The efficacy of the *Dimensions of Attitudes toward Science (DAS)* for explaining primary preservice teachers' intention to teach science

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Abstract

There is a need for robust, empirically-validated conceptualisations of teachers' attitudes towards teaching science, with a view to understand how these might explain their intention to teach science. The *Dimensions of Attitudes Toward Science* (DAS) theoretical framework suggests that cognitive, affective and perceived control dimensions of teachers' professional attitudes may be related to their behavioural intention to teach science. While the DAS framework has been employed in numerous studies investigating the attitudes of preservice and inservice teachers, its efficacy remains mostly unknown. The current study employed a cross-sectional survey research design to investigate the question, *to what extent does the DAS theoretical framework explain primary preservice teachers' intention to prioritise teaching science in their future practice?* Early childhood and primary preservice teachers (*n*=250) at an Australian university completed the DAS instrument prior to completing a science curriculum unit. Structural equation modelling revealed inadequate/poor model fit across multiple indices. Perceived relevance of science education and enjoyment teaching science were statistically significant predictors of preservice teachers' intention to prioritise teaching science, whereas other attitudinal constructs from the framework were not significant in this research. These findings warrant further attention to theories of behaviour and behaviour change in science education research.

Keywords: professional attitudes; behavioural intention; science teaching

Introduction

An emphasis on science, technology, engineering, and mathematics (STEM) in global educational discourse has emerged over the past two decades. Scientific knowledge and skills are frequently viewed as being essential to the economic advancement and social wellbeing of the international community (Organisation of Economic Cooperation and Development [OECD], 2018). While science education plays a critical role in achieving these global imperatives, of concern is the variable extent to which science is taught in primary schools. International studies have shown that science may receive less instructional time in primary school classrooms than other subjects (e.g., Blank, 2013), which can limit students' opportunity to learn science (Curran & Kitchin, 2019). In Queensland, Australia, where the current study was conducted, the Department of Education recommends that just 30 minutes per week is allocated to science in Preparatory Year ('Prep'; cf. Kindergarten) to Year 2, while 1 hour 45 minutes is allocated to science in Years 3 to 6 (Queensland Department of Education, 2021). By way of comparison, 7 hours per week is recommended for English and 5 hours per week is recommended for mathematics in Prep to Year 2 (Queensland Department of Education, 2021). Additionally, primary school teachers in Queensland are generally responsible for their scheduling their own science teaching, meaning there is no guarantee that this recommended learning time is met. One way to address this concern is to investigate teachers' professional attitudes towards teaching science, which are thought to be associated with their intention to teach science (van Aalderen-Smeets, van der Molen, & Asma, 2012).

The objective of this study is to evaluate the efficacy of a theoretical model of professional attitudes, the *Dimensions of Attitudes Towards Teaching Science* (DAS), for its utility to explain primary preservice teachers' intention to prioritise science teaching in their future practice. This paper begins by describing the origins of the DAS framework, before reviewing trends and gaps in extant DAS research, to show how the present study addresses a gap in current scholarship. The research design and procedures are described next, before the research findings are presented and discussed in the context theories of behaviour and behaviour change, as well as the role of initial science teacher education in promoting positive professional attitudes.

The *Dimensions of Attitudes Towards Teaching Science* (DAS) framework

While teachers' attitudes have been examined in educational research for decades, only recently has there been a well-defined framework for teachers' professional attitudes towards science (i.e., attitudes towards *teaching* science). In 2012, van Aalderen-Smeets and her colleagues developed a new theoretical framework for describing and researching teachers' professional attitudes towards science based on an extensive literature review of attitudinal concepts. According to the framework, attitudes towards teaching science comprise cognitive, affective and perceived control dimensions (Figure 1). Cognitive beliefs refer to teachers' beliefs about the relevance and importance of teaching science (e.g., I think that science education is essential for helping primary school students become more involved with society's problems), the perceived difficulty attributed to the task of teaching science relative to other learning areas (e.g., I think that most primary school teachers find science content to be a difficult subject to teach), and perceived gender-stereotypical beliefs about teaching and learning science (e.g., I believe that boys in primary school are more enthusiastic about experimenting than girls). Affective states refer to the feelings and emotions a primary school teacher may experience when teaching science, categorized as enjoyment in teaching science (e.g., I enjoy teaching science) or anxiety about teaching science (e.g., Teaching science makes me anxious). These affective states are not two opposites or extremities of a single dimension, but are independent, although related, subcomponents (van Aalderen-Smeets et al., 2012). Perceived control refers to teachers' perceptions about internal and external obstacles that might hinder the teaching of science in elementary school. Perceived control is determined by the subcomponents self-efficacy and perceived dependence on contextual factors. While 'self-efficacy' refers to teachers' beliefs about their ability to teach science based on their knowledge, confidence and skills (e.g., I have enough science content knowledge to teach this subject well in primary school), context dependency refers to external factors that they perceive to influence their science teaching, such as time, resources or leadership (e.g., For me, the availability of a ready-to-use existing package of materials [e.g., science kits] is an essential prerequisite for being able to teach science in class). Finally, behavioural intention refers to the degree to which a person has formulated conscious plans to perform or not perform some specific future behaviour (Warshaw & Davis, 1985).

<Insert Figure 1 here>

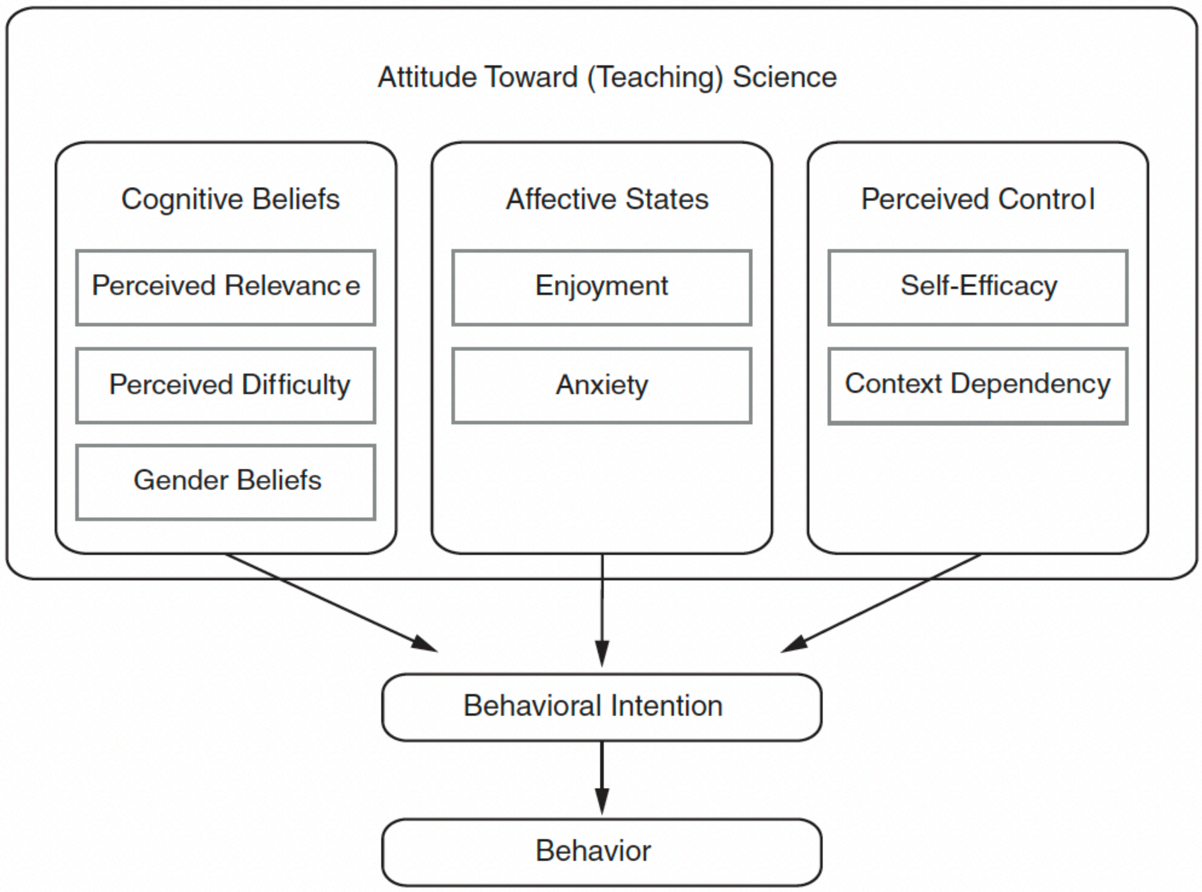

Figure 1. A theoretical framework for teachers' attitudes toward teaching science (from van Aalderen-Smeets et al., 2012, p. 176)

Unlike other tripartite models of attitudes that comprise cognitive, affective and behavioural dimensions (Eagly & Chaiken, 1993), the DAS framework positions attitudes as antecedents of behavioural intention, in-line with Ajzen's (1985, 1991) theory of planned behaviour. In brief, the TPB comprises three domains: (1) behavioural beliefs (attitude toward the behaviour; e.g., favourable or unfavourable attitude toward teaching science); (2) normative beliefs (subjective norm; e.g., perception of approval or disapproval from others in relation to teaching science); and (3) control beliefs (perceived behavioural control; e.g., perception of how much control teachers have in implementing science education). This could include factors outside their control, such as level of leadership support. The TPB indicates behavioural actions are directed by these belief domains which, in turn, form behavioural intention, a direct antecedent to actual behaviour (Ajzen, 1991). Given its utility in understanding and predicting behaviours associated with science-related behaviour (such as teaching science), the theory of planned behaviour remains "at the forefront of competing models for shaping attitude research in science education" (Summers & Abd-El-Khalick, 2018, p. 184), informing the development of theoretical frameworks such as the DAS. Nevertheless, integrated theories of behaviour and behaviour change "can only be as good as the validity of the theory … [*they are*] based on" (Brown, 2018, p. 7). To this end, it is important to understand and test the constructs and proposed mechanisms that underpin instruments like the DAS to determine their utility.

Trends and gaps in DAS research

The DAS framework has been used in numerous studies to understand primary preservice and inservice teachers' attitudes toward teaching science, including general exploratory studies (Ualesi & Ward, 2018) and intervention studies that have evaluated the impact of initial teacher education curriculum units (McDonald & Klieve, 2020) or professional development activities and programs (Marec et al., 2021; van Aalderen-Smeets & Walma van der Molen, 2015; van Aalderen-Smeets et al., 2017). The DAS instrument has also been validated across several international contexts (van Aalderen-Smeets & Walma van der Molen, 2013; Korur et al., 2016; Wendt & Rockinson-Szapliw, 2018). While these studies have employed the DAS instrument to measure teachers' attitudes towards science, they have not considered how adequately the underlying framework may explain science teaching intention and behaviour.

van Aalderen-Smeets and colleagues (2017) used the DAS instrument to investigate the effectiveness of Dutch primary school teachers' (*n*=62) participation in an action-research style inquiry project about their teaching practice on their attitudes towards teaching science using the same inquiry approach. The study reported only a marginal increase in teachers' positive attitudes towards teaching science using inquiry methods overall, and a limited change in their reported science teaching behaviour from the beginning to the end of the project. While behavioural intention may not necessarily lead to a desired behaviour (Sheeran, 2002), this finding may also be explained by a lack of targeted attitudes-focused content within the project. Current scholarship has not investigated which components and subcomponents of the DAS framework may contribute most strongly to behavioural intention and ought to be developed through initial teacher education or teacher professional learning.

Another study was more successful in enhancing the amount and quality of science education delivered in primary schools. In this study, Dutch primary school teachers (*n*=61) participated in a uniquely designed attitudes-focused professional learning course that incorporated training, discussions and assignments explicitly about, in part, attitudes towards teaching science (van Aalderen-Smeets et al., 2015). While this professional learning was effective in markedly enhancing teachers' attitudes towards teaching science (as measured by the DAS instrument) and their reported science teaching behaviour, it remains unclear to what extent the subcomponents of the teachers' attitudes contributed to their science teaching behaviour before and after the professional learning course, and in turn, how the professional learning course actually impacted upon their behaviour.

Teachers' lived experiences of teaching science have been examined using the DAS framework to analyse their experiences (Ualesi & Ward, 2018). In this study, primary school teachers from New Zealand (*n*=6) were interviewed and asked about their science teaching. It was revealed that teachers who had well-formed ideas about the purpose of science education felt most positive towards teaching in this discipline area, because they perceived the subject matter to be both relevant and important for young children to understand the world around them and to take up a science-related career, if they wished (Ualesi & Ward, 2018). While some teachers in this study found enjoyment in teaching science, particularly if they were afforded autonomy over their own science teaching practices, the highly specialised scientific vocabulary inherent to the science learning area was perceived by the teachers as a source of discomfort and anxiety (Ualesi & Ward, 2018). Finally, if a structured science program was available to the teachers (e.g., unit outlines, pre-written teacher resources and student booklets), and they could access the teaching space and resource materials needed to teach science, they felt more positive towards teaching science (Ualesi & Ward, 2018). These findings provide an interesting insight into associations between the subcomponents of the DAS framework and preservice teachers' intention to prioritise science teaching in their future practice.

Summary and research question

Despite a notable flurry of recent research around the DAS framework (e.g., Korur et al., 2016; Marec et al., 2021; McDonald et al., 2020; Ualesi & Ward, 2018; van Aalderen-Smeets et al., 2012; van Aalderen-Smeets et al., 2013; van Aalderen-Smeets et al., 2015; van Aalderen-Smeets et al., 2017; Wendt & Rockinson-Szapkiw, 2018), the relationship between professional attitudes and behavioural intention remains unknown. In other words, existing research assumes that the seven components of attitudes towards teaching science, when considered alongside one another as they are presented in the DAS framework, are related (and uniquely related) to intention. Our research progresses current thinking about the framework to explicate further whether these components adequately explain intention. The research was guided by the following question: *To what extent does the DAS theoretical framework explain primary preservice teachers' intention to prioritise teaching science in their future practice?* In doing so, the current study responds directly to the call to evaluate the theoretical framework that underpins the DAS framework, "… including the relationships between the components and the weights of the various components and subcomponents in predicting behavioural intention" (van Aalderen-Smeets et al., 2012, p. 179).

Research Design and Procedures

A cross-sectional survey research design (Creswell, 2014; de Vaus, 2013) was used to examine preservice teachers' attitudes towards science and their behavioural intention to teach science. Preservice teachers (n=250) enrolled in a Bachelor of Education (Primary), Bachelor of Education (Early Childhood), Master of Teaching (Primary) and Master of Teaching (Early Childhood) in 2018–2020 at a large, metropolitan university in Australia were invited to participate in the study by responding to the DAS instrument at the beginning of the university semester. At the time of the study, the participants were enrolled in a science curriculum unit. The instrument was administered electronically to all preservice teachers who gave informed consent to participate. The questionnaire took participants about 15 minutes to complete. Cohort demographics revealed most participants identified as being female school-leavers studying a Bachelor of Education (Primary) (Table 1).

<Insert Table 1 here>

Table 1
Demographics of research participants

	n	%
Female	217	86.8
Male	26	10.4
Other identified	3	1.2
Missing	4	1.6
Course Enrolment		
Bachelor of Education (Early Childhood)	17	13.4
Bachelor of Education (Primary)	70	55.1
Master of Teaching	40	31.5
Enrolment Type		
Internal	151	60.4
External	98	39.2
Missing	1	0.4
Highest Level of Qualification		
High school	98	39.2
Certificate or Diploma	37	14.8
Bachelor Degree	85	34.0
Graduate Diploma	11	4.4
Masters or PhD	19	7.6

Data collection

Data were obtained through administration of the English language version of the DAS instrument (Wendt & Rockinson-Szapkiw, 2018). The DAS instrument is a Likert-style instrument composed of 28 items within the seven aforementioned subscales: (1) perceived relevance; (2) perceived difficulty; (3) gender-stereotypical beliefs; (4) enjoyment; (5) anxiety; (6) self-efficacy; and (7) context dependency (Table 2). Preservice teachers' intention to teach science in the future was also measured, in accordance with other studies that have used the DAS instrument to examine attitudes and behavioural intention (van Aalderen-Smeets et al., 2015, 2017). The DAS instrument was not validated in the current study, given that it has already been validated in several international educational contexts (van Aalderen-Smeets & Walma van der Molen, 2013; Korur, Vargas, & Serrano, 2016; Wendt & Rockinson-Szapliw, 2018).

<Insert Table 2 here>

Preservice teachers reported how much they agreed with the items on a five-point scale from Strongly Disagree (1) to Strongly Agree (5). The subscales were prefaced with the statement *'How much do you agree or disagree with the following statements?'*, with the exception of Subscale 7 (context dependency) and Subscale 8 (behavioural intention), which asked preservice teachers to think about their intention to *prioritise* teaching science in their future practice as a classroom teacher (i.e., give careful consideration to the *amount* and *quality* of science education enacted). This was necessary for the items to make sense, because in Queensland, Australia, where the present study was carried out, a recommended time allocation per week is stipulated for primary science teaching (Queensland Department of Education, 2021). Furthermore, the word "elementary" was replaced with "primary" to suit the Australian educational context of the present study. For example, Item 1a was changed from *'I think that science education is essential for helping elementary school students become more involved with society's problems'* to *'I think that science education is essential for helping primary school students become more involved with society's problems'*. The internal consistency of each subscale proved to be high, as indicated by Cronbach's alpha coefficient (Table 3).

<Insert Table 3 here>

Table 3
Subscale means and internal consistency in the present research

Subscale	Number of Items	Mean	Cronbach's alpha
1. Relevance	5	4.41	.894
2. Gender beliefs	5	2.14	.831
3. Difficulty	3	3.26	.902
4. Enjoyment	4	3.92	.946
5. Anxiety	4	2.63	.932
6. Self-efficacy	4	3.55	.914
7. Context dependency	3	3.34	.695
8. Behavioural intention	5	3.37	.739

<Insert Table 2 here>

Table 2

Subscales and items of the DAS instrument and their corresponding response options (Wendt & Rockinson-Szapliw, 2018)

Subscales / **Items**	**Response Options (Score)**				
1. Relevance					
1a. I think that science education is essential for helping primary school students become more involved with society's problems 1b. I believe that science education is essential for primary school children's general development as a citizen 1c. I think that science must be included in primary education as early as possible 1d. I believe that science education in the primary school is essential for students to be able to make good educational and career choices 1e. Because science education is so important in primary school, I think that inexperienced teachers should receive additional training in this area	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
2. Gender beliefs					
2a. I believe that boys in primary school are more enthusiastic about experimenting than girls 2b. I think that in primary schools, boys are more likely than girls to choose assignments more concerned with science 2c. I think that I would unconsciously be more likely to choose a boy for a science demonstration than a girl 2d. I believe that in primary schools, male teachers can do an investigation with students more easily than female teachers 2e. I think that in primary schools, male teachers experience more enjoyment in teaching science than female teachers	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)

3. Difficulty					
3a. I think that most primary school teachers find science content to be a difficult subject to teach 3b. I think that most primary school teachers find it difficult to teach subjects concerning science 3c. I think that most primary school teachers find the topics that come up in science class complicated	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
4. Enjoyment					
4a. Teaching science makes me cheerful 4b. I feel happy while teaching science 4c. I feel enthusiastic when teaching science 4d. I enjoy teaching science	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
5. Anxiety					
5a. I feel nervous while teaching science 5b. I feel tense while teaching science 5c. Teaching science makes me anxious 5d. I feel stressed when I have to teach science	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
6. Self-efficacy					
6a. I have enough science content knowledge to teach this subject well in primary school 6b. I am able to deal effectively with questions from students about science 6c. I have a sufficient command of science content to support primary students effectively with research/inquiry activities in the classroom 6d. I think I can succeed in helping primary students reach a solution during assignments about science	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
7. Context dependency					

7a. For me, having sufficient knowledge of specific science teaching methods (e.g., inquiry-based learning, problem-based learning, etc.) is decisive for whether or not I will teach science in class 7b. For me, the availability of a ready-to-use existing package of materials (e.g., science kits) is an essential prerequisite for being able to teach science in class 7c. For me, the support of my colleagues is decisive for whether or not I teach science in class	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)
8. Behavioral intention					
8a. Do you intend to teach science in your future classroom? 8b. Do you intend to do a research inquiry project with your students in your future classroom? 8c. Do you intend to plan original science lessons in your future classroom? 8d. Do you intend to integrate science into other key learning areas in your future classroom? 8e. Do you intend to take a science excursion in the context of science education (museum, exhibition, company visit, etc.) in your future classroom?	Daily (5)	Weekly (4)	1 to 3 times per month (3)	Several times per year (2)	Seldom or never (1)

Data analysis

Hypothesised relations among the DAS constructs in the model were tested using a full latent variable structural equation model (SEM) implemented in the lavaan package in R (R Development Core Team, 2020; Rosseel, 2012). All constructs were latent variables indicated by single or multiple items. Parameters were freed between the latent variable according to the hypothesised model. The effects of self-identified gender and highest educational achievement were controlled for in the model by freeing paths for these variables to all other model variables. Missing data was handled using the full information maximum likelihood (FIML) method. Simulation studies demonstrate that the FIML approach to handling missing data provides the least biased parameters estimates in SEM (Enders & Bandalos, 2001; Wothke, 1998). In essence, this approach conducts regression analyses on latent constructs (i.e., inclusive of the variability between each item that represents the latent construct) to give the best estimate of the explanative/predictive ability of one construct to another.

The maximum likelihood estimator was used with bootstrapped standard errors (using 1000 bootstrap replications) when running the model. Multiple criteria were used in assessing the goodness-of-fit including the goodness-of-fit chi-square (χ^2), the comparative fit index (CFI), the standardised root mean-squared of the residuals (SRMR), and the root mean square error of approximation (RMSEA) and its 90% confidence interval (90% CI). Complex models often find a statistically significant chi-square value, leading to adequate models being rejected. To compensate for this, we also focused on the incremental fit indices whereby values for the CFI should exceed 0.95, values for the SRMR should be less than or equal to 0.08, and values for the RMSEA should be below 0.05 with a narrow 90% confidence interval (Hu & Bentler, 1999).

Findings

Descriptive statistics for the study variables are presented in Table 3. Preservice teachers' perceptions of the relevance of science were high (*M* = 4.41, *SD* = .65). They also reported relatively low perceived anxiety in regards to the notion of teaching science (*M* = 2.63, *SD* = .96), and they did not demonstrate gender-stereotypical beliefs about teaching and learning science (*M* = 2.14, *SD* = .81) (noting that these items were negatively-worded). For all other variables, participants' responses were generally neutral or slightly positive. Regarding behavioural intention, specifically, participants' responses to the DAS were generally neutral (*M* = 3.37, *SD* = .56).

Standardised parameter estimates for the hypothesised relations among model factors are presented in Figure 2 and Table 4. Overall, the model accounted for 27.3% of the variance in preservice primary teachers' intention to prioritise the amount and quality of science education taught in the classroom. The model exhibited inadequate/poor model fit across multiple of the indices for the hypothesized model (CFI = .846; TLI = .830; RMSEA = .082, 95% CI = .077 - .087; SRMR = .190). Results should be interpreted with caution given the poor fit of the data to the model. The implications of this for evaluating the efficacy of the DAS instrument for explaining preservice teachers' science teaching behaviour are examined critically in the discussion.

With regards to the preservice teachers' cognitive beliefs about teaching science, perceived relevance had a statistically significant positive direct effect on intention while perceived difficulty and gender beliefs displayed null effects. With regards to the preservice teachers' affective states while teaching science, enjoyment had a statistically significant positive direct effect on intention while anxiety exhibited no significant effect. With regards to the preservice teachers' perceived control beliefs about teaching science, neither self-efficacy nor context dependency demonstrated significant effects on intention (Figure 2).

<Insert Figure 2 here>

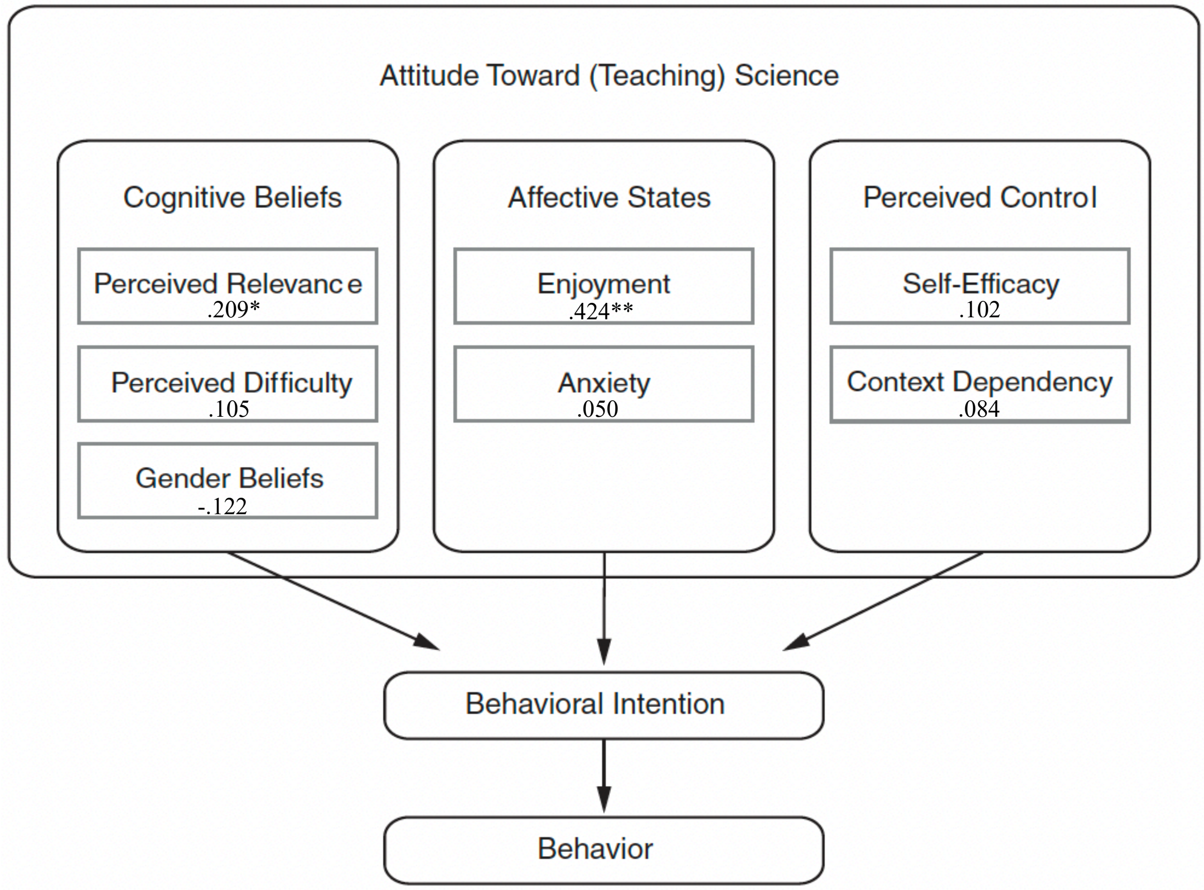

Figure 2. *DAS instrument effects*

Table 4
Standardised parameter estimates

Direct effects	β	*p*	95%CI	
			LL	UL
Perceived Relevance → Intention	.209	.011	.017	.237
Perceived Difficulty → Intention	.105	.158	-.013	.121
Gender Beliefs → Intention	-.122	.138	-.326	.012
Enjoyment → Intention	.424	<.001	.092	.320
Anxiety → Intention	.050	.617	-.065	.117
Self-Efficacy → Intention	.102	.293	-.039	.141
Context Dependency → Intention	.084	.341	-.057	.209
Education → Perceived Relevance	.194	.003	.030	.142
Education → Perceived Difficulty	.054	.413	-.038	.099
Education → Gender Beliefs	.073	.284	-.061	.125
Education → Enjoyment	.177	.074	-.013	.139
Education → Anxiety	-.083	.202	-.131	.028
Education → Self-Efficacy	-.043	.515	-.114	.057
Education → Context Dependency	-.112	.144	-.094	.015
Education → Intention	-.001	.992	-.039	.037
Gender → Perceived Relevance	.056	.389	-.158	.429
Gender → Perceived Difficulty	.036	.584	-.193	.356
Gender → Gender Beliefs	-.213	.002	-.846	-.036
Gender → Enjoyment	-.031	.631	-.371	.213
Gender → Anxiety	.155	.018	.045	.763
Gender → Self-Efficacy	-.167	.012	-.789	-.140
Gender → Context Dependency	.069	.362	-.139	.326
Gender → Intention	.041	.571	-.120	.202

Note. Education and gender were set as "control variables". By regressing gender and education onto each variable it accounts for the effects of gender and education on subsequent variables. As such, the effects of the other variables on intention are free from the effects of gender and education.

Discussion

This study examined the efficacy of the DAS instrument by evaluating the extent to which primary preservice teachers' attitudes toward teaching science may explain their intention to teach science. Analysis of cross-sectional data from primary preservice teachers in Australia (n=250) revealed that the DAS instrument explains 27.30% of variance in behavioural intention, with an inadequate/poor model fit demonstrated by multiple indices. Only two constructs (perceived relevance of science education and enjoyment while teaching science) were statistically significant predictors of intention to teach science in the present study. Notwithstanding the limitation of the current study (i.e., it reports on the teaching intentions of a small sample of Queensland pre-service teachers from one university), these findings call into question whether the DAS is a useful framework to explain science teaching intention and behaviour, and suggest further work is needed in this field of research, globally.

A regression analysis performed by van Aalderen-Smeets and van der Molen (2013) determined the utility of the DAS instrument for predicting behavioural intention. The authors concluded that "at least two of the three attitude dimensions [*i.e., affective states and perceived control – specifically, the self-efficacy, context-dependency, enjoyment and anxiety constructs*] show predictive value for intended science-teaching behaviour" (Aalderen-Smeets & van der Molen, 2013, p. 592). In the current study, only perceived relevance and enjoyment were identified as statistically significant predictors of behavioural intention and even this should only be interpreted with caution given the poor model fit.

This research presents an important contribution to scholarship because it evaluates the efficacy of a widely-accepted attitudinal model of behavioural intention in the field of science education. The DAS instrument has been used to investigate the impact of a range of interventions aimed at enhancing preservice and in-service teachers' professional attitudes (Marec et al., 2021; McDonald & Klieve, 2020; van Aalderen-Smeets & Walma van der Molen, 2015; van Aalderen-Smeets et al., 2017). Author (2018) asserts that researchers must "… become more adept at mapping theoretical determinants of behaviour to their interventions to provide greater confidence in the findings … To this end, it is of great importance to understand and test the constructs and proposed mechanisms within theories to determine the utility of the theory" (p. 7). While van Aalderen-Smeets et al.'s (2012) theoretical framework suggests that, individually, the seven constructs may explain behavioural intention, as shown in Figure 1, there may be more nuanced mediating and/or moderating relationships between the constructs. Additionally, there may be other important variables that moderate or mediate behavioural intention. For example, variables such as past behaviour and behavioural automaticity (i.e., habit) as well as motivation (e.g., autonomous or controlled motivation) have been shown to play important roles in predicting behaviour via mediating TPB variables (Brown et al., 2018; Brown, Hagger, & Hamilton, 2020; Hagger et al., 2015). Similarly, other established psychological models of human behaviour capture a more nuanced representation of variables, across multiple phases, that predict and explain intentions and behaviour (Heckhausen & Gollwitzer, 1987; Schwarzer, 1992; Triandis, 1977).

As noted by Zint (2002), future research regarding teachers' intention to teach science "should focus on identifying determinants that can further enhance the ability of these theories to predict and explain science teachers' behaviors" (p. 819). With a view to advance research in this field, additional theory-driven determinants of behaviour could be explored to enhance the predictive or explanatory power of van Aalderen-Smeets et al.'s (2012) theoretical framework. For example, complementary theoretical approaches are commonly employed in other fields exploring human behaviour. For example, self-determination theory (see Deci & Ryan, 2008) incorporates quality of motivation, while theorists of dual-phase models seek to account for the intention-behaviour gap through mechanisms such as action planning (i.e., specifying when, where, how, and how often one will engage in the behaviour such as explicitly timetabling when and where science will be taught in a primary school) and coping planning (i.e., specifying how one will overcome barriers to engaging in the behaviour such as outlining when one can make up the time to do a science lesson if, for some reason, it could not be done in the normal timetabled time) (Gollwitzer, 1999). In addition, subjective norms (beliefs about other people's expectations to perform the behaviour; for example, "*I believe that my school principal wants me to teach science*") is not included in van Aalderen-Smeets et al.'s (2012) theoretical framework for teachers' attitudes toward science, despite the likely influence from department leads and school principals on subject prioritisation.

The conceptualisation of the DAS framework was informed heavily by the theory of planned behaviour (Ajzen, 1985, 1991). While the TPB recognises that people do not have complete volitional control of their behaviour, it has nonetheless been criticised for its focus on deliberative, conscious processes as predictors of behaviour, to the exclusion of other important implicit, non-conscious and automatic processes (Hagger & Chatzisarantis, 2014; Sniehotta et al., 2014). To this end, attitudinal constructs from other fields of research that examine non-conscious processes may also offer useful insight in understanding and predicting science teaching behaviour, including accounting for the effects of past behaviour ("*Teaching science is something I do frequently*"; "*Teaching science is something I have done recently*"; "*Teaching science is part of my normal routine*") and habit, which concerns constructs such as repetition (Brown et al., 2020; Hagger et al., 2015).

Notwithstanding the limited interpretation possible due to the poor model fit in the present study, the finding that preservice teachers' perceived relevance and enjoyment of teaching science were statistically significant predictors of their intention to prioritise science teaching suggests that establishing the relevance and importance of science education, while supporting preservice teachers' positive engagement with and enjoyment of teaching science, should be important goals of preservice science teacher education. To this end, preservice teachers can reflect upon and clarify their thinking about the individual, societal and vocational relevance of science education (Stuckey et al., 2013), as well as at each dimension across time (present-future) and for different purposes (intrinsic-extrinsic). This may be achieved by explicitly clarifying the purposes and objectives of science education at different levels (personally, locally/nationally and internationally) and from different perspectives, such as their own personal beliefs and those championed in science education curricula, STEM policies and professional bodies. Broader recommendations for promoting the relevance of science in preservice science teacher education include authentic experiences with scientific inquiry, context-based or socio-scientific approaches to teaching science, and appreciation of science careers and the role scientists play in technological and economic advancement globally (Stuckey, 2013).

The finding that enjoyment was a statistically significant predictor of behavioural intention also provides significant impetus for supporting preservice teachers' positive emotional engagement with science, beyond enhancing their immediate interest in or motivation to engage with science. Possible sources of anxiety for teaching science may include organising and setting-up materials; conducting scientific experiments, especially for the first time; and not knowing students very well, feeling pressured to make a good impression (Tobin et al., 2016; Bellocchi et al., 2019). Conversely, enjoyment while teaching science may relate to the teacher feeling happy and satisfied around their teaching practices such as including students in learning and moving away from doing 'chalk and talk' (Tobin et al., 2016). With a view to support preservice teachers' enjoyment teaching science, we suggest that opportunities for teaching science should be embedded in coursework. This can include demonstrations and scientific explanations as well as role playing ('micro teaching') primary science lessons. For example, in a study by Henderson and King (2021), roleplay was an effective approach to evoking positive emotional engagement in learning science. Explicitly addressing the emotions elicited by science teachers' work may also be fruitful (Bellocchi, 2019; Bellocchi et al., 2019).

Concluding Remarks

Drawing from learnings of other disciplines, the DAS framework will likely need to evolve to increase its predictive and explanative ability. This may be achieved by incorporating other important variables that have already been shown to play a role in predicting and explaining behaviour, and by re-thinking the relationships and inclusion of the current identified variables. Furthermore, there is need for continued comprehensive tests of the DAS framework and any future iterations, in their entirety, to validate the relationships between the variables (i.e., nomological validity). The model should be tested in high-powered and diverse samples in multi-phase prospective designs to provide robust evidence of the proposed relations, before attempting experimental designs to confirm the direction of effects and to infer causality.

Ethics Statement

This research was approved by QUT Human Research Ethics Committee (Approval Number 1700000511).

Disclosure Statement

The authors report there are no competing interests to declare.

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