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Changes to students' motivation to learn science

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Abstract

Studies that investigated the relations between the environment and students' motivation to engage with science have typically looked at the *state* of students' motivation at a given time and its relations with the environment. This study took a different perspective; it looked at the *changes* to students' motivation to engage with science that occurred over a school year and investigated what drove these changes. According to goal orientation theory, students typically shift their personal goal orientations towards their perceptions of the goal emphases of their environment. For example, if students perceive their science teachers as highly emphasizing mastery orientation, they are likely to become more mastery oriented towards science with time. However, different environmental influences, such as parents, peer, teachers, and general school culture, push and pull the students in different directions. Using survey data gathered from Israeli adolescents that came from low SES backgrounds, we demonstrated that any shift in students' mastery orientation towards science was not related to their perceptions of the environmental emphases, but rather to the differences they perceived between the environment and themselves. In addition, we identified which environmental influences were stronger predictors of shifts in students' mastery orientation towards science. These results help to clarify the influence of the environment on students' motivation to engage with science, can help understand why interventions may sometimes lead to counter-intuitive results, and can provide the basis for a model that may be useful for predicting how students' motivation for science may change over a school year.

Introduction

Motivation is important. It is the door to learning because motivation leads to engagement, and without engagement learning is unlikely to occur. "Motivation is the process whereby goal-directed activity is instigated and sustained" (Schunk, Pintrich, & Meece, 2008, p. 4). Studies conducted over the past few decades have indicated that there is a general tendency for students' motivation to engage with science, in and out of school, to decrease during adolescence (Anderman & Midgley, 1997; Meece, 1991; Vedder-Weiss & Fortus, 2012). Many potential reasons have been found for this declining motivation for science, with some of the main culprits being various environmental pressures on and expectations of

students as they mature (Ames, 1992; Mucherah, 2008; Song, Bong, Lee, & Kim, 2015; Vedder-Weiss & Fortus, 2013). Motivational studies have typically been either correlational, such as looking at the relations between various characteristics of the school or of the home environments and the state of students' motivation, or qualitative, inquiring into the personal motivational stories of individuals in relation to their environment.

Building off goal orientation theory (Ames, 1992; Dweck, 1986), traditional studies have shown that there tends to be a positive correlation between the goal orientations adolescents adopt towards science and those of their parents and their science teachers (Miller & Murdock, 2007; Song et al., 2015; Vedder-Weiss & Fortus, 2013). This can be explained thus: if parents (or science teachers) emphasize/de-emphasize a certain type of goal in science, over time we expect these parents' children (or science teachers' students) to become more/less

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oriented towards this goal, because they are being “pulled” towards a specific goal by these significant adults. However, past studies have typically looked at students’ goal orientations towards science at a single time in a school year. These studies have not looked to see how students’ goal orientations change over a school year in response to their “exposure” to a given science teacher from the beginning of a school year. Overall the students are expected to drift in their orientations towards the goals emphasized by their science teacher (leading to the positive correlations mentioned above, if the measurements are held late enough during the school year to capture the effect of the teacher’s influence). However, an analysis that looks closely at the changes to students’ goal orientations in science over the school year may show, for example, that there was an increase in most students’ orientation towards a goal emphasized by the science teacher, but there will be students whose orientation towards that goal barely changed and maybe even some whose orientation towards this goal even decreased. Identifying these patterns and trying to understand them is possible only if students’ goal orientations towards science are measured at least twice in a single year, so as to be able to identify how they changed.

This study focused on the changes to students’ goal orientations in science. Like Festinger (1957), who theorized that people have an inner need to minimize the cognitive dissonance between their various attitudes and behaviors (see also Elliot & Devine, 1994), we surmised that the positive correlations described above between students’ goal orientations towards science and the goal emphases of the significant factors in their environment (e.g., parents, science teacher, school culture and peers), resulted from an inner striving by students to *close the gap* between their personal goal orientations and those emphasized by the environment. This means that any changes to students’ goal orientations that occur over the school year should be positively correlated with any differences between the students’ initial goal orientations towards science and the goals they perceive as being emphasized by their environment. This is different than the traditional assumption that there should be a positive correlation between the changes to students’ goal orientations that occur over a school year and the students’ perceptions of the goals emphasized by the environment. Thus, if we are correct, even though a science teacher may be seen by her students as emphasizing a particular goal in science, we would expect to see a *decrease* in the orientation towards that goal of students who, at the start of the school year, were even more focused on that particular goal than the teacher. We would expect to see no change

in the goal orientation towards science of students who, at the start of the school year, had similar goal orientations towards science as their teacher.

Different environmental factors pull the students in different directions; some may emphasize one type of goal orientation, others may emphasize other goal orientations or de-emphasize the first type of goal orientation, some may be relatively neutral. In addition, different environmental factors pull the students towards various goal orientations with different strengths, that is, the students may be more attuned to one environmental factor (for instance, peers) than to another (for instance, their parents). Thus, any changes that occur to a student’s motivation to engage with science will be the outcome of a complex interplay between the student’s initial goal orientation and multiple environmental factors, which may be unrelated to one another.

We built two regression models, one which tested whether it was students’ perceptions of the environmental emphases that drove the changes to their personal goal orientations towards science, as might be expected from past studies, and a second model which tested whether it were the *differences* between students’ perceptions of the environmental emphases and their goal orientations towards science that drove these changes.

The rest of this article describes in detail the theory underlying our approach, the methods we used to gather our data and analyze it, our findings and the implications of these findings.

Background

Goal orientation theory

Goal orientation theory (Dweck, 1986) is a motivation theory that addresses the goals which influence people’s engagement in various activities. There have been several versions to this theory, with some distinguishing between two types of goals (e.g., Ames, 1992) – mastery-oriented goals and performance-oriented goals – and others coming later distinguishing between three types of goals – self-oriented goals, task-oriented goals, and others-oriented goals (e.g., Elliot & Hulleman, 2017; Elliot, Murayama, & Pekrun, 2011). In addition, each type of goal has two valences – approach and avoidance (Elliot & McGregor, 2001), leading to 2×2 model and 3×2 models. As stated by Elliot and Hulleman (2017, p. 50), “... by no means is a later model meant to make obsolete a former model; a researcher’s specific question of interest should dictate the goal model on which he or she focuses. Likewise, ... using a subset of the goals from a particular model that match one’s research question is a sensible empirical strategy.” As will be explained later on, in this study we chose to focus on the 2×2 model and in particular on a single type of goal orientation – mastery-approach goals towards science.

According to the 2 × 2 model (mastery and performance × approach and avoidance), individuals who are mastery-approach oriented are motivated to improve themselves, to develop understanding and mastery of a subject or a specific task, such as when a person invests energy in reading about quantum mechanics until they have an inner sense that they understand the ideas. If individuals are mastery-avoidance oriented, they are motivated to avoid a situation where they will not have understanding or will not be able to complete a task, for example, when an elderly person is concerned about his deteriorating cognition and is driven to learn and practice a new language in the hope that this mental activity will prevent cognitive decline. Finally, with performance-oriented goals, individuals are motivated by the desire that others will recognize them as being capable, such as the desire to be at the top of the class (performance-approach orientation), or they may be afraid to ask questions in class because they are afraid of being recognized as being ignorant (performance-avoidance orientation).

Goal orientation theory has been widely used to understand the motivation (or the lack of it) in academic settings (e.g., Kaplan & Maehr, 2007; Linnenbrink & Pintrich, 2002) and with just about every age group (Utman, 1997). It was also used as the theoretical underpinning of a series of studies on the motivation to engage with science (Fortus & Daphna, 2017; Vedder-Weiss & Fortus, 2012, 2013, 2018) done by the authors whose findings provided the impetus for this present study. In general, it has been found that it is desirable to be mastery-approach oriented, as this orientation is usually positively correlated with many other desirable characteristics, such self-efficacy, interest, effort and persistence, retention of material learned and transfer of problem-solving strategies, so name a few (Anderman & Young, 1994; Bereby-Meyer & Kaplan, 2005; Cho, Weinstein, & Wicker, 2011; DeBacker & Nelson, 2000; Elliot, McGregor, & Gable, 1999; Elliot & McGregor, 1999; Patrick & Yoon, 2004). The evidence regarding performance-oriented goals is inconclusive (Harackiewicz, Barron, & Elliot, 1998; Urdan, 1997). When performance-approach goals were coupled with mastery-approach goals, they too led to desirable outcomes (Pintrich, 2000). However, the avoidance valence of all goals is usually associated with undesirable forms of engagement (Senko, Hulleman, & Harackiewicz, 2011).

In the rest of this article we focus solely on mastery-approach orientation towards science (we will call this for short MAOTS – Mastery-Approach Orientation Towards Science). Our goal was to develop a model that can explain the changes to adolescents' goal orientations towards science that occur over a single school year and we began from the simplest possible model, one that focused on only a single type of goal orientation. We chose

to begin with MAOTS because past research has shown it to be an important and desirable goal orientation in all situations. Clearly, the other goal orientations are also important and deserve to be studied; we believe that similar models can probably be developed for them as well, but further research is needed to evaluate them.

Student' perceptions of environmental goal emphases

Students' goal orientations are shaped by the emphases their environments places on different goals (Kaplan & Maehr, 2007; Mucherah, 2008), or actually by students' perceptions of these environmental emphases (Meece, Herman, & McCombs, 2003; Nolen & Haladyna, 1990; Vedder-Weiss & Fortus, 2013). If parents consistently relay to their child that they expect her to be at the top of her class in science, the child is likely to develop a performance-approach goal orientation towards science. Certain teaching practices have been shown to encourage students to embrace mastery-approach goals, such as providing for a degree of student autonomy (Vedder-Weiss & Fortus, 2018). However, just because teachers or parents try to convey certain motivational message doesn't necessarily mean that the student interprets these messages as they were intended to be understood. Meece, Anderman, and Anderman (2006, p. 496) have argued that "it is students' subjective perceptions that are most critical for understanding achievement-related patterns in the classroom."

We considered students' perceptions of four different environmental factors that have been shown in past studies to play a role in influencing students' motivation in general and in science in particular – school culture, parents, science teachers, and peers.

School culture

School culture is a term that is used to designate the norms, goals and values and beliefs of a school and the practices that result from them (Deal & Peterson, 2016; Kaplan & Maehr, 1997; Sarason, 1996). School culture plays a role in shaping students' motivation, engagement and achievement, both through its influence on teachers' practices (Deemer, 2004) and beyond the teachers' influence (Eccles et al., 1993; Kaplan & Maehr, 1997; Maehr & Midgley, 1991).

Relatively few studies have looked at student's perceptions of their school's goals emphases and the influence of these perceptions on the students' personal goal orientation. Roeser, Midgley, and Urdan (1996) showed that middle school students who perceived their school as emphasizing mastery goals (or performance goals) were more likely to be more mastery oriented themselves (or performance oriented). Maehr and Midgley (1991) demonstrated that school culture could be modified to increase an emphasis on mastery goals, leading to an

increase in students' personal goals orientation. Midgley, Anderman, and Hicks (1995) showed that school culture tends to be perceived as emphasizing performance orientation and de-emphasizing mastery orientation more by middle school students than by elementary school students. Related to this, and specifically in science, Vedder-Weiss and Fortus (2013) showed that the relative strength of the relationship between perceived school's emphasis on mastery in science and personal MAOTS was higher in middle school than in elementary school.

Parents

Parents can influence their children's motivation for learning by emphasizing the value of learning (Lamborn, Brown, Mounts, & Steinberg, 1992) or by the way they respond to their child's academic successes and failures (Kamins & Dweck, 1999). Students tend to adopt mastery goals and to be more persistent and effortful during demanding learning tasks when they are highly supported and encouraged by their parents to learn for the sake of understanding (Hokoda & Fincham, 1995; Wentzel, 1998).

However, only few studies investigated students' perceptions of their parents' goals emphases (Vedder-Weiss & Fortus, 2013). Friedel, Cortina, Turner, and Midgley (2007) and Gonida, Kiosseoglou, and Voulala (2007) showed that these perceptions were related to adolescents' personal goals orientations. Maehr (1991) showed that the motivation of young students was better predicted by their perceptions of their parents' goal emphases than by their perceptions of their school's emphases; as students matured, this changed, so that older students' goal orientations were better predicted by their perceptions of their school's goal emphases.

Science teachers

Teachers influence their students' motivation through their instructional practices (Swarat, Ortony, & Revelle, 2012), by encouraging the students (Wang & Eccles, 2012) and by acting as role models (Sjaastad, 2012). Teachers relay messages regarding desired goal emphases. Studies have shown that students tend to adopt goals that are associated with their teachers' emphases (Friedel et al., 2007; Meece et al., 2006; Vedder-Weiss & Fortus, 2013). Elementary school teachers tend, more than middle school teachers, to use instructional practices that emphasize a mastery orientation (Midgley et al., 1995), leading middle school students to perceive their teachers as emphasizing mastery less and performance more than do elementary school students (Anderman & Anderman, 1999).

Peers

While during adolescence peer relationships become very important to students, making peers a potentially influential factor on students' motivation for learning (Lee & Shute, 2010; Olitsky, Flohr, Gardner, & Billups, 2010), the mechanisms of their influence are still not fully understood. In one study, peers' academic support predicted students' motivation learning in English and in math (McInerney, 2012). Students' attitudes towards science were highly correlated with their friends' attitudes towards science (Simpson & Oliver, 1990), though it is unclear whether adolescents choose friends with similar attitudes to their own or whether one's friends' attitudes actually influence those of oneself. On the other hand, Vedder-Weiss and Fortus (2013) found that peers' influence on adolescents' goal orientation towards science was minor compared to the influence of significant adults, namely parents and science teachers.

Gender

Past studies have identified that boys and girls are not alike in issues related to affect towards science. For example, studies that have looked at attitudes towards science (Breakwell & Beardsell, 1992), motivation (Britner, 2008; DeBacker & Nelson, 2000), self-efficacy (Britner & Pajares, 2006), continuing motivation in science (Fortus & Vedder-Weiss, 2014), and career choice (Hazari, Sonnert, Sadler, & Shanahan, 2010; Sadler, Sonnert, Hazari, & Tai, 2012) have identified gender-based differences. Although it meant that our samples would be smaller, we chose in this study to look at boys and girls separately.

Looking at change rather than at state

Research on motivation has traditionally looked at the relations between perceptions of environmental factors and the *state* of an individual's motivation in order to try to explain why an individual's motivation is as it is. As stated in the introduction, in this study, however, we investigated the *change* to students' motivation for science learning, more specifically, the change to students' mastery-approach orientation to science (MAOTS) over a single school year. We studied whether this change is driven by: (A) students' perceptions of the emphasis placed on mastery in science by their science teacher, as predicted by past correlational studies of motivation, or by (B) the *differences* between students' perceptions of the science teacher's emphasis on mastery and their own personal MAOTS. According to the first perspective, changes to students' MAOTS over a school year should be independent of their MAOTS at the start of the year. According to the second perspective, students' MAOTS will increase or decrease during a school year, depending on whether their initial MAOTS was smaller or greater

than the emphasis they perceived the science teacher as having on mastery in science.

In addition, we hypothesized that the strength of the influence of the science teacher on a student's MAOTS is related to the magnitude of the difference between the student's perception of the science teacher's emphasis on MAOTS (e.g., how a student perceives their science teacher as emphasizing or de-emphasizing MAOTS) and the student's personal level of MAOTS. This quantitative perspective can help explain why one student's personal MAOTS changes faster than that of another student and perhaps also predict how much a student's personal MAOTS can change over the course of a year. These are features that could not be explained or predicted using the first perspective which does not consider the direction and size of the gaps between the individual and the science teacher. According to this new perspective, when a student perceives the science teacher as emphasizing MAOTS more/less than the student does themselves, the student's MAOTS should increase/decrease over time, causing the gap between the perceived science teacher's emphasis and the student's personal orientation to shrink. Not only that, the greater this initial gap is, the larger the shift in personal MAOTS we expect to see. When, at the start of a school year, a student's personal level of MAOTS is no different than the perceived emphasis of the science teacher on MAOTS, no change is expected.

However, reality is a bit more complicated. Students are influenced by many different environmental factors, not just by their science teachers, and these various environmental factors may reinforce or counteract one another. To be able to model the changes to a student's MAOTS, one needs to take into consideration the effects of all the major environmental factors. For example, a student's parents may highly emphasize MAOTS while the student's teacher may de-emphasize MAOTS, and so on. We need to consider all these influences simultaneously in order to be able to understand their combined effect and to figure out how the student's personal MAOTS will change because of them.

If this model is correct, once the relative influences of the various environmental factors on the students' MAOTS are known, we should be able to predict how their MAOTS will change over time.

Research questions

We developed two models, one which assumed, according to the traditional perspective on goal orientation research, that changes to students' MAOTS over a school year should be independent of their MAOTS at the start of the year. The second model assumed that students' MAOTS will increase or decrease during a school year, depending on whether their initial MAOTS was smaller

or greater than the emphasis they perceived the science teacher as having on mastery in science. The questions which motivated this study were: Which model best accounts for the changes to students' MAOTS over a single school year: one that uses students' perceptions of the environmental emphases on MAOTS as predictors, or one that uses the differences between students' perceptions of the environmental emphases on MAOTS and their own personal level of MAOTS at the start of the school year as predictors? Do these models differ for male and female students?

Methods

Data collection and participants

As part of a larger investigation, data were collected twice during a single school year from grades 5-8 of five schools in the same city in Israel, once during the second month of the school year (October) and once during the last 2 months of the school year (May-June). In some of the schools the data was during the 2012-2013 school year, while in others it was collected during the 2013-2014 school year. The city is one of the poorest in central Israel and is known intimately by one of the authors, who grew up there. Many of the city's inhabitants come from families that originated in North Africa, the Soviet Union and Ethiopia; 24% of the population are Moslems. All schools and teachers volunteered to participate. IRB approval was obtained from the ministry of education and required parents' signed consent.

After coding and "cleaning" the data, the total sample consisted of 1073 cases, of which only 510 were students who were sampled twice in the same year and fully completed their questionnaires both times. This high level of attrition in longitudinal studies is typical of the high poverty population in this town. The number of participants per grade, school, and gender who were sampled twice and completed their questionnaires, once at the beginning of a year and once at its end, is given in Table 1.

Instruments – questionnaire

We used a questionnaire in this study that was very similar to one used in previous studies (Vedder-Weiss & Fortus, 2013; Fortus & Daphna, 2017) but with a few modifications. Items that had exhibited low statistical reliability in prior administrations were removed, shortening the questionnaire. The questionnaire was also divided into sections to provide more clarity to the respondents. Each section focused on a different theoretical construct – personal goal orientation toward science, perceptions of science teacher emphases, perceptions of parents' emphases, etc.). The assessed constructs were students' personal mastery-approach, performance-approach and performance-

Table 1 Number of participants per grade, school, and gender

School	Grade	Boys	Girls	Total
A	5th	8	6	14
	6th	14	19	33
	7th	10	17	27
	8th	12	24	36
B	5th	9	10	19
	6th	8	7	15
	7th	9	10	19
	8th	19	14	33
C	9th	27	21	48
D	9th	47	45	92
E	5th	25	20	45
	6th	17	22	39
	7th	22	35	57
	8th	14	19	33

avoidance orientation towards science, and students' perceptions of their schools', parents', science teachers' and peers' emphasis on mastery-approach, performance-approach and performance-avoidance in science. The only constructs that interested us, for the purpose of this particular study, were students' personal mastery-approach orientation towards science (MAOTS) and their perceptions of their schools', parents', science teachers' and peers' emphasis on MAOTS. The items used to measure these constructs are provided, after being translated into English, in Additional file 1.

The participants received instruction for completing the questionnaires from one of the authors, who distributed the questionnaires, was present while students completed it, answered their questions, and collected the questionnaires from each student. The teachers were not present while the questionnaires were administered.

After the first year of data collection, it became apparent that the number of questions in the questionnaire was too large for the youngest students (whose reading skills were not as developed as those of participants who had responded in prior administrations of the questionnaire, which resulted in many incomplete questionnaires). It was decided to remove the section in the questionnaire that asked about peers' emphases. This decision was based on results from previous work (Vedder-Weiss & Fortus, 2013) that found only a weak relation between students' perceptions of their peers' goal emphases on MAOTS and the students' personal MAOTS at this age group. Our results from the sub-sample of students who completed the entire questionnaire in the first year of

the study, including items dealing with their perceptions of their peers, indicated that the choice we made was probably sound, as we found no significant relations that involved students' perceptions of their peers' motivational emphases.

Analyses

All analyses were done using R (R Core Team, 2018), the *rgl* (Adler, Nenadic, & Zucchini, 2003), *car* (Fox et al., 2007), *dplyr* (Wickham, Francois, Henry, & Müller, 2015) and *ggplot2* (Wickham, 2011) packages and the ConstructMap software (Wilson, 2010).

Since Likert items provide ordinal rather than interval data, polytomous Rasch analysis (Bond & Fox, 2001), specifically the graded response model (GRM) (Samejima, 1997), was used to transform the ordinal data into interval results, to validate the structure of each construct, and to calculate student scores for each construct. Since students responded to the questionnaire twice, once at the beginning of the school year and once near its end, each response was treated as a separate case when calculating the Rasch scores.

We first performed an analysis of variance of the change to personal MAOTS by grade ($F = 1.003$, $p = 0.406$), to verify that students from different grades could be pooled together.

To test the traditional perspective that changes to MAOTS should be driven by perceptions of the environmental emphases on MAOTS, linear regression was run between the changes to students' personal MAOTS and each of the students' perceptions of the various environmental emphases. To test the second perspective, that the *differences* between the perceptions of the environmental emphases and the personal MAOTS were what drove the changes to students' MAOTS, linear regression was run between the changes to students' personal MAOTS and each of the differences between students' perceptions of the environmental emphases and their personal MAOTS near the beginning of the school year. These regressions are akin to repeated measures ANOVA; what distinguishes them is what is used as the exogenous variable – in the first case it is the students' perceptions of the environmental emphases, while in the second case it is the differences between these perceived emphases and the students' personal MAOTS.

Finally, to identify which variables were the dominant predictors of changes to MAOTS, we performed a multiple-variable logistic regression of the changes to students' personal MAOTS. This choice was made due to the nonlinearity of the relations, as will be described in the Results section. In transforming the change in personal MAOTS to a binary variable, 1 indicated an increase in personal MAOTS while 0 a decrease in personal MAOTS.

Results

The infit for all items for all constructs fell within the 0.75–1.33 range. Table 2 presents the reliability scores (Cronbach *alpha*) for each construct. In addition, Wright maps and infit graphs for all constructs are presented in the Additional file 2.

We first checked to see that students' personal MAOTS at the end of the school year were positively correlated with their perceptions of the environments' emphases on MAOTS – See Table 3. The positive results confirmed prior research's findings – students are more likely to have a positive MAOTS orientation when they are in an environment that promotes MAOTS.

We then tested the traditional perspective, whether students' perceptions of the environmental emphases on MAOTS predicted the changes to their personal MAOTS. We constructed 2-dimensional scatterplots that depicted the change to the students' personal MAOTS vs. their perceived environmental emphases on MAOTS and ran a linear regression on each pairing of personal MAOTS with a perceived environmental emphasis. Figure 1 presents the results for all various environmental factors, disaggregated by gender. No significant linear relations were apparent ($p > .05$ for all scatterplots). This led us to conclude that the perceptions of the environmental emphases are not the drivers of change to MAOTS, as the traditional perspective predicts.

We then constructed the same set of graphs as in Fig. 1, except now we used the differences between the perceptions of the environmental emphases on MAOTS and the personal level of MAOTS as the variables on the horizontal axes – see Fig. 2.

A positive relation for both genders can be seen with regards to the parents, school and the science teacher (boys: parents- $\beta = 0.34$, $p < 0.001$; school - $\beta = 0.35$, $p < 0.001$; teacher - $\beta = 0.28$, $p < 0.001$; girls: parents - $\beta = 0.31$, $p < 0.001$; school - $\beta = 0.38$, $p < 0.001$; teacher - $\beta = 0.42$, $p < 0.001$). This means that the change in students' personal MAOTS is related to the gaps between their perception of the emphases of these environmental factors on MAOTS and their personal MAOTS at the beginning of the school year. This was the first indication we received that the second perspective might be correct, that it is the differences between the perceptions of the environment

and the students that lead to change, not the perceptions of the environment on their own.

Although 2-dimensional graphs were a good starting point, since we were dealing with multiple exogenous variables, they did not allow us to fully visualize any trends, so we moved to 3-dimensional graphs which allowed us to better visualize the interplay between the variables. To assist in visualizing this interplay, a smooth non-linear best-fit surface was added to the plot. Figures 3 and 4 show the change in personal MAOTS as a function of two variables on the axes – the difference between perceived teachers' emphasis on MAOTS and personal MAOTS (marked Teacher–Student on one of the horizontal axes) and the difference between perceived parents' emphasis on MAOTS and personal MAOTS (marked Parents–Student on the other horizontal axis), and as a function of a third variable – the difference between perceived school's emphasis on MAOTS and personal MAOTS – in the layers of the graph. Figure 3 is for boys and Fig. 4 is for girls.

Figures 3 and 4 show a clear dependency of the change to both boys' and girls' personal MAOTS on the difference between their perceptions of the environment's emphasis on MAOTS and their own personal MAOTS. The best-fit surfaces are clearly nonlinear.

Since the relations between the variables was non-linear, a logistic regression of the change to personal MAOTS by the various environmental variables was run; the results are given in Table 4. We see that the difference between boys' perceptions of their teachers' emphasis on MAOTS and their personal MAOTS was the principal predictor of changes to the personal MAOTS, while for girls both the difference between their perceptions of their parents' emphasis on MAOTS and their personal MAOTS and the difference between their perceptions of their school's emphasis on MAOTS and their personal MAOTS were significant predictors.

Discussion

Traditionally, research on goal orientation has considered how the environment influences students' goal orientations by looking at the *state* of students' motivation, their perceptions of the environment, and possible connections between the two (Meece et al., 2003; Nolen &

Table 2 Cronbach *alpha* values for each construct

Construct name	Number of Items	Cronbach <i>alpha</i>
Perception of School's Emphasis on MAOTS	4	0.66
Perception of Teacher's Emphasis on MAOTS	6	0.81
Personal MAOTS	5	0.88
Perception of Parents' Emphasis on MAOTS	4	0.74

Table 3 Correlations between students’ personal MAOTS and their perceptions of the environmental emphases on MAOTS

	Teachers’ Emphasis on MAOTS	School’s Emphasis on MAOTS	Parents’ Emphasis on MAOTS
Boys’ Personal MAOTS	$r = 0.52$ $t = 9.11, df = 222, p < .001$	$r = 0.29$ $t = 4.55, df = 228, p < .001$	$r = 0.39$ $t = 6.24, df = 222, p < .001$
Girls’ Personal MAOTS	$r = 0.38$ $t = 6.49, df = 246, p < .001$	$r = 0.33$ $t = 5.54, df = 258, p < .001$	$r = 0.44$ $t = 7.71, df = 252, p < .001$

Haladyna, 1990). It has been found, for example, that when children had science teachers that were perceived as emphasizing a particular goal orientation, these children were likely to adopt that same goal orientation in science, leading to a positive correlation between the children’s goal orientations in science and those they perceived their science teachers as having (Vedder-Weiss & Fortus, 2013).

This study went a step further, and rather than focusing on the *state* of students’ goal orientation towards science at a given time during the year, it focused on the *changes* to students’ goal orientations towards science during a single school year. We hypothesized that when students find themselves in an environment that emphasizes/de-emphasizes a particular goal orientation towards science in a manner that differs from their

Fig. 2 Changes to personal MAOTS vs. difference between perceived environmental emphases on MAOTS and personal MAOTS

personal goal orientations, their personal goal orientations would change by drifting with time towards the goals they perceived being emphasized by the environment, leading to positive correlations between the two. Different environmental emphases would pull the students in different directions and with different strengths, with the overall change to students' goal orientations towards science being the outcome of the aggregated influence of the various environmental emphases. This study provides the first empirical evidence to support this hypothesis.

Using mastery-approach as the first goal orientation to be tested under this hypothesis, we measured students' MAOTS near the beginning and the end of a school year and from them calculated the change to their personal MAOTS over the school year. This is the *change* in

MAOTS. In parallel we measured their perceptions of their parents', science teachers', and school's emphases on MAOTS near the start of the school year and calculated the differences between these perceived emphases and their personal MAOTS at the beginning of the school year. These are the external influences, the *forces* to which the students' MAOTS are subjected. Linear regression indicated that: A) there was a positive relation between the *state* of students' MAOTS and their perceptions of the environmental emphases, as has been shown in past studies (e.g., Vedder-Weiss & Fortus, 2013); B) there was no significant relation between the *change* in students' MAOTS and their perceptions of the environmental emphases, even though this is predicted by the traditional perspective; and C) there were positive and significant relations between the *change* in students'

Table 4 Odd-ratio results for logistic regression

Variable	Males		Females	
	Estimate	p-value	Estimate	p-value
Intercept	1.11	ns	1.19	ns
Teacher-student difference	1.03	ns	1.56	0.02
School-student difference	1.15	ns	1.49	0.04
Parents-student difference	1.81	< 0.001	1.13	ns

personal MAOTS and the external *forces* to which they were subjected, as is predicted by the new perspective. All these statistical tests were done for boys and girls separately and provided similar results.

These positive findings are impressive because they were received despite several possible confounders: (A) When students meet their science teacher at the start of a school year, the teacher may have taught them also in the prior year or not. If she taught them in the prior year, her influence on the students MAOTS will be different than if this was the first time she was teaching these students (Zahorik & Dichanz, 1994). Does a new teacher have a greater or smaller influence on the students' MAOTS than a second-year teacher? We did not distinguish between the two cases, but had we gathered that data and had a large enough sample, it should have been possible to study the possible effect this may have had. (B) How long does it take for a teacher to have a measurable influence on her students' MAOTS? If it is very rapid, it is very important to measure students' initial MAOTS at the very start of the school year, not a month or a bit more later. The initial data in this study were not gathered at the very beginning of the school year, but about a month later. A future study could gather data at the very start of the year and then throughout the school year, not just at its end. This would allow us to see how the students' personal MAOTS actually develops with time and whether it stabilizes after a certain time. (C) What happens if the goal emphasis of a science teacher, of parents or the school, changes during the school year? We expect such changes will change the direction of any shift occurring to the students. However, we expect to see less change to adults' goal emphases unless they too are engaged in an environment that can lead to shift within them, such as a teacher undergoing professional development (PD) with a focus on goal orientations. To the best of our knowledge, none of the teachers whose students participated in this study underwent any PD on goal orientations, none of the school principals changed during the study, so we ignored this potential confounder. (D) As students' goal orientations change, it is to be expected that their perceptions of the environment change as well (Meece et al., 2006), and as these change, their influence on the students will change as well. We did not measure

changes to students' perceptions of the environmental emphases so we cannot say how big these changes are and if they may be of importance. (E) 5th graders are not the same as 9th graders. Younger children are likely to be more responsive to their parents than older children who are in the middle of adolescence and possibly attempting to gain some autonomy from their parents (Steinberg, 1987). We did not disaggregate between students in different age groups because our sample was too small for that. A future study would study different aged students separately to see how their attentiveness to the different environmental emphases change as they mature.

A nice additional confirmation of the new perspective is given by the neutral point: Students who happen to perceive their environment as promoting MAOTS in a manner that is identical to their own level of MAOTS, meaning that the differences between the two vanish (no external forces), should not change their personal MAOTS over time. Graphically this means then when, for example TEACHER – STUDENT and PARENTS – STUDENT in Figs. 3 and 4 are both equal zero, the change to MAOTS should also be zero. This, as Figs. 3 and 4 indicate, appears to be so. This is confirmed by the values of the intercept given in Table 4.

Our model assumes a linear relation between the external *force* and *change in state*. Figure 3 indicates that this is not so, that positive environmental forces have a greater impact on the change in state than negative environmental forces (the gradient at the upper right-hand side of the surface is greater than at the lower left-hand side). This is encouraging because it means that it is easier, over the span of a single school year, to enhance students' MAOTS than it is to make it wane.

Conclusions

What do these results mean? When we are surrounded by people who are similar to us, value and emphasize the same things, there is no reason for us to change. However, when there is a person in our environment who differs from us, who does things differently and stresses different things, if that person is someone who is important and significant to us, we may re-evaluate our own position and change somewhat due to that person's influence, adopting more of what we perceive that person as emphasizing. If there are many people in our environment who are important to us and whose goal emphases appear to us to be similar, there is a greater chance that we will change to become more like the way we perceive them. This study indicates that not all external factors are of equal importance in driving changes to our mastery-approach orientation in science; it appears, for the students who participated in this study, that

teachers were the most influential factor, followed by parents, with school culture playing the smallest role.

It is important to emphasize to science teachers, both in their pre-service and in-service training, that the way they are perceived by their students is a significant and important influence on their students' motivation. Messages that they explicitly and implicitly relay about what is important in the learning of science, such as whether it is about getting good grades, wanting to really get to the bottom of things, developing a personal interest, or just doing what you're told, have a real impact on students' motivation (Rosenthal & Jacobson, 1968; Vedder-Weiss & Fortus, 2018). Even students who already appear to be mastery-oriented need to receive reinforcing messages about the importance of mastery in science, otherwise their motivation is likely to wane.

We wish to remind the readers how culturally bound motivational studies can be. This study was done with low-SES Israeli students. Past motivational studies done in Israel have shown different motivational trends and relationships for different Israeli groups. We assume that had this study been done with mid-high SES Israeli students or with students elsewhere in the world, the details of the results would have changed, for example, finding that schools play a more important role than they did in this study. However, we trust that the main finding, that the changes to personal MAOTS are dependent on the differences between the perceived environmental emphasis and the personal MAOTS, would remain intact.

We believe that this study may open up a new direction in the quantitative study of motivation. The next steps we would recommend would involve studying the relevance of the potential confounding factors mentioned above, evaluating whether similar findings are received when studying MAOTS in different cultural groups, and investigating whether goal orientations to science other than self-approach behave similarly. Hopefully this new perspective will allow us to deepen our understanding of the ways in which the environment shapes students' motivation to engage with science and to design interventions that aim at enhancing this motivation.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s43031-020-00029-0>.

Additional file 1.

Additional file 2.

Acknowledgements

The first author is the Chief Justice Bora Laskin Professorial Chair of Science Teaching.

Authors' contributions

Both authors contributed equally to the study. The author(s) read and approved the final manuscript.

Funding

No external funding was received for this study.

Availability of data and materials

Not applicable.

Ethics approval and consent to participate

Approval to conduct this study was given by the Office of the Chief Scientist of the Israeli Ministry of Education.

Consent for publication

Not applicable.

Competing interests

Neither one of the authors has any competing financial or non-financial interests.

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Received: 2 September 2020 Accepted: 26 November 2020

Published online: 04 January 2021

References

- Adler, D., Nenadic, O., & Zucchini, W. (2003, March). Rgl: A r-library for 3d visualization with opengl. In *Proceedings of the 35th Symposium of the Interface: Computing Science and Statistics, Salt Lake City*, (vol. 35, pp. 1–11).
- Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology*, 84, 261–271.
- Anderman, E. M., & Midgley, C. (1997). Changes in achievement goal orientations, perceived academic competence, and grades across the transition to middle-level schools. *Contemporary Educational Psychology*, 22(3), 269–298.
- Anderman, E. M., & Young, A. J. (1994). Motivation and strategy use in science: Individual differences and classroom effects. *Journal of Research in Science Teaching*, 31(8), 811–831.
- Anderman, L. H., & Anderman, E. M. (1999). Social predictors of changes in students' achievement goal orientations. *Contemporary Educational Psychology*, 24(1), 21–37.
- Bereby-Meyer, Y., & Kaplan, A. (2005). Motivational influences on transfer of problem-solving strategies. *Contemporary Educational Psychology*, 30(1), 1–22.
- Bond, T. G., & Fox, C. M. (2001). *Applying the Rasch model: Fundamental measurement in the human sciences*. Mahwah: Lawrence Erlbaum.
- Breakwell, G. M., & Beardsell, S. (1992). Gender, parental and peer influences upon science attitudes and activities. *Public Understanding of Science*, 1(2), 183–197.
- Britner, S. L. (2008). Motivation in high school science students: A comparison of gender differences in life, physical, and earth science classes. *Journal of Research in Science Teaching*, 45(8), 955–970.
- Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching*, 43(5), 485–499.
- Cho, Y., Weinstein, C. E., & Wicker, F. (2011). Perceived competence and autonomy as moderators of the effects of achievement goal orientations. *Educational Psychology*, 31(4), 393–411.
- Deal, T. E., & Peterson, K. D. (2016). *Shaping school culture*. Hoboken: Wiley.
- DeBacker, T. K., & Nelson, M. R. (2000). Motivation to learn science: Differences related to gender, class type, and ability. *The Journal of Educational Research*, 93(4), 245–254.
- Deemer, S. (2004). Classroom goal orientation in high school classrooms: Revealing links between teacher beliefs and classroom environments. *Educational Research*, 46(1), 73–90.
- Dweck, C. S. (1986). Motivational processes affecting learning. *American Psychologist*, 41, 1040–1048.
- Eccles, J. S., Wigfield, A., Midgley, C., Reuman, D., Mac Iver, D., & Feldlaufer, H. (1993). Negative effects of traditional middle schools on students' motivation. *The Elementary School Journal*, 93(5), 553–574.

- Elliot, A. J. and P. G. Devine (1994). On the motivational nature of cognitive dissonance: Dissonance as psychological discomfort. *Journal of Personality and Social Psychology* 67(3), 382–394.
- Elliot, A. J., & Hulleman, C. S. (2017). Achievement goals. *Handbook of Competence and Motivation: Theory and Application*, 2, 43–60.
- Elliot, A. J., McGregor, H. A., & Gable, S. (1999). Achievement goals, study strategies, and exam performance: A mediational analysis. *Journal of Educational Psychology*, 91(3), 549–563.
- Elliot, A. J., & McGregor, H. A. (1999). Test anxiety and the hierarchical model of approach and avoidance achievement motivation. *Journal of Personality and Social Psychology*, 76(4), 628–644.
- Elliot, A. J., & McGregor, H. A. (2001). A 2 X 2 achievement goal framework. *Journal of Personality and Social Psychology*, 80(3), 501–519.
- Elliot, A. J., Murayama, K., & Pekrun, R. (2011). A 3x 2 achievement goal model. *Journal of Educational Psychology*, 103(3), 632.
- Festinger, L. (1957). A theory of cognitive dissonance, Stanford University Press.
- Fortus, D., & Daphna, L. (2017). Adolescents' goal orientations for science in single-gender Israeli religious schools. *International Journal of Science Education*, 39(1), 86–103.
- Fortus, D., & Vedder-Weiss, D. (2014). Measuring students continuing motivation for science learning. *Journal of Research in Science Teaching*, 51(4), 497–522.
- Fox, J., Friendly, G. G., Graves, S., Heiberger, R., Monette, G., Nilsson, H., ... Suggests, M. A. S. S. (2007). The car package. In *R Foundation for Statistical Computing*.
- Friedel, J. M., Cortina, K. S., Turner, J. C., & Midgley, C. (2007). Achievement goals, efficacy beliefs and coping strategies in mathematics: The roles of perceived parent and teacher goal emphases. *Contemporary Educational Psychology*, 32(3), 434–458.
- Gonida, E. N., Kiosseoglou, G., & Voulala, K. (2007). Perceptions of parent goals and their contribution to student achievement goal orientation and engagement in the classroom: Grade-level differences across adolescence. *European Journal of Psychology of Education*, 22(1), 23–39.
- Harackiewicz, J. M., Barron, K. E., & Elliot, A. J. (1998). Rethinking achievement goals: When are they adaptive for college students and why? *Educational Psychologist*, 33(1), 1–21.
- Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M.-C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, 47(8), 978–1003.
- Hokoda, A., & Fincham, F. D. (1995). Origins of children's helpless and mastery achievement patterns in the family. *Journal of Educational Psychology*, 87(3), 375–385.
- Kamins, M., & Dweck, C. S. (1999). Person versus process praise and criticism: Implications for contingent self-worth and coping. *Developmental Psychology*, 35(3), 835–848.
- Kaplan, A., & Maehr, M. L. (1997). School cultures. In A. Walberg, & G. Haertel (Eds.), *Psychology and educational practice*, (pp. 342–355). Berkeley: McCutchan.
- Kaplan, A., & Maehr, M. L. (2007). The contributions and prospects of goal orientation theory. *Educational Psychological Review*, 19(2), 141–184.
- Lamborn, S. D., Brown, B. B., Mounts, N. S., & Steinberg, L. (1992). Putting school in perspective: The influence of family, peers, extracurricular participation, and part-time work on academic engagement. In F. M. Newmann (Ed.), *Student engagement and achievement in American secondary schools*, (pp. 153–181). New York: Teachers College Press.
- Lee, J., & Shute, V. J. (2010). Personal and socio-contextual factors in K-12 academic performance: An integrative perspective on student learning. *Educational Psychologist*, 45(3), 185–202.
- Linnenbrink, E. A., & Pintrich, P. R. (2002). Achievement goal theory and affect: An asymmetrical bidirectional model. *Educational Psychologist*, 37(2), 69–78.
- Maehr, M. L. (1991). The "psychological environment" of the school: A focus for school leadership. In P. Thurstone, & P. Zoghates (Eds.), *Advances in Educational Administration*, (vol. 2: School leadership, pp. 51–81). Greenwich: JAI Press.
- Maehr, M. L., & Midgley, C. (1991). Enhancing student motivation: A school wide approach. *Educational Psychologist*, 26(3 & 4), 399–427.
- McInerney, D. M. (2012). Parents, teachers, and peers: Who has most influence on student motivation and achievement? In *Paper presented at the American Educational Research Association, Vancouver, British Columbia, Canada*.
- Meece, J. L. (1991). The classroom context and students' motivational goals. In M. L. Maehr, & P. R. Pintrich (Eds.), *Advances in motivation and achievement*, (vol. 7, pp. 261–285). Greenwich: JAI Press.
- Meece, J. L., Anderman, E. M., & Anderman, L. H. (2006). Classroom goal structure, student motivation, and academic achievement. *Annual Review of Psychology*, 57, 487–503.
- Meece, J. L., Herman, P., & McCombs, B. L. (2003). Relations of learner-centered teaching practices to adolescents' achievement goals. *International Journal of Educational Research*, 39(4-5), 457–475.
- Midgley, C., Anderman, E. M., & Hicks, L. (1995). Differences between elementary and middle school teachers and students: A goal theory approach. *The Journal of Early Adolescence*, 15(1), 90.
- Miller, A. D., & Murdock, T. B. (2007). Modeling latent true scores to determine the utility of aggregate student perceptions as classroom indicators in HLM: The case of classroom goal structures. *Contemporary Educational Psychology*, 32(1), 83–104.
- Mucherah, W. (2008). Classroom climate and students' goal structures in high-school biology classrooms in Kenya. *Learning Environment Research*, 11(1), 63–81.
- Nolen, S. B., & Haladyna, T. M. (1990). Motivation and studying in high school science. *Journal of Research in Science Teaching*, 27(2), 115–126.
- Olitsky, S., Flohr, L. L., Gardner, J., & Billups, M. (2010). Coherence, contradiction, and the development of school science identities. *Journal of Research in Science Teaching*, 47(10), 1209–1228.
- Patrick, H., & Yoon, C. (2004). Early adolescents' motivation during science investigation. *The Journal of Educational Research*, 97(6), 319–328.
- Pintrich, P. R. (2000). Multiple goals, multiple pathways: The role of goal orientation in learning and achievement. *Journal of Educational Psychology*, 92(3), 544.
- R Core Team (2018). *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing Retrieved from <http://www.R-project.org/>.
- Roeser, R. W., Midgley, C., & Urdan, T. C. (1996). Perceptions of the school psychological environment and early adolescents' self appraisals and academic engagement: The mediating role of goals and belonging. *Journal of Educational Psychology*, 88(3), 408–422.
- Rosenthal, R., & Jacobson, L. (1968). *Pygmalion in the classroom: Teacher expectation and pupils' intellectual development*. Holt: Rinehart & Winston.
- Sadler, P. M., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education*, 96(3), 411–427.
- Samejima, F. (1997). Graded response model. In *Handbook of modern item response theory*, (pp. 85–100). New York: Springer.
- Sarason, S. B. (1996). *Revisiting "The culture of the school and the problem of change"*. New York: Teachers College Press.
- Schunk, D. H., Pintrich, P. R., & Meece, J. L. (2008). *Motivation in education: Theory, research and application*. Upper Saddle River: Pearson.
- Senko, C., Hulleman, C. S., & Harackiewicz, J. M. (2011). Achievement goal theory at the crossroads: Old controversies, current challenges, and new directions. *Educational Psychologist*, 46(1), 26–47.
- Simpson, R. D., & Oliver, J. S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education*, 74(1), 1–18.
- Sjaastad, J. (2012). Sources of inspiration: The role of significant persons in young people's choice of science in higher education. *International Journal of Science Education*, 34(10), 1615–1636.
- Song, J., Bong, M., Lee, K., & Kim, S.-I. (2015). Longitudinal investigation into the role of perceived social support in adolescents' academic motivation and achievement. *Journal of Educational Psychology*, 107(3), 821.
- Steinberg, L. D. (1987). Family processes at adolescence: A developmental perspective. *Family Therapy*, 14(2), 77.
- Swarat, S., Ortony, A., & Revelle, W. (2012). Activity matters: Understanding student interest in school science. *Journal of Research in Science Teaching*, 49(4), 515–537.
- Urdan, T. (1997). Achievement goal theory: Past results, future directions. *Advances in Motivation and Achievement*, 10, 99–141.
- Utman, C. H. (1997). Performance effects of motivational state: A meta-analysis. *Personality and Social Psychology Review*, 1(2), 170–182.
- Vedder-Weiss, D., & Fortus, D. (2012). Students' declining motivation to learn science: A follow up study. *Journal of Research in Science Teaching*, 49(9), 1057–1095.
- Vedder-Weiss, D., & Fortus, D. (2013). School, teacher, peers and parents' goals emphases and adolescents' motivation to learn science in and out of school. *Journal of Research in Science Teaching*, 50(8), 952–988.

- Vedder-Weiss, D., & Fortus, D. (2018). Teachers' mastery goals: Using a self-report survey to study the relations between teaching practices and students' motivation for science learning. *Research in Science Education*, 48(1), 181–206.
- Wang, M. T., & Eccles, J. S. (2012). Adolescent behavioral, emotional, and cognitive engagement trajectories in school and their differential relations to educational success. *Journal of Research on Adolescence*, 22(1), 31–39.
- Wentzel, K. R. (1998). Social relationships and motivation in middle school: The role of parents, teachers, and peers. *Journal of Educational Psychology*, 90(2), 202–209.
- Wickham, H. (2011). ggplot2. *Wiley Interdisciplinary Reviews: Computational Statistics*, 3(2), 180–185.
- Wickham, H., Francois, R., Henry, L., & Müller, K. (2015). dplyr: A Grammar of Data Manipulation. R package version 0.4.3. R Found. Stat. Comput., Vienna. <https://CRAN.R-project.org/package=dplyr>.
- Wilson, M. (2010). *ConstructMap*. Berkeley: University of Berkeley Retrieved from <https://bearcenter.berkeley.edu/software/constructmap>.
- Zahorik, J. A., & Dichanz, H. (1994). Teaching for understanding in German schools. *Educational Leadership*, 51(5), 75–77.

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