic variables such as gender, age and migration background. Moreover, MCII teaching benefits children with low and high self-regulation abilities at baseline alike. It is in this regard different from the effects of growth mindset interventions whose effects seem to occur primarily in low-achieving children[47].

Effects on secondary school track choice three years after treatment

Given that we found treatment effects on important outcomes in a one-year follow-up, the question arises whether the MCII teaching has an even longer-run effect on a high-stakes outcome. We therefore evaluate its effect on secondary school track choice three years after the MCII teaching—a very important and far-reaching educational decision. It turns out that children in the treatment group are 13.3 percentage points more likely to choose the advanced track (d.f. = 30, $P < 0.01$, effect size = 13.3 percentage points, 95% CI = [0.040; 0.226]; see Fig. 3 and Supplementary Table 7, column 1) if we estimate the treatment effect with a linear probability model. The result is very similar when we estimate a probit model.

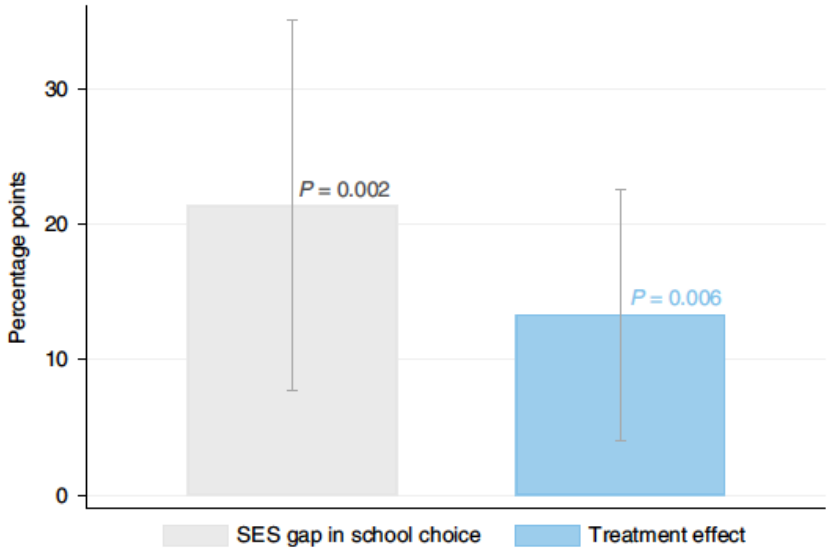


Fig. 3 | The long-term effects of self-regulation teaching on children's enrolment in advanced secondary school track. The left bar shows the socio-economic gap in enrolment to the advanced track of secondary school based on whether the child's mother has a university degree (controlling for baseline IQ). Children whose mother has a university degree are 21.4 percentage points more likely to enrol in the advanced track. The right bar shows the estimated 13.3 percentage point increase in enrolment generated by the MCII teaching (based on Supplementary Table 7, column 1). The estimate is based on a linear probability weighing model controlling for school fixed effects and further controls (Supplementary Section 1.5 and Supplementary Table 7), but the results are robust to using probit or inverse probability weighting models. Standard errors are clustered at the classroom level.

To benchmark the size of this effect, we compare it with the difference in enrolment in the advanced track by maternal education in the control group (controlling for baseline IQ): children whose mothers have a university degree are 21.4 percentage points more likely to be enroled in an advanced track secondary school compared with those whose mothers do not have a university degree. Thus, the treatment effect of MCII teaching is roughly 13.3/21.4 = 62% as large as this important socio-economic gap.

Because there is attrition in parents' participation in the survey that asks about school track choice, we also examined the robustness of our findings by testing whether attrition is related to treatment assignment. Fortunately, however, this is not the case: if we regress participation in the survey on the treatment condition, gender of the child, age of the child, and school fixed effects, we do not find significant effects. In addition, we control for attrition by inverse probability weighting and show that the treatment effect on school track choice is robust (Supplementary Table 7, column 3; d.f. = 30, $P < 0.001$, effect size = 15.8 percentage points, 95% CI = [0.071; 0.245]).

The results described above indicate that MCII teaching caused improvements in outcome category 1 (Fig. 1) and outcome category 2 (Fig. 2). Is the improvement in outcome measures in these two categories a reason for the significantly higher enrolment of the treated children in an advanced track secondary school? To examine this question, we conducted a mediation analysis and included the t_3 values of these outcome measures as regressors for the school track choice (Supplementary Table 7, column 2 and column 4). We indeed find that the children's performance in the reading test, their ability to find careless mistakes, and their overall self-regulation ability in t_3 are important mediators of the treatment effect on school track choice. Reading ability as indicated by the reading test in t_3, in particular, seems to be a strong mediator of school track choice—a 1 s.d. increase in reading ability is associated with a 15.3 percentage points increase in advanced school track choice (d.f. = 30, $P < 0.0001$, 95% CI = [0.096; 0.211]). However, a 1 s.d. improvement in finding careless mistakes or in overall self-regulation is also associated with substantial increases in enroling in the advanced track by 6.3 percentage points (d.f. = 30, $P = 0.043$, 95% CI = [0.002; 0.123]) and 8.3 percentage points (d.f. = 30, $P = 0.002$, 95% CI = [0.032; 0.134]), respectively. Moreover, the treatment variable is no longer significant if we include the children's abilities in t_3.

Discussion

Self-regulation is generally thought to be of fundamental importance for children's educational and lifetime success. There is also a reason to believe that the earlier schoolchildren acquire self-regulation skills, the more they benefit from them in the long-run. However, how can the teaching of effective self-regulation to young schoolchildren be integrated into their school curriculum without reducing other productive uses of teaching time? Is it possible to teach self-regulation in a way that it even substantially improves children's performance in core school subjects and thus has the potential to affect their educational career path? And how can this teaching method be designed to render it easily scalable to a larger subject population? As an answer to these questions, we have proposed a few self-regulation teaching lessons that are based on MCII (see Figs. 4 and 5 for details on implementation).

We conducted a randomized controlled field experiment involving 572 first graders that overcomes the challenges of teaching MCII-based self-regulation to first graders. The findings indicate that five self-regulation teaching lessons spread over five weeks can be used to generate substantial improvements in academic skills—such as reading—that are part of the standard curriculum. In addition, we show that teaching self-regulation has far-transfer effects on general inhibitory and attentional abilities and improves the children's overall self-regulation behaviour in the classroom.

We do not observe fade-out effects for the positively affected skills. Potential reasons for the observed sustainability are that the skills we address are thought to be not only malleable but also fundamental[48] in the sense that they are crucial for the further development of self-regulation (self-productivity) and they increase the productivity of other skill investments (dynamic

complementarity)[49]. Moreover, our intervention differs in important aspects from the two MCII studies in a school context mentioned above[37,38]: our intervention is more intensive (5 hours); it is conveyed in a playful, vivid, and meaningful manner; and we apply it not only to one but to several different goals, making it more likely that children will internalize the metacognitive strategy, thus enhancing self-regulation behaviour at school in general. By addressing basic literacy skills and the monitoring of careless mistakes in particular, we also directly target skills that are fundamental for subsequent learning progress, both within and beyond the domain of reading. A distinguishing feature of our intervention is also that we randomized between (and not within) school classes. Hence, we take advantage of beneficial peer or classroom effects that may lead to a subsequently enriched environment in the treated classes, which may be crucial for sustaining earlier skill gains[48]. Positive peer group effects appear particularly plausible in view of the fact that the children stay together in the same class for four years in primary school. Overall, this sustainability translates into a striking effect on children's school career choices three years after the MCII teaching—making it considerably more likely that they will be enroled in an advanced track secondary school, which is known to deeply affect the children's life-time education and labour market trajectory.

Despite all our efforts to provide reliable and robust evidence, we acknowledge certain limitations of our study. First, some of our outcome measures were rated by teachers who were not blind to treatment condition. In this context, it is important to emphasize that our main conclusions are based on both standardized computer-based tests of, for example, reading ability and teachers' ratings of children's reading ability.

Moreover, the strong correlation between the results of the objective tests and the teachers' ratings makes us confident about the reliability of our measures. Also, the treatment effects measured using objective tests and using teachers' ratings are very similar with regard to effect size and temporal patterns. Nevertheless, while these patterns provide little reason to doubt the validity of the teachers' ratings, we cannot fully rule out that they may contain some bias.

Second, the sample from which we draw inferences adds limitations. Especially in light of the classroom-level randomization, our sample size is limiting, for example, the analysis of heterogeneous treatment effects. We also target a specific (and challenging) age group (first graders) in a specific education system of a developed country (Germany). Further research is necessary to learn whether the findings also hold in different age groups, in other education systems, or for settings in developing countries.

Finally, while the number of lessons replaced by our self-regulation teaching unit is very small and therefore, in our view, negligible, we do not have perfect control over the amount of time that treatment versus control classes spent practising reading or learning to find careless mistakes. We deem it highly unlikely that a few additional lessons of practising reading would yield these large and long-term effects and prefer the interpretation that children learned a self-regulation strategy that helped them to improve their learning and goal striving over the following three years.

The implementation of the teaching lessons is associated with very little cost per child, as the teaching unit requires only a few hours of training for the teachers and five teaching lessons for the children. Moreover, they yield high benefits even if we make rather conservative assumptions by only counting the benefits from improved reading abilities and neglecting improvements in overall self-regulation, inhibition control, or the finding of careless mistakes (Supplementary Section 1.6). If we consider only the benefits of improved reading skills that already accrue one year after the MCII teaching, the cost-benefit ratio is 1:1.5, meaning that the benefits amount to €1.5 for every euro spent.

If we take a longer-run perspective and calculate the increased lifetime earnings from improved reading skills, the cost-benefit ratio is even in the range of 1:10.

In addition to its very favourable cost-benefit ratio, the proposed method of teaching self-regulation is also easily scalable to a much larger population, as there is little reason to believe that the fully scripted self-regulation lessons we developed could not be applied to other first graders. All it takes is as little as three hours of training for the teachers to render them able to apply the method. Finally, the findings also indicate that—at least among first graders—self-regulation teaching did not automatically transfer to other academic subjects like mathematics in the one-year period after the intervention. However, if it is possible to apply self-regulation lessons to the teaching of reading skills, we see little reason why it should not be possible to apply the lessons to teach foreign languages or other academic subjects. In fact, synergistic benefits might arise if MCII-based self-regulation teaching is applied to more than one academic field. Future research may thus extend the self-regulation teaching unit to other areas such as mathematics or science. Additionally, collecting information on the detailed time use of the control classes, more "active" control conditions, as well as detailed data on the use of the self-regulation strategy after the intervention has ended would be useful to learn about the specific mechanisms underlying the treatment effects.

Methods

The study was conducted in primary schools in Mainz, Germany in 2013-2014. It consisted of a five-week intervention, four data collection waves and a long-term follow-up survey three years after the intervention. Our study received ethical approval from the Human Subjects Committee of the Faculty of Economics, Business Administration and Information Technology at the University of Zurich in September 2012. We confirm that we have complied with all relevant ethical regulations.

In the context of a large school project[50], we recruited 12 schools with 31 classes for the study. There were 599 children in these classes in November 2012. We received 580 parental consent forms that allowed us to collect data in evaluation waves t_0–t_3, resulting in a consent rate of 96.8%. We were able to evaluate 572 children of the 580 for whom we received parental consent to collect data for our final dataset. The children we could not evaluate either switched to non-participating classes or schools, moved away or were ill for a longer period of time during data collection; we did not exclude any available data. Among the sample of 572 children, 292 were girls (51%) and 280 were boys (49%). n = 315 children were in the self-regulation treatment group, n = 257 children in the control group. We conducted other treatments (unrelated to the self-regulation teaching) in the same sample, with a randomly chosen part of the self-regulation treatment group and a randomly chosen part of the control group. For details, see Supplementary Section 1.5. Mean age before the intervention (January 2013) was 6.84 years (s.d. = 0.36 years). All children received a small toy for participating in the evaluation waves. We did not pay a financial compensation to children for their participation.

Addressing the challenges of teaching MCII to first graders

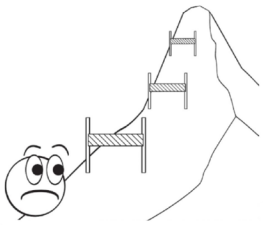
To address children's limited ability for abstract thinking, we developed an illustrated storybook with an appealing main character named "Hurdy", the hurdle jumper. The story unfolds in an emotionally involving way so that the children quickly identify with Hurdy, whose first goal is to climb to the top of a high mountain (Fig. 4). Hurdy imagines the great view he (In German, a ball is masculine.

Therefore, Hurdy was a 'he' in our story) will enjoy from the top of the mountain but contrasts this goal with the many hurdles he faces along the way. Hurdy's when-then plan is that "when he faces a hurdle, then he jumps over it". In this way the abstract MCII strategy is conveyed in a playful manner; it becomes concrete, vivid and meaningful for the children. This enables us to use the main character's ideas and actions as a role model that helps us in transferring the strategy to further goals, obstacles and plans.

a **Introducing Hurdy, and how he imagines** the great feelings he would experience when enjoying the spectacular view at the top of the mountain

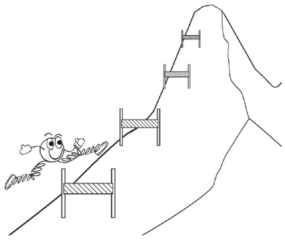
"Once upon a time, there was a small, cheerful ball. He wanted to go all the way to the top of a high mountain. He closed his eyes and imagined how wonderful he would feel when he would get aaaall, all the way to the top. He might be above the clouds, maybe even a bit closer to the stars. He imagined how wonderful the view would be up there: a panorama over broad fields, the long river, the many houses and cars that would surely look like tiny little toy cars from all the way up here. He knew: way up on top of the mountain, he would be the happiest little ball in the whole world!"

b **Identifying the obstacles**



"But the mountain was very steep, and the ball would certainly roll down again and again. Moreover, there were lots of hurdles that he could not go over. And so the ball rolled sadly back and forth at the base of the mountain. He thought and thought again and again about how he could get to the summit of the mountain. And then! He suddenly had an idea how he could acquire legs and arms that enable him to walk, run and jump!"

c **Overcoming the obstacles**



"At the base of the mountain, he picked up speed, hopped a couple of times, and jumped as high as he could and—suddenly he jumped over the first hurdle. And he jumped like this further up the mountain, and hopped over the next and the next, and then all the other hurdles. It was very tiring for the little ball, but he did not give up. He was so happy that he was getting closer and closer to his goal—and he thought how beautiful it would be when he finally reached the top. He hopped further and further up the mountain and jumped over one hurdle after the other …. Until he was aaaall, all the way at the top."

d **Enjoying goal achievement**

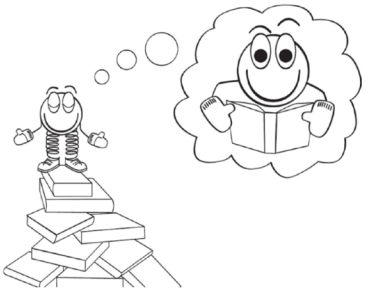
"He enjoyed the heavenly view and was so very happy that he had almost forgotten his great effort. The view was even broader and more breathtaking than he had ever imagined it could be. He lifted his arms into the air, and even though he had reached the summit, he jumped for joy into the air again and again. He was so happy and was sure that he now could jump over every hurdle that might be in his way—a wonderful feeling!"

Fig. 4 | Introducing generic components of MCII to first graders with the help of an emotionally involving story about Hurdy, the hurdle jumper.
a, Imagining a desirable goal. **b**, Identifying obstacles and developing a solution. **c**, When–then rule: whenever there was a hurdle, Hurdy jumped over it. **d**, Enjoying goal achievement. All scenes in **a–d** are communicated with the help of a storybook containing both the pictures (on the left) and the text (on the right) that the teacher read aloud in a stepwise manner. After each step in **a–d**, the children discussed the story in the classroom.

Once the general idea behind MCII was playfully introduced (Fig. 4), the children subsequently applied it to three goals. To practise the MCII strategy and account for the children's limited goal setting skills, the first two goals were set by us. The first goal was to become better in reading by practising reading out loud, because reading is a skill that is fundamental for all other subjects taught in primary school. The second goal was for the children to find careless mistakes in their own schoolwork by using a self-monitoring technique—the detection (and correction) of own mistakes. We used this goal because the lack of metacognitive self-monitoring strategies has been put forward as a major factor explaining cross-country differences in academic achievements in the Program for International Student Assessment (PISA study)[51]. The third goal was individually chosen by each child.

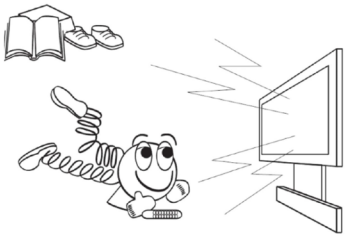
Every new goal was introduced with the help of the main character, Hurdy. For example, Fig. 5, illustrates how we used Hurdy as a role model for the application of MCII teaching to the reading goal. The teacher began by reading aloud a story where Hurdy imagines how wonderful he would feel to be able to read (Fig. 5a). After the teacher had read the story, the children themselves publicly discussed what they would enjoy most if they were able to read well. Likewise, after the teacher read aloud about the obstacles that Hurdy faced (Fig. 5b) or the when-then rule that Hurdy developed (Fig. 5c), the children subsequently discussed publicly the hurdles they face themselves and possible when-then rules that help them overcome their obstacles.

a Imagining the joy associated with becoming a better reader



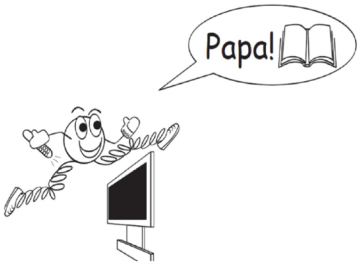
"Once Hurdy noticed how wonderful it was to reach his own goals after crossing a lot of hurdles, he soon identified his next wish. He really, really wanted to be able to read well. He wanted to be able to read all the exciting stories about the "Wild Soccer Kids" on his own. Most of all, late at night with a flashlight under his cover. He did not just want to look at the pictures in his new dinosaur book, but wanted to read the names of the dinosaurs and how they once lived on their own. And he dreamt about how proud grandpa and grandma would be of him if he could read aloud to them. Hurdy knew that he would have to practice reading a lot, but he really wanted to do it. It was his big dream."

b Identifying the obstacle that prevents Hurdy from becoming a better reader



"But there were hurdles to jump over on Hurdy's journey to his new reading goals. On the way home from school, he often planned to practice a lot of reading. But then, when he got home, the big television was in the middle of the room. Hurdy took his shoes off, left his book lying next to the shoes, and turned the TV on. He had already forgotten what he had planned. The book was only lying around, and Hurdy did not worry about it anymore."

c Overcoming the obstacle for becoming a better reader with a when-then rule



"When Hurdy was lying in front of the TV, he suddenly remembered how wonderful he felt when he imagined how it would be if he could read really well. How his grandma would have praised him and how he thought he would feel if he could read exciting stories under his cover at night with the flashlight. He shouted loudly, *"Papa, can I read something to you?"*, turned the TV off, ran over to his father, grabbed his book, and read something aloud to him. He realized that he could turn the TV on again after reading and watch in peace with a better feeling. He then resolved: *"**When** I want to watch TV, **then** I will first call my father, read him something aloud, and watch TV afterwards"*. In this way, Hurdy jumped over at least one TV hurdle a day and became much better in reading."

d Enjoying goal achievement

"Hurdy was then proud of himself because he had jumped over so many hurdles and was thus very good in reading. He read so much that he collected a real mountain of books from which he could always grab a book and start reading. The greatest pictures played inside his head, and he could see all of the stories with his inner eyes. When he read about heroes' adventures in the stories, he felt as if he had been a part of the adventure himself. His father and mother were very proud of him, and grandpa and grandma even more so."

Fig. 5 | Applying MCII to the goal of improving reading abilities. a, Imagining a desirable goal. **b**, Identifying obstacles. **c**, Developing and implementing a solution for overcoming the obstacle. All scenes in **a–c** are communicated with the help of the picture on the left and the text on the right that the teacher read aloud. **d**, In addition, the teacher also read a story about how Hurdy enjoyed the success of becoming a good reader. After the teacher had read a textbox, the story was discussed in the classroom, and the children contributed their own imaginations, obstacles and ideas to the context. In addition, the children applied each step in **a–d** to their situation by drawing pictures in a workbook (Supplementary Fig. 2) that expressed their individual imaginations, obstacles and when–then rules.

The use of Hurdy as a role model helps us transfer the MCII strategy across different goals while addressing the children's limited transfer capabilities. To further deal with this issue, we applied a scaffolding method that gradually reduces the level of support in the application of MCII. The children's obstacles and plans thus become more and more personalized from goal one to goal three, implying an increasing need for own transfer thinking. In this context, classroom discourse

also played an important role because it served the purpose of fostering the transfer of the MCII components from the role model's thoughts, actions, and plans to the children's individual context. For example, after the children listened to the short story describing Hurdy's obstacle towards becoming better at reading (Fig. 5b), the subsequent classroom discourse induced the children to undertake a first small step of applying the obstacle identification component of MCII to their own situations.

To further practise and personalize the application of MCII, each child received a prepared workbook that visualized the different steps of the MCII strategy. The workbook also contained space so that the children could apply the strategy to their individual context with their own added drawings (Supplementary Fig.2). For example, children drew their ideas of the positive consequences of reaching a goal or of their individual obstacle after discussing it with classmates. The visual structure in combination with the individual drawings enables the children to internalize the MCII strategy without requiring reading or writing skills. The children thus experienced a diverse set of interesting tasks during the MCII teaching lessons—listening to Hurdy's story, discussing with their classmates, individualizing their goals in their workbooks—that kept them interested and compensated for their limited attention spans.

We addressed children's limited perseverance by spreading the five MCII teaching lessons over five weeks during which we encouraged them to pursue progressively more ambitious sub-goals related to reading and monitoring their mistakes. To constantly remind them of the different steps of the MCII strategy, a large poster that looks exactly like the first figure in their workbook (Supplementary Fig. 2) remained on the wall in their classroom during the five weeks. In addition, flash cards (Supplementary Figs. 3 and 4) were attached to the poster that reminded the children of the current goal, obstacles and plan.

In principle, we could have involved the parents into the teaching and application of the MCII strategy. However, we deliberately wanted to avoid this for three reasons. First, involving the parents complicates the intervention, making it more expensive and less easily scalable. Second, if the parents take responsibility for implementing parts of MCII, the children's self-responsibility for their learning may be undermined. Because we wanted to foster their self-responsibility, the story is based on Hurdy's desire to reach the top of the mountain or become a good reader. Likewise, it is Hurdy who wants to become a good "error detective" (that is, find careless mistakes), and the children's third goal was entirely self-determined. Third, involving parents might introduce heterogeneous treatment effects that depend on parents' socio-economic characteristics—a possibility that we wanted to avoid.

Measuring the effects of self-regulation teaching

To evaluate the effects of self-regulation teaching, we measured four types of outcomes. First, we are interested in outcomes related to the first two goals the MCII strategy was applied to—the reading goal and the goal of monitoring and correcting one's own mistakes. We measured reading comprehension skills with an objective computer-based reading test (Supplementary Section 1.4) and, in addition, teachers assessed the children's overall reading abilities. Teachers also assessed the extent to which the children committed careless mistakes during their usual classroom sessions. These measures allow us to answer the question whether MCII is more effective than usual classroom teaching in fostering children's abilities in domains to which MCII has been directly applied. If this was the case, MCII would be directly useful in achieving the goals of the standard curriculum.

Second, we are interested in outcomes that measure more general self-regulation skills that are not explicitly taught in the MCII teaching lessons. These are skills such as the ability to inhibit pre-potent impulses and to pay attention—measured by an objective computer-based go/no-go task (Supplementary Section 1.4)—as well as an overall teacher assessment of children's self-regulation and discipline in the classroom. In the go/no-go task, the children need to attend to rapidly emerging and vanishing pictures of different animals; they have to click a button for all animals (the "go animals") except for one (the "no-go animal") within the short time period during which the animal is on the screen. Because most of the time "go animals" appear on the screen, the children are tempted to constantly push the button. However, a "no-go animal" appeared occasionally on the screen, and then they had to refrain from pushing the button. Pushing the button for "no-go animals" indicates thus a failure to inhibit a prepotent response (commission error), while not pushing the button for a "go animal" can be interpreted as an attentional failure (omission error).

Overall self-regulation in the classroom was measured with items such as "The child often disturbs class instruction" or "The child has trouble waiting until it is his/her turn" or "The child has a lot of self-discipline". The answers to these items are aggregated into an overall self-regulation index (Supplementary Section 1.4). Notice that we do not train general inhibitory or attentional abilities like those required in the go/no-go task during the application of MCII to reading and careless mistakes. Likewise, the teaching lessons do not directly prevent children from disturbing class instruction or inducing them to be more patient until "it is his/her turn". A treatment-induced improvement in these outcomes therefore indicates far-transfer effects.

Third, we want to examine whether the taught MCII strategy automatically spills over to other academic domains that self-regulation teaching did not target. This helps answer the question whether first graders automatically apply the strategy to novel academic domains. In this context, we measure whether MCII teaching improved children's mathematics skills. In addition, we measure their stamina in a tedious and frustration-inducing letter discrimination task. In this task, the children saw a long string of different letters on the screen, and they had to indicate only the letter b and p but not the others. The string of letters is typically so long that children cannot finish a given letter sequence before the next one appears on a new screen. The task therefore induced an element of frustration that children need to overcome. Both the mathematics and the stamina measures are based on objective computer-based tests (Supplementary Section 1.4).

Finally, and perhaps most importantly from a policy viewpoint, we are interested in how MCII teaching affects the children's long-run school career path. For this purpose, we administered a short survey to parents in which we asked them about their child's school track in secondary school—a decision that parents must take roughly half a year before the end of primary school (grade 4). Therefore, this survey took place during the final months of primary school, that is, about three years after the self-regulation teaching unit.

There are essentially three different secondary school tracks available in Rhineland-Palatinate, the federal state in Germany where we conducted our study: (1) an advanced track (*Gymnasium*), (2) a mixed track (*Integrierte Gesamtschule*) and (3) a lower track (*Realschule Plus*). In Rhineland-Palatinate, 86% of the children in the advanced track earn a degree that qualifies them for general university enrolment (*Abitur*), whereas only 25% of children in the mixed track earn this degree[52]. For children who enter the lower track in secondary school, the probability of switching track is very small (< 5% per year)[53]. Moreover, by predetermining educational career paths, early school track choice has substantial influence on later wages[54]. Thus, the choice of the secondary school track constitutes a major educational decision that strongly affects a child's future outcomes and lifetime earnings.

Reporting summary and additional information

Further information on research design will be available in the Nature Research Summary and the Supplementary Information linked to the article in Nature Human Behaviour.

Data availability

The data for this publication have been collected in a project that has compiled a large set (and combination) of children's abilities, preferences and family (sociodemographic) characteristics (Supplementary Sections 1.3 and 1.4) and thus represents highly sensitive data. This dataset cannot be made available for data protection reasons. In addition, parental consent for data usage only covers strictly scientific purposes. The restriction to scientific purposes was also necessary to comply with data protection requirements, and use of the data for strictly scientific purposes cannot be guaranteed if the dataset is made (publicly) available. Not all the data collected in this project are analyzed for this publication; see Supplementary Section 1.4 for details. Researchers interested in replicating our findings can get access to the dataset after filling out a research agreement with us. We confirm that in the paper and the Supplementary Information, we have reported all measures, conditions, data exclusions, and how we determined our sample sizes.

In the printed version, Acknowledgements and Author Contributions are placed behind the References.

Acknowledgments:

We thank all teachers, schools, and educational authorities as well as all parents and children for their participation in the project. We are also thankful to countless excellent research assistants who made this field study possible. Moreover, we thank M. Wolf for support and provision of code in conducting the multiple testing correction. We are grateful for generous financial support that allowed us to conduct this project: All authors acknowledge support by the Jacobs Foundation (project 2013-1078-00). E.F. acknowledges support from the University Research Priority Program of the University of Zurich on Equality of Opportunity (project U-302-01-01). D.S. acknowledges support by the university research priority programme 'Interdisciplinary Public Policy' at Johannes Gutenberg University Mainz (project FI 2/2014-2016). E.M.B. acknowledges support by the German Research Foundation (BE 5436/1-1). H.H. acknowledges support by the German Academic Scholarship Foundation and the Research Council of Norway (FAIR, project 262675). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Author Contributions:

E.F. and D.S. initiated and supervised the study throughout all stages. E.F., D.S., E.M.B., and K.W. conceptualized the study and all authors developed the field design. E.M.B., H.H., D.S., and K.W. developed intervention materials and outcome measures for the study. H.H. conducted the field experiment with input from E.M.B., E.F., D.S., and K.W.; E.M.B. and H.H. performed the data analysis with input from E.F., D.S., and K.W.; all authors were involved in the interpretation of the results and all authors wrote the paper.

Competing Interests: The authors declare no competing interests.

References and Notes:

1 Bargh, J. A., Gollwitzer, P. M. & Oettingen, G. in *Handbook of social psychology* Vol. 5 (eds Susan T. Fiske, Daniel T. Gilbert, & Gardner Lindzey) 268-316 (Wiley, 2010).

2 de Ridder, D. T. D., Lensvelt-Mulders, G., Finkenauer, C., Stok, F. M. & Baumeister, R. F. Taking Stock of Self-Control: A Meta-Analysis of How Trait Self-Control Relates to a Wide Range of Behaviors. *Personality and Social Psychology Review* **16**, 76-99, doi:10.1177/1088868311418749 (2012).

3 Duckworth, A. & Gross, J. J. Self-Control and Grit: Related but Separable Determinants of Success. *Curr Dir Psychol Sci* **23**, 319-325, doi:10.1177/0963721414541462 (2014).

4 McClelland, M. M. & Cameron, C. E. Self-Regulation in Early Childhood: Improving Conceptual Clarity and Developing Ecologically Valid Measures. *Child Development Perspectives* **6**, 136-142, doi:10.1111/j.1750-8606.2011.00191.x (2012).

5 Zhou, Q., Chen, S. H. & Main, A. Commonalities and Differences in the Research on Children's Effortful Control and Executive Function: A Call for an Integrated Model of Self-Regulation. *Child Development Perspectives* **6**, 112-121, doi:10.1111/j.1750-8606.2011.00176.x (2012).

6 Blair, C. & Raver, C. C. School readiness and self-regulation: a developmental psychobiological approach. *Annu Rev Psychol* **66**, 711-731, doi:10.1146/annurev-psych-010814-015221 (2015).

7 McClelland, M. M. & Cameron, C. E. Self-regulation and academic achievement in elementary school children. *New Dir Child Adolesc Dev* **2011**, 29-44, doi:10.1002/cd.302 (2011).

8 Moffitt, T. E. *et al.* A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences of the United States of America* **108**, 2693-2698, doi:10.1073/pnas.1010076108 (2011).

9 Heckman, J. J., Stixrud, J. & Urzua, S. The effects of cognitive and noncognitive abilities on labor market outcomes and social behavior. *Journal of Labor Economics* **24**, 411-482, doi:10.1086/504455 (2006).

10 Bowles, S., Gintis, H. & Osborne, M. The determinants of earnings: A behavioral approach. *Journal of Economic Literature* **39**, 1137-1176, doi:10.1257/jel.39.4.1137 (2001).

11 Richmond-Rakert, L. S. *et al.* Childhood self-control forecasts the pace of midlife aging and preparedness for old age. *PNAS* **118**, 1, doi:10.1073/pnas.2010211118 (2021).

12 Duckworth, A. L., Peterson, C., Matthews, M. D. & Kelly, D. R. Grit: Perseverance and passion for long-term goals. *Journal of Personality and Social Psychology* **92**, 1087-1101, doi:10.1037/0022-3514.92.6.1087 (2007).

13 Duckworth, A. L. *Grit - The Power of Passion and Perseverance*. (Simon & Schuster, 2016).

14 Banerjee, A. V. & Duflo, E. (Dis) Organization and Success in an Economics MOOC. *Am Econ Rev* **104**, 514-518, doi:10.1257/aer.104.5.514 (2014).

15 Ng Lee Yen, A. M. The influence of self-regulation processes on metacognition in a virtual learning environment. *Educational Studies* **46**, 1-17 (2020).

16 Huang, R. H. *et al. Guidance on Active Learning at Home during Educational Disruption - Promoting student's self-regulation skills during COVID-19 outbreak*. (Smart Learning Institute of Beijing Normal University, 2020).

17 Baumeister, R. F., Vohs, K. D. & Tice, D. M. The Strength Model of Self-Control. *Current Directions in Psychological Science* **16**, 351-355, doi:10.1177/1745691617716946 (2007).

18 Jacob, R. & Parkinson, J. The Potential for School-Based Interventions That Target Executive Function to Improve Academic Achievement: A Review. *Review of Educational Research* **85**, 512-552, doi:10.3102/0034654314561338 (2015).

19 Berkman, E. T. in *Handbook of self-regulation : research, theory, and applications* Vol. 3 (eds Kathleen D. Vohs & Roy F. Baumeister) (Guilford, 2016).
20 Baumeister, R. F. & Vohs, K. D. Strength Model of Self-Regulation as Limited Resource: Assessment, Controversies, Update. *Adv Exp Soc Psychol* **54**, 67-127 (2016).
21 Alan, S., Boneva, T. & Ertac, S. Ever Failed, Try Again, Succeed Better: Results from a Randomized Educational Intervention on Grit. *Quarterly Journal of Economics* **134**, 1121-1162, doi:10.1093/qje/qjz006 (2019).
22 Gunzenhauser, C. & Nuckles, M. Training Executive Functions to Improve Academic Achievement: Tackling Avenues to Far Transfer. *Front Psychol* **12**, 624008, doi:10.3389/fpsyg.2021.624008 (2021).
23 Santos, I. V. *et al.* Can Grit Be Taught ? Lessons from a Nationwide Field Experiment with Middle-School Students. (The World Bank, Policy Research Working Papers, 2021).
24 Pandey, A. *et al.* Effectiveness of Universal Self-regulation-Based Interventions in Children and Adolescents: A Systematic Review and Meta-analysis. *JAMA Pediatr* **172**, 566-575, doi:10.1001/jamapediatrics.2018.0232 (2018).
25 Dignath, C., Buettner, G. & Langfeldt, H. P. How can primary school students learn self-regulated learning strategies most effectively? A meta-analysis on self-regulation training programmes. *Educational Research Review* **3**, 101-129, doi:10.1016/j.edurev.2008.02.003 (2008).
26 Takacs, Z. K. & Kassai, R. The efficacy of different interventions to foster children's executive function skills: A series of meta-analyses. *Psychol Bull* **145**, 653-697, doi:10.1037/bul0000195 (2019).
27 Currie, J. Early childhood education programs. *Journal of Economic Perspectives* **15**, 213-238 (2001).
28 Diamond, A., Barnett, W. S., Thomas, J. & Munro, S. The early years - Preschool program improves cognitive control. *Science* **318**, 1387-1388 (2007).
29 Heckman, J. J. The economics, technology, and neuroscience of human capability formation. *Proceedings of the National Academy of Sciences of the United States of America* **104**, 13250-13255, doi:10.1073/pnas.0701362104 (2007).
30 Diamond, A. & Lee, K. Interventions Shown to Aid Executive Function Development in Children 4 to 12 Years Old. *Science* **333**, 959-964, doi:10.1126/science.1204529 (2011).
31 Aizer, A. & Currie, J. The intergenerational transmission of inequality: Maternal disadvantage and health at birth. *Science* **344**, 856-861 (2014).
32 Oettingen, G. & Gollwitzer, P. M. in *Social psychological foundations of clinical psychology* (eds J. E. Maddux & J. P. Tangney) 114 - 134 (Guilford Press, 2010).
33 Oettingen, G. Future thought and behaviour change. *European Review of Social Psychology* **23**, 1-63 (2012).
34 Gollwitzer, P. M. Weakness of the will: Is a quick fix possible? *Motivation and Emotion* **38**, 305-322 (2014).
35 Dweck, C. S. & Yeager, D. S. Mindsets: a view from two eras. *Perspect. Psychol. Sci.* **14**, 481–496 (2019).
36 Wang, G., Wang, Y. & Gai, X. A Meta-Analysis of the Effects of Mental Contrasting With Implementation Intentions on Goal Attainment. *Front Psychol* **12**, 565202, doi:10.3389/fpsyg.2021.565202 (2021).
37 Gawrilow, C., Morgenroth, K., Schultz, R., Oettingen, G. & Gollwitzer, P. M. Mental contrasting with implementation intentions enhances self-regulation of goal pursuit in schoolchildren at risk for ADHD. *Motivation and Emotion* **37**, 134-145, doi:10.1007/s11031-012-9288-3 (2013).

38 Duckworth, A. L., Kirby, T. A., Gollwitzer, A. & Oettingen, G. From Fantasy to Action: Mental Contrasting With Implementation Intentions (MCII) Improves Academic Performance in Children. *Social Psychological and Personality Science* **4**, 745-753 (2013).
39 Duckworth, A. L., Milkman, K. L. & Laibson, D. Beyond Willpower: Strategies for Reducing Failures of Self-Control. *Psychological Science in the Public Interest* **19**, 102 - 129 (2019).
40 Frison, L. & Pocock, S. J. Repeated Measures in Clinical-Trials - Analysis Using Mean Summary Statistics and Its Implications for Design. *Statistics in Medicine* **11**, 1685-1704, doi:DOI 10.1002/sim.4780111304 (1992).
41 McKenzie, D. Beyond baseline and follow-up: The case for more T in experiments. *Journal of Development Economics* **99**, 210-221, doi:10.1016/j.jdeveco.2012.01.002 (2012).
42 Dynarski, S. M. *For Better Learning in College Lectures, Lay Down the Laptop and Pick up the Pen*. (The Brookings Institution, 2017).
43 Slavin, R. E. Best-evidence synthesis: an alternative to meta-analytic and traditional reviews. *Education Research* **15**, 5-11 (1986).
44 Hill, C. J., Bloom, H. S., Black, A. R. & Lipsey, M. W. Empirical Benchmarks for Interpreting Effect Sizes in Research. *Child Development Perspectives* **2**, 172-177, doi:DOI 10.1111/j.1750-8606.2008.00061.x (2008).
45 Kraft, M. A. Interpreting Effect Sizes of Education Interventions. *Educational Researcher* **49**, 241-253 (2020).
46 Hanushek, E. A. & Rivkin, S. G. in *Handbook of the Economics of Education* Vol. 2 (eds E. A. Hanushek & F. Welch) Ch. 18, 1051 - 1078 (North Holland, 2006).
47 Yeager, D. S. *et al.* A national experiment reveals where a growth mindset improves achievement. *Nature* **573**, 364-+, doi:10.1038/s41586-019-1466-y (2019).
48 Bailey, D., Duncan, G. J., Odgers, C. L. & Yu, W. Persistence and Fadeout in the Impacts of Child and Adolescent Interventions. *J Res Educ Eff* **10**, 7-39, doi:10.1080/19345747.2016.1232459 (2017).
49 Cunha, F. & Heckman, J. The technology of skill formation. *Am Econ Rev* **97**, 31-47, doi:10.1257/aer.97.2.31 (2007).
50 Berger, E. M., Fehr, E., Hermes, H., Schunk, D. & Winkel, K. *The Impact of Working Memory Training on Children's Cognitive and Noncognitive Skills* (University of Mainz, 2022).
51 Cohors-Fresenborg, E., Kramer, S., Pundsack, F., Sjuts, J. & Sommer, N. The role of metacognitive monitoring in explaining differences in mathematics achievement. *ZDM* **42**, 231-244 (2010).
52 Rhineland-Palatine, S. O. *Allgemeinbildende Schulen im Schuljahr 2017/2018*. (Statistisches Landesamt Rheinland-Pfalz, 2018).
53 Bellenberg, G. Schulformwechsel in Deutschland. Durchlässigkeit und Selektion in den 16. Schulsystemen der Bundesländer innerhalb der Sekundarstufe I. (Bertelsmann Stiftung, 2012).
54 Dustmann, C. Parental background, secondary school track choice, and wages. *Oxford Economic Papers-New Series* **56**, 209-230, doi:10.1093/oep/gpf048 (2004).