Electronic Supplementary Information

Investigation of evidence for the internal structure of a modified science motivation questionnaire II (mSMQ II): a failed attempt to improve instrument functioning across course, subject, and wording variants

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Table S1. Trajectory of scales and item modifications from the original SMQ to the SMQ II

(2006; Original SMQ)		(2009; SMQ Modifications)		(2011; SMQ II)	
Intrinsically Motivated Science Learning	--	**Intrinsic Motivation and Personal Relevance**	--	**Intrinsic Motivation**	I am curious about discoveries in science.
	--		--		Learning science makes my life more meaningful.
	I enjoy learning the science.		I enjoy learning the science.		I enjoy learning science.
	The science I learn is more important to me than the grade I receive.		The science I learn is more important to me than the grade I receive.		--
	I find learning the science interesting.		I find learning the science interesting.		Learning science is interesting.
	I like science that challenges me.		I like science that challenges me.		--
	Understanding the science gives me a sense of accomplishment.		Understanding the science gives me a sense of accomplishment.		--
Relevance of Learning Science to Personal Goals	The science I learn relates to my personal goals.		The science I learn relates to my personal goals.		--
	I think about how the science I learn will be helpful to me.		I think about how the science I learn will be helpful to me.		--
	I think about how I will use the science I learn.		I think about how I will use the science I learn.		--
	The science I learn is relevant to my life.		The science I learn is relevant to my life.		The science I learn is relevant to my life.
	The science I learn has practical value for me.		The science I learn has a practical value for me.		--
Confidence (Self-efficacy) in Learning Science	I expect to do as well or better than other students in the science course.	**Self-efficacy and Assessment Anxiety**	--	**Self-efficacy**	--
	I am confident I will do well on the science labs and projects.		I am confident I will do well on the science labs and projects.		I am confident I will do well on science labs and projects.
	I believe I can master the knowledge and skills in the science course.		I believe I can master the knowledge and skills in the science course.		I believe I can master science knowledge and skills.
	I am confident I will do well on the science tests.		I am confident I will do well on the science tests.		I am confident I will do well on science tests.
	I believe I can earn a grade of "A" in the science course.		I believe I can earn a grade of "A" in the science course.		I believe I can earn a grade of "A" in science.
	--		--		I am sure I can understand science.
Anxiety About Science Assessment	I am nervous about how I will do on the science tests.		I am nervous about how I will do on the science tests.		--
	I become anxious when it is time to take a science test.		I become anxious when it is time to take a science test.		--
	I worry about failing the science tests.		I worry about failing the science tests.		--
	I am concerned that the other students are better in science.		I am concerned that the other students are better in science.		--
	I hate taking the science tests.		I hate taking the science tests.		--

Table S1. (continued)

2006 (Original SMQ)		2009 (SMQ Modifications)		2011 (SMQ II)	
Responsibility (Self-determination) for Learning Science	If I am never having trouble learning the science, I try to figure out why.	**Self-determination**	If I am never having trouble learning the science, I try to figure out why.	**Self-determination**	----------
	I put enough effort into learning the science.		I put enough effort into learning the science.		I put enough effort into learning science.
	I use strategies that ensure I learn the science well.		I use strategies that ensure I learn the science well.		I use strategies to learn science well.
	It is my fault if I do not understand the science.		----------		----------
	I prepare well for the science tests and labs.		I prepare well for the science tests and labs.		I prepare well for science tests and labs.
	----------		----------		I study hard to learn science.
	----------		----------		I spend a lot of time learning science.
Extrinsically Motivated Science Learning	I think about how learning the science can help me get a good job.	**Career Motivation**	I think about how learning the science can help me get a good job.	**Career Motivation**	----------
	I think about how learning the science can help my career.		I think about how learning the science can help my career.		----------
	----------		----------		Learning science will help me get a good job.
	----------		----------		Understanding science will benefit me in my career.
	----------		----------		Knowing science will give me a career advantage
	----------		----------		I will use science problem-solving skills in my career.
	----------		----------		My career will involve science.
	Earning a good science grade is important to me.	**Grade Motivation**	Earning a good science grade is important to me.	**Grade Motivation**	Getting a good science grade is important to me
	I think about how my science grade will affect my overall grade point average.		I think about how my science grade will affect my overall grade point average.		----------
	I like to do better than the other students on the science tests.		I like to do better than the other students on the science tests.		I like to do better than other students on science tests.
	----------		I expect to do as well as or better than other students in the science course.		----------
	----------		It is my fault, if I do not understand the science.		----------
	----------		----------		I think about the grade I will get in science.
	----------		----------		Scoring high on science tests and labs matters to me.
	----------		----------		It is important that I get an "A" in science.

Table S2. Summary of SMQ II studies utilizing exploratory factor analysis.

Citation	Sample	Modifications	Rotation	Method	Number of Factors
(Glynn *et al.*, 2011)	340 university biology students	None	Varimax and Direct Oblimin	Principal Components Analysis and Principal Axis Factoring	Five
(Ardura and Pérez-Bitrián, 2018)	530 high school students	Translated to Spanish; Physics and chemistry wording	Varimax	Principal Components Analysis	Five
(Austin *et al.*, 2018)	2648 university chemistry students	Organic chemistry wording; Removed six items	Promax	Principal Axis Factoring	Four
(Kwon, 2016)	334 middle school students	Technology wording; Changed response scale; Removed six items	Varimax	Principal Axis Factoring	Five
(Schmid and Bogner, 2017)	209 high school students	Changed response scale; Only used self-efficacy, self-determination, and career motivation scales; Reduced scales to four items each	Oblimin	Principal Axis Factoring	Three
(Schumm and Bogner, 2016)	226 high school students	Adapted for German; Removed three items	Oblique	Principal Axis Factoring	Five
(Yamamura and Takehira, 2017)	165 pharmacy students	Translated to Japanese; Pharmacy wording; Removed 12 items including all self-efficacy items	Promax	Maximum Likelihood	Four

Table S3. Summary of SMQ II studies utilizing confirmatory factor analysis with acceptable data-model fit index values bolded.

Citation	Sample	Modifications	[a]Fit Indices			Model	Estimator
			CFI	**RMSEA**	**SRMR**		
(Glynn *et al.*, 2011)	340 university biology students	None	0.91	0.07	**0.04**	Correlated five-factor	Not reported
(Ardura and Pérez-Bitrián, 2018)	530 high school students	Translated to Spanish; Physics and chemistry wording	0.92	0.07	**0.04**	Correlated five-factor	Not reported
(González *et al.*, 2017)	520 high school students	Translated to Spanish; Physics wording; Only self-efficacy scale	**0.998**	**0.043**	**0.011**	Single factor	Not reported
(Komperda *et al.*, 2018)	146 university general chemistry students	None	0.94	0.08	Not reported	Correlated five-factor	WLSMV
(Komperda *et al.*, 2018)	141 university general chemistry students	Chemistry wording	**0.96**	0.08	Not reported	Correlated five-factor	WLSMV
(Komperda *et al.*, 2018)	189 university introductory chemistry students	None	**0.97**	0.07	Not reported	Correlated five-factor	WLSMV
(Komperda *et al.*, 2018)	184 university introductory chemistry students	Chemistry wording	0.94	0.09	Not reported	Correlated five-factor	WLSMV
(Kwon, 2016)	334 middle school students	Technology wording; Changed response scale	0.939	0.067	Not reported	Correlated five-factor	Not reported
(Salta and Koulougliotis, 2015)	330 high school students	Translated to Greek; Chemistry wording; Removed lab references	0.91	**0.06**	**0.06**	Correlated five-factor	ML

Table S3. (continued)

Citation	Sample	Modifications	[a]Fit Indices			Model	Estimator
			CFI	RMSEA	SRMR		
(Tosun, 2013)	306 high school students	Translated to Turkish; Chemistry wording; Removed six items	**0.96**	**0.059**	Not reported	Correlated five-factor	Not reported
(Tosun, 2013)	266 university students	Translated to Turkish; Chemistry wording; Removed five items	**0.96**	**0.059**	Not reported	Correlated five-factor	Not reported
(Vasques *et al.*, 2018)	203 university students (Pre)	Translated to Japanese; Removed a self-efficacy item	0.86	0.10	Not reported	Correlated five-factor	Not reported
Vasques *et al.*, 2018)	230 university students (Post)	Translated to Japanese; Removed a self-efficacy item	0.86	0.11	Not reported	Correlated five-factor	Not reported
(Yamamura and Takehira, 2017)	165 pharmacy students	Translated to Japanese; Pharmacy wording; Removed 12 items including all self-efficacy items	**0.994**	**0.020**	Not reported	Correlated four-factor with cross loadings	Not reported

[a]Fit index values recommended by Hu and Bentler (1999) are CFI ≥ 0.95; RMESA ≤ 0.06 and SRMR ≤ 0.08.

Table S4. Codes assigned to student responses to SMQ II items. Italicized portions of the examples represent language reflective of the respective code.

Code – Definition	Example quote	Response	Item
Frequency-based Used words from the frequency scale or similar time-based words.	"I feel like I take to chemistry pretty well. *Occasionally* there's things I struggle with, things I need to study harder with. But I feel like I understand chemistry well and *frequently* do well on my tests and stuff."	Usually	SE1
	"I'm pretty confident, you know, in my skills with chemistry. So, it's *not always* on my mind…."	Sometimes	G4
Quantity-based Used language that involved quantity or comparison in their response that was not specifically time-based.	"I really love science, but chemistry seems to be most math for me. Math is, like, the scariest thing I can imagine. If I imagine hell, it's just doing math over and over again. Yeah, so it's sometimes because *I love science but not the math part*."	Sometimes	I5
	"I think it kinda relates to the same question earlier, where it does give a career advantage because it does open up *more opportunities for more open jobs, compared to the average person*. So that's why I thought that it would give you the career advantage."	Usually	C2

Table S5. Percentages of experts (n=12) indicating alignment of each SMQ II item with a response scale. Cells with a majority of expert selections are bolded.

Item		SMQ II wording	Frequency (%)	Likert (%)	Either (%)
Intrinsic	I1	The science I learn is relevant to my life	8%	**58%**	33%
	I2	Learning science is interesting	25%	33%	42%
	I3	Learning science makes my life more meaningful	8%	**75%**	17%
	I4	I am curious about discoveries in science	25%	33%	42%
	I5	I enjoy learning science	8%	33%	**58%**
Self-determination	SD1	I put enough effort into learning science	**67%**	0%	33%
	SD2	I use strategies to learn science well	**58%**	0%	42%
	SD3	I spend a lot of time learning science	42%	25%	33%
	SD4	I prepare well for science tests and labs	**67%**	0%	33%
	SD5	I study hard to learn science	**67%**	0%	33%
Self-efficacy	SE1	I am confident I will do well on science tests	42%	25%	33%
	SE2	I am confident I will do well on science labs and projects	42%	25%	33%
	SE3	I believe I can master science knowledge and skills	25%	**50%**	25%
	SE4	I believe I can earn a grade of "A" in science	25%	**58%**	17%
	SE5	I am sure I can understand science	17%	**58%**	25%
Grade	G1	I like to do better than other students on science tests	17%	**58%**	25%
	G2	Getting a good science grade is important to me	8%	**58%**	33%
	G3	It is important that I get an A in science	17%	**75%**	8%
	G4	I think about the grade I will get in science	**75%**	8%	17%
	G5	Scoring high on science tests and labs matters to me	25%	42%	33%
Career	C1	Learning science will help me get a good job	0%	**92%**	8%
	C2	Knowing science will give me a career advantage	0%	**92%**	8%
	C3	Understanding science will benefit me in my career	0%	**83%**	17%
	C4	My career will involve science	0%	**92%**	8%
	C5	I will use science problem-solving skills in my career	17%	42%	42%

Table S6. Exemplar student responses to SMQ II items during interviews.

Item	Wording	Student Response
I3	Learning science makes my life more meaningful	“Yeah, I think it provides, it's part of the understanding of what's in front of me, that kind of stuff that I think. I don't know. I just like understanding and I think that's an important part of my life.”
		“Yeah. I feel it really helps out in a lot of ways and especially just an understanding of the world around you and stuff.”
G4	I think about the grade I will get in science	“All the time. Yeah. I mean, I'm still thinking about going into the health field, and they stress grades. And so I have to think about it all the time.”
		“All the time, that's just another thing, I gotta get good grades to get into the program. To get a good job.”
SE2	I am confident I will do well on science labs and projects	“I did pretty well on my labs. We don't have any kind of projects in gen chem”
		“I'm pretty confident with my science labs. I'm not sure about projects because I don't think I've done any.”
		“Yeah. The reason why that wasn't usually is the labs part, I think it's more difficult for me to feel like I will do well on labs because personally, I feel like I don't know what to expect as much as just the tests, but I still think it's possible for me to do well on them.”
		“Usually, because I think the labs compared to the tests are more give and take, and you can interact with our T.A, and see what you did wrong immediately and get feedback. So I think usually I'll do well on those with the occasional difficulty.”

Table S7. Descriptive statistics for phase two mSMQ II data.

Item	Course	Wording	n	Mean	St. dev.	Median	Min	Max	Skew	Kurtosis
I1	Prep Chem	Science	0	--	--	--	--	--	--	--
		Chemistry	137	3.71	1.02	4	1	5	–0.56	–0.13
	Gen Chem	Science	245	4.18	0.94	4	1	5	–1.09	0.73
		Chemistry	852	3.42	1.19	4	1	5	–0.42	–0.67
	Gen Bio	Science	19	4.58	0.61	5	3	5	–1.17	0.58
		Biology	261	3.93	1.12	4	1	5	–0.96	0.25
I1a	Prep Chem	Science	139	4.35	0.80	5	2	5	–1.13	0.74
		Chemistry	0	--	--	--	--	--	--	--
	Gen Chem	Science	832	4.32	0.87	5	1	5	–1.34	1.53
		Chemistry	261	3.8	1.06	4	1	5	–0.69	–0.28
	Gen Bio	Science	258	4.43	0.81	5	1	5	–1.65	3.22
		Biology	20	3.95	1.19	4	1	5	–1.14	0.63
I2	Prep Chem	Science	139	4.48	0.81	5	1	5	–1.93	4.40
		Chemistry	137	3.89	1.08	4	1	5	–1.07	0.77
	Gen Chem	Science	835	4.43	0.85	5	1	5	–1.72	3.02
		Chemistry	855	3.82	1.12	4	1	5	–0.89	0.09
	Gen Bio	Science	258	4.52	0.80	5	1	5	–2.20	5.86
		Biology	263	4.2	1.00	4	1	5	–1.48	2.04
I3a	Prep Chem	Science	139	4.37	0.92	5	1	5	–1.54	2.05
		Chemistry	137	3.86	1.04	4	1	5	–0.66	–0.09
	Gen Chem	Science	835	4.46	0.80	5	1	5	–1.65	2.95
		Chemistry	855	3.84	1.12	4	1	5	–0.88	0.07
	Gen Bio	Science	258	4.47	0.73	5	2	5	–1.29	1.15
		Biology	263	4.18	1.03	4	1	5	–1.40	1.53
I3b	Prep Chem	Science	139	4.26	0.96	5	1	5	–1.19	0.85
		Chemistry	137	3.54	1.14	4	1	5	–0.40	–0.61
	Gen Chem	Science	835	4.33	0.88	5	1	5	–1.37	1.70
		Chemistry	855	3.65	1.14	4	1	5	–0.61	–0.35
	Gen Bio	Science	258	4.37	0.80	5	1	5	–1.17	0.99
		Biology	263	4.03	1.08	4	1	5	–0.94	0.19
I4	Prep Chem	Science	139	4.39	0.83	5	1	5	–1.53	2.42
		Chemistry	137	3.72	1.11	4	1	5	–0.71	–0.07
	Gen Chem	Science	835	4.41	0.84	5	1	5	–1.62	2.73
		Chemistry	855	3.67	1.16	4	1	5	–0.67	–0.37
	Gen Bio	Science	258	4.39	0.86	5	1	5	–1.47	2.07
		Biology	263	3.97	1.07	4	1	5	–1.06	0.62
I5	Prep Chem	Science	139	4.39	0.88	5	1	5	–1.56	2.38
		Chemistry	137	3.64	1.13	4	1	5	–0.69	–0.19
	Gen Chem	Science	835	4.35	0.88	5	1	5	–1.51	2.20
		Chemistry	855	3.52	1.25	4	1	5	–0.55	–0.70
	Gen Bio	Science	258	4.43	0.85	5	1	5	–1.97	4.63
		Biology	263	4.01	1.11	4	1	5	–1.02	0.25
SD1a	Prep Chem	Science	139	4.5	0.64	5	2	5	–1.27	1.96
		Chemistry	137	4.31	0.82	4	1	5	–1.29	1.84
	Gen Chem	Science	835	4.41	0.73	5	1	5	–1.30	2.11
		Chemistry	855	4.24	0.83	4	1	5	–1.17	1.49
	Gen Bio	Science	258	4.51	0.70	5	1	5	–1.56	3.01
		Biology	263	4.4	0.82	5	1	5	–1.53	2.40

Table S7. (continued)

Item	Course	Wording	n	Mean	St. dev.	Median	Min	Max	Skew	Kurtosis
SD2	Prep Chem	Science	139	4.17	0.84	4	2	5	–0.71	–0.30
		Chemistry	137	3.83	0.95	4	1	5	–0.59	–0.03
	Gen Chem	Science	835	4.07	0.9	4	1	5	–0.73	–0.06
		Chemistry	855	3.72	1.00	4	1	5	–0.64	–0.06
	Gen Bio	Science	258	4.09	0.89	4	2	5	–0.78	–0.10
		Biology	263	3.98	0.91	4	1	5	–0.78	0.34
SD3	Prep Chem	Science	139	4.35	0.75	4	1	5	–1.21	2.10
		Chemistry	137	3.74	1.20	4	1	5	–0.76	–0.27
	Gen Chem	Science	835	4.34	0.81	5	1	5	–1.13	0.77
		Chemistry	855	4.07	0.95	4	1	5	–0.90	0.23
	Gen Bio	Science	258	4.33	0.83	5	1	5	–1.33	1.86
		Biology	263	4.11	0.97	4	1	5	–1.15	0.87
SD4a	Prep Chem	Science	139	4.13	0.90	4	1	5	–1.11	1.27
		Chemistry	137	3.99	1.02	4	1	5	–1.09	0.83
	Gen Chem	Science	835	3.91	0.94	4	1	5	–0.81	0.40
		Chemistry	855	3.76	1.01	4	1	5	–0.69	–0.06
	Gen Bio	Science	258	4.07	0.91	4	1	5	–1.12	1.31
		Biology	263	4	0.99	4	1	5	–0.94	0.52
SD5	Prep Chem	Science	139	4.47	0.73	5	2	5	–1.35	1.53
		Chemistry	137	4.13	0.99	4	1	5	–1.19	1.04
	Gen Chem	Science	835	4.31	0.84	5	1	5	–1.27	1.47
		Chemistry	855	4.1	0.94	4	1	5	–0.97	0.46
	Gen Bio	Science	258	4.36	0.83	5	1	5	–1.31	1.40
		Biology	263	4.27	0.88	4	1	5	–1.24	1.21
SD5a	Prep Chem	Science	139	4.47	0.74	5	2	5	–1.33	1.36
		Chemistry	137	4.07	1.00	4	1	5	–1.05	0.70
	Gen Chem	Science	835	4.48	0.77	5	1	5	–1.6	2.68
		Chemistry	855	4.4	0.83	5	1	5	–1.55	2.46
	Gen Bio	Science	258	4.46	0.82	5	1	5	–1.70	2.87
		Biology	263	4.4	0.80	5	1	5	–1.51	2.77
SE1	Prep Chem	Science	139	3.65	1.18	4	1	5	–0.79	–0.21
		Chemistry	137	3.45	1.28	4	1	5	–0.58	–0.75
	Gen Chem	Science	835	3.41	1.13	4	1	5	–0.37	–0.68
		Chemistry	855	3.13	1.24	3	1	5	–0.23	–0.98
	Gen Bio	Science	258	3.5	1.15	4	1	5	–0.57	–0.44
		Biology	263	3.24	1.23	3	1	5	–0.32	–0.86
SE2a	Prep Chem	Science	139	3.92	1.05	4	1	5	–0.83	–0.16
		Chemistry	137	3.83	1.15	4	1	5	–1.09	0.46
	Gen Chem	Science	835	3.77	1.01	4	1	5	–0.64	–0.18
		Chemistry	855	3.63	1.15	4	1	5	–0.62	–0.49
	Gen Bio	Science	258	3.83	1.01	4	1	5	–0.81	0.14
		Biology	263	3.66	1.15	4	1	5	–0.68	–0.33
SE3a	Prep Chem	Science	139	4.12	0.93	4	1	5	–1.07	0.98
		Chemistry	137	3.8	1.21	4	1	5	–0.94	0.01
	Gen Chem	Science	835	3.94	1.04	4	1	5	–0.82	0.02
		Chemistry	855	3.61	1.18	4	1	5	–0.62	–0.52
	Gen Bio	Science	258	3.97	1.01	4	1	5	–0.98	0.47
		Biology	263	3.84	1.09	4	1	5	–0.84	0

Table S7. (continued)

Item	Course	Wording	n	Mean	St. dev.	Median	Min	Max	Skew	Kurtosis
SE4a	Prep Chem	Science	139	4	1.12	4	1	5	–1.18	0.73
		Chemistry	137	3.96	1.16	4	1	5	–1.22	0.76
	Gen Chem	Science	835	3.88	1.08	4	1	5	–0.81	–0.11
		Chemistry	855	3.68	1.21	4	1	5	–0.67	–0.54
	Gen Bio	Science	258	4.1	1.01	4	1	5	–1.16	0.79
		Biology	263	3.76	1.24	4	1	5	–0.84	–0.34
SE5	Prep Chem	Science	139	4.25	0.89	4	1	5	–1.39	2.01
		Chemistry	137	3.99	1.04	4	1	5	–1.22	1.12
	Gen Chem	Science	835	4.18	0.89	4	1	5	–1.07	0.92
		Chemistry	855	3.84	1.08	4	1	5	–0.85	0.01
	Gen Bio	Science	258	4.29	0.86	4	1	5	–1.42	2.22
		Biology	263	4.06	1.01	4	1	5	–1.12	0.75
G1a	Prep Chem	Science	139	4.33	0.82	5	2	5	–0.92	–0.17
		Chemistry	137	4.21	1.01	5	1	5	–1.39	1.76
	Gen Chem	Science	835	4.31	0.88	5	1	5	–1.08	0.45
		Chemistry	855	4.16	0.97	4	1	5	–1.02	0.47
	Gen Bio	Science	258	4.22	0.97	5	1	5	–1.19	1.04
		Biology	263	4.13	1.01	4	1	5	–1.06	0.60
G2	Prep Chem	Science	139	4.84	0.45	5	2	5	–3.44	13.92
		Chemistry	137	4.83	0.49	5	1	5	–4.45	27.37
	Gen Chem	Science	835	4.78	0.51	5	1	5	–2.86	11.00
		Chemistry	855	4.76	0.52	5	1	5	–2.50	7.74
	Gen Bio	Science	258	4.86	0.41	5	2	5	–3.33	13.14
		Biology	263	4.82	0.51	5	1	5	–4.19	24.41
G3a	Prep Chem	Science	139	4.79	0.50	5	3	5	–2.41	5.04
		Chemistry	137	4.66	0.70	5	1	5	–2.91	10.82
	Gen Chem	Science	835	4.68	0.62	5	1	5	–2.26	6.07
		Chemistry	855	4.64	0.66	5	1	5	–2.14	5.16
	Gen Bio	Science	258	4.79	0.50	5	2	5	–2.89	10.66
		Biology	263	4.74	0.57	5	1	5	–3.11	14.04
G4	Prep Chem	Science	139	4.79	0.53	5	2	5	–3.11	11.16
		Chemistry	137	4.7	0.66	5	1	5	–3.22	13.73
	Gen Chem	Science	835	4.74	0.58	5	1	5	–2.70	9.04
		Chemistry	855	4.74	0.60	5	1	5	–2.71	8.41
	Gen Bio	Science	258	4.86	0.38	5	3	5	–2.72	7.06
		Biology	263	4.73	0.61	5	1	5	–3.15	12.8
G4a	Prep Chem	Science	139	4.47	0.94	5	1	5	–1.82	2.37
		Chemistry	137	4.2	1.20	5	1	5	–1.48	1.09
	Gen Chem	Science	835	4.51	0.89	5	1	5	–2.12	4.32
		Chemistry	855	4.47	0.90	5	1	5	–1.92	3.34
	Gen Bio	Science	258	4.53	0.86	5	1	5	–2.20	4.79
		Biology	263	4.52	0.88	5	1	5	–2.23	4.95
G5a	Prep Chem	Science	139	4.81	0.43	5	3	5	–2.09	3.70
		Chemistry	137	4.73	0.61	5	1	5	–3.09	12.41
	Gen Chem	Science	835	4.71	0.60	5	1	5	–2.64	9.24
		Chemistry	855	4.71	0.60	5	1	5	–2.56	8.53
	Gen Bio	Science	258	4.81	0.45	5	3	5	–2.29	4.68
		Biology	263	4.72	0.63	5	1	5	–3.00	11.42

Table S7. (continued)

Item	Course	Wording	n	Mean	St. dev.	Median	Min	Max	Skew	Kurtosis
C1	Prep Chem	Science	139	4.55	0.76	5	1	5	–1.89	3.88
		Chemistry	137	3.99	1.02	4	1	5	–1.0	0.66
	Gen Chem	Science	835	4.53	0.75	5	1	5	–1.87	3.94
		Chemistry	855	3.73	1.23	4	1	5	–0.69	–0.50
	Gen Bio	Science	258	4.52	0.79	5	2	5	–1.63	1.92
		Biology	263	4.05	1.10	4	1	5	–1.07	0.44
C2	Prep Chem	Science	139	4.56	0.82	5	1	5	–2.34	5.92
		Chemistry	137	4.04	1.05	4	1	5	–1.10	0.80
	Gen Chem	Science	835	4.56	0.72	5	1	5	–1.83	3.59
		Chemistry	855	3.87	1.15	4	1	5	–0.84	–0.14
	Gen Bio	Science	258	4.62	0.73	5	1	5	–2.22	5.51
		Biology	263	4.17	1.10	5	1	5	–1.39	1.29
C3	Prep Chem	Science	139	4.59	0.84	5	1	5	–2.44	6.29
		Chemistry	137	4.09	1.08	4	1	5	–1.20	0.96
	Gen Chem	Science	835	4.64	0.69	5	1	5	–2.16	4.96
		Chemistry	855	3.87	1.22	4	1	5	–0.89	–0.20
	Gen Bio	Science	258	4.68	0.78	5	1	5	–3.01	9.64
		Biology	263	4.35	1.00	5	1	5	–1.78	2.69
C4	Prep Chem	Science	139	4.42	1.02	5	1	5	–1.83	2.61
		Chemistry	137	3.85	1.25	4	1	5	–0.83	–0.35
	Gen Chem	Science	835	4.59	0.78	5	1	5	–2.19	4.90
		Chemistry	855	3.57	1.35	4	1	5	–0.60	–0.84
	Gen Bio	Science	258	4.66	0.79	5	1	5	–2.93	9.14
		Biology	263	4.11	1.25	5	1	5	–1.39	0.84
C5	Prep Chem	Science	139	4.41	0.91	5	1	5	–1.68	2.54
		Chemistry	137	3.73	1.16	4	1	5	–0.75	–0.20
	Gen Chem	Science	835	4.53	0.76	5	1	5	–1.88	4.07
		Chemistry	855	3.74	1.20	4	1	5	–0.76	–0.31
	Gen Bio	Science	258	4.47	0.81	5	1	5	–1.86	4.17
		Biology	263	4.05	1.14	4	1	5	–1.14	0.47

Exploratory factor analysis of phase one data

Methods

Due to the low number of responses from students enrolled in preparatory chemistry courses, only data from general chemistry and general biology courses were used to create the training dataset for the exploratory factor analysis (EFA), leaving the intact preparatory chemistry data as cross validation for testing the confirmatory factor models. The R package caret (version 6.0-80; Kuhn, 2008) was used with the general biology and general chemistry data to create two equal partitions of data for each course and wording condition with the restriction of attempting to create equivalent gender distributions in each partition. The EFA was conducted on these two training datasets using functions available in the psych package (version 1.8.4; Revelle, 2018). Prior to conducting the EFA, the data sets for each wording and course conditions were checked for suitability using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity, as was done in the most recent development of the SMQ II by the original developers (Glynn *et al.*, 2011).

Given the inherent non-normality of data collected on a five-point Likert-type scale, along with the fact that the mSMQ II descriptive statistics showed that all five scale points were not being utilized, especially on the grade scale that showed high skew and kurtosis, the data were analyzed with polychoric correlations when used in EFA. Both principal components and principal axis factoring (PAF) methods were used in prior SMQ II research and the results were reported to be similar (Glynn *et al.*, 2011). Therefore, PAF was used for the mSMQ II data. Decisions about the number of factors to retain were made based on having eigenvalues greater than 1, as in previous SMQ II studies (Glynn *et al.*, 2011), as well as the results of parallel analysis (Bandalos and Finney, 2010) with polychoric correlations. Oblique rotation (oblimin) was selected for this analysis since previous research had demonstrated that the motivation factors were correlated (Glynn *et al.*, 2011).

Results

Exploratory factor analysis (EFA) was not conducted on the preparatory chemistry data due to low sample size. Instead all of the preparatory chemistry data was reserved for the later confirmatory factor analysis (CFA) allowing it to serve as in independent cross validation dataset. For the general chemistry and biology training datasets, results of KMO and Bartlett's test were similar to results reported by the original developers (Table S8). These tests indicate that the data were acceptable for EFA with an overall KMO above 0.70 for all course and wording conditions and highly statistically significant Bartlett's tests (Field *et al.*, 2012). For the general biology data, these tests were run excluding the intrinsic item in which the majority of the item response data were missing due to the survey deployment issue (item I1 for the science wording and I1a for the biology wording). For all EFAs, a five-factor solution was reasonable based on eigenvalues greater than one or the results of parallel analysis.

Table S8. Results of tests of mSMQ II data suitability for exploratory factor analysis.

Class	General Chemistry		General Biology	
Wording	Science	Chemistry	Science	Biology
n	418	429	130	133
KMO	0.76	0.91	0.84	0.89
Bartlett's	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$

As a result of using oblique rotation, the EFA results provide distinct sets of pattern and structure coefficients, therefore, the term 'loading' is not used to avoid confusion (Henson and Roberts, 2006; Bandalos and Finney, 2010). Since the mSMQ II factors were moderately to strongly correlated (majority falling between 0.25 and 0.60), the structure coefficients were more difficult to interpret than the pattern coefficients, as each factor had a strong relation with all items. Therefore, only the values for the pattern coefficients for each EFA are plotted in Figure S1 and the factor correlations are provided in Tables S9 and S10.

Figure S1. Pattern coefficients from exploratory factor analysis (EFA) using principle axis factoring and oblique rotation with mSMQ II data by course and wording conditions. Items are ordered as in manuscript Table 1 (or Supplementary Information Table S7) and asterisks indicate items removed after EFA.

Table S9. EFA factor correlations for general chemistry data. Science wording in upper diagonal, chemistry wording in lower diagonal.

	I	SD	SE	G	C
Intrinsic	1	0.44	0.50	0.37	0.66
Self-determination	0.19	1	0.27	0.54	0.44
Self-efficacy	0.35	0.05	1	0.13	0.28
Grade	0.26	0.51	0.02	1	0.44
Career	0.61	0.26	0.15	0.32	1

Table S10. EFA factor correlations for general biology data. Science wording in upper diagonal, chemistry wording in lower diagonal.

	I	SD	SE	G	C
Intrinsic	1	0.34	0.45	0.30	0.54
Self-determination	0.39	1	0.19	0.32	0.26
Self-efficacy	0.43	0.23	1	0.26	0.33
Grade	0.37	0.59	0.12	1	0.41
Career	0.61	0.33	0.22	0.35	1

In Figure S1, each of the extracted factors is represented with its own plot showing the pattern coefficients for each item on that factor. Items are ordered along the x-axis based as they appear in manuscript Table 1 (or Supplementary Information Table S7) and also color coded by the scale of their intended association. The developers of the SMQ II used a cutoff of 0.35 to signify that an item was associated with its intended scale to an acceptable degree (Glynn *et al.*, 2011), therefore, a dashed line representing this value (both positive and negative) is shown in Figure S1. For the general biology plots in Figure S1, the intrinsic item with missing data (I1 or I1a) is not plotted depending on the wording condition. To confirm that the low associations between the intrinsic factor and items I1 and I1a were not artifacts of the missing data for these items, separate EFAs were conducted using only a subset of the training data where all students saw both I1 and I1a; only the general chemistry course data provided enough sample size for these calculations (see manuscript Table 2). Results from these EFAs were similar to the larger dataset and are provided in Tables S11 and S12 as well as Figure S2.

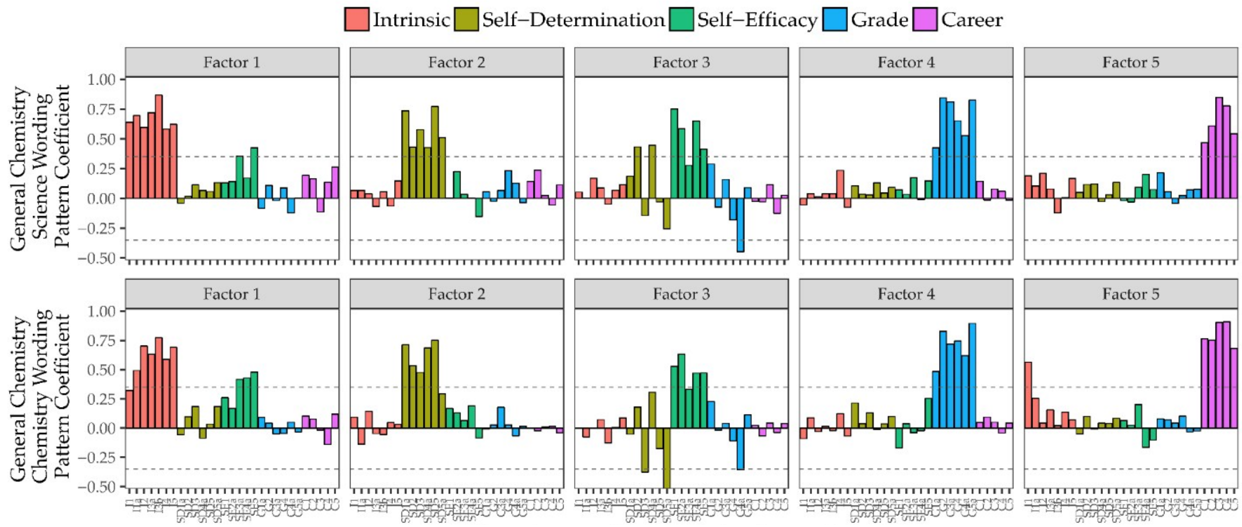

Figure S2. Exploratory factor analysis results for a subset of general chemistry data in which both I1 and I1a were viewed by participants. Items are ordered as in manuscript Table 1 (or Supplementary Information Table S7).

Table S11. Results of tests of data suitability for exploratory factor analysis with subset of general chemistry data responding to both I1 and I1a.

Wording	Science	Chemistry
n	123	133
KMO	0.86	0.83
Bartlett's	$p < 0.001$	$p < 0.001$

Table S12. EFA factor correlations for subset of general chemistry data viewing both I1 and I1a. Science wording in upper diagonal, chemistry wording in lower diagonal.

	I	SD	SE	G	C
Intrinsic	1	0.38	0.44	0.36	0.63
Self-determination	0.25	1	0.17	0.51	0.49
Self-efficacy	0.29	0.03	1	0.13	0.22
Grade	0.15	0.38	–0.13	1	0.49
Career	0.43	0.18	–0.07	0.32	1

The EFA results were used to identify potentially problematic items that should be removed before moving into a confirmatory framework. Items were determined to be problematic if they showed low relation to their intended scale factor, if they showed evidence of association with more than one factor, or if they displayed an inconsistent pattern of association with a factor across different wording and course conditions. This last condition is particularly important for the mSMQ II since the original SMQ II is intended to be used to measure motivation in different contexts. Items identified as problematic are indicated in Table 1 in the manuscript and Figure S1, with an asterisks below their coefficient bar for the factor they were intended to be associated with.

On the intrinsic scale, I1 had a strong association (> 0.35) with the career factor in the chemistry wording condition, replicating the concerns that led to its rewording as I1a. Those concerns being that the theoretical framework for the SMQ II identified intrinsic and career motivation as distinct constructs. Additionally, the career motivation scale grew out of a previous extrinsic motivation scale (Glynn *et al.*, 2009) and intrinsic and extrinsic motivation represent opposite sends of the self-determination continuum (Ryan and Deci, 2000). Of additional concern was that the association between I1 and the career factor was not consistent across course and wording conditions. Though neither I1 nor I1a had pattern coefficients below the 0.35 threshold, they were lower in the chemistry courses than in the biology courses providing additional evidence of inconsistent functioning. As a result of these concerns, I1 and I1a were removed.

Three self-determination items were identified for removal due to strong association with the self-efficacy factor. Items SD2, SD4a, and SD5a had the most pronounced association with self-efficacy in the biology courses when seen with the science wording. While SD2 and SD4a had a positive association with the self-efficacy factor above 0.35, item SD5a had a negative association stronger than –0.35. Since these three items were functioning inconsistently across course and wording conditions, and in some cases were functioning more similarly to self-efficacy items, from which they are intended to be theoretically distinct constructs, they were removed.

The self-efficacy item SE3a showed low association with the self-efficacy factor in all conditions. The association was particularly low for both wordings in the biology courses and the science wording in the chemistry courses. Item SE5 had a similar, though less pronounced, pattern of association and in the general chemistry courses showed an association over 0.35 with the intrinsic scale. These two self-efficacy items were removed.

Two items on the grade scale, G1a and G4a, showed poor association with the grade factor. For both items when seen with the science wording by biology students the association was below the 0.35 threshold. The revised item, G4a, "I worry about my science grade" showed an unintended strong negative association with the self-efficacy factor, an indication that it may be measuring a lack of self-efficacy, which further strengthened its case for removal. On the career scale, item C5 had the lowest association with the career factor and in the biology wording condition had a strong association with the intrinsic factor. Therefore, items G1a, G4a and C5 were removed as well. The items removed as a result of the EFA are indicated in Table 1 of the manuscript, leaving 19 items to be tested through confirmatory factor analysis.

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