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Do Science Teachers Distinguish Between Their own Learning and the Learning of Their Students?

Heike Brauer[1] · **Matthias Wilde**[1]

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Abstract Learning beliefs influence learning and teaching. For this reason, teachers and teacher educators need to be aware of them. To support students' knowledge construction, teachers must develop appropriate learning and teaching beliefs. Teachers appear to have difficulties when analysing students' learning. This seems to be due to the inability to differentiate the beliefs about their students' learning from those about their own learning. Both types of beliefs seem to be intertwined. This study focuses on whether pre-service teachers' beliefs about their own learning are identical to those about their students' learning. Using a sample of pre-service teachers, we measured general beliefs about "constructivist" and "transmissive" learning and science-specific beliefs about "connectivity" and "taking pre-concepts into account". We also analysed the development of these four beliefs during teacher professionalisation by comparing beginning and advanced pre-service teachers. Our results show that although pre-service teachers make the distinction between their own learning and the learning of their students for the general tenets of constructivist and transmissive learning, there is no significant difference for science-specific beliefs. The beliefs pre-service teachers hold about their students' science learning remain closely tied to their own.

Keywords Teaching beliefs · Learning beliefs · Constructivist · Transmissive · Teaching professionalisation

Introduction

"Teachers' beliefs lie at the very heart of teaching" (Kagan 1992, p. 85). This means that beliefs deeply affect all aspects of teaching and learning (Pajares 1992). Kleickmann et al. (2012) showed that pre-service teachers' beliefs were deeply influenced by their own learning biography. They based their beliefs about their students' learning on their beliefs about their

✉ Matthias Wilde
matthias.wilde@uni-bielefeld.de

[1] Universität Bielefeld, Fakultät für Biologie, Biologiedidaktik, Universitätsstraße 25, D-33615 Bielefeld, Germany

own learning. Additionally, teachers tend to transfer their own attitudes about learning to the learning of their students and are therefore not able to diagnose students' learning properly (Cain 2012; Nespor 1987). As such, understanding teacher beliefs may contribute to the successful development of school education (Bolhuis and Voeten 2004).

Beliefs are considered to be propositions that individuals think are true (Luft and Roehring 2007). They can be core or peripheral (Brownlee et al. 2002) and can also be intertwined within each other, making them difficult to distinguish (Luft and Roehring 2007). Teachers' beliefs about teaching and learning are rooted in their life experiences (Kagan 1992). Richardson (1996) identified two kinds of experiences influencing the development of beliefs about teaching: experience with schooling and instruction and experience with formal knowledge. Experience with schooling seems to mainly influence generalised beliefs, whereas professionalisation at university seems instead to influence specific beliefs (Cain 2012). A study of pre-professional experience with schooling and instruction has suggested that university students come to pre-service teaching programmes with a set of deep beliefs about the nature of teaching based on their own experiences as students (Kleickmann et al. 2012).

Beliefs serve as a reference framework (Helmke 2010), and pre-service teachers seem to transfer individual experiences to present teaching situations (Cain 2012). Teachers seem to be creating in their mind ideal or alternative interpretations of situations that might differ from the reality of the learner (Nespor 1987). Additionally, pre-service teachers extrapolate their own experiences as learners assuming that their students have aptitudes, interests, and problems similar to their own (Kagan 1992). Particularly at the beginning of their teaching career, teachers suppose that their observations and experiences as students themselves will be the same for the students they are now teaching (Meyer et al. 1999). Experienced teachers possibly extend their views on students' learning, but they still seem to view it from their one-sided perspective and may assume that their students are learning in the same way they did (Huibregtse et al. 1994). Therefore, they may overemphasise approaches and methods appropriate to their own learning at the expense of other teaching approaches (Huibregtse et al. 1994). Projecting their own way of learning onto their students may be one reason that teachers often fail to predict students' learning difficulties (van Driel and de Jong 2002).

Trigwell and Prosser (1993) classified two general frameworks for teaching and learning (see also Norton et al. 2005). The first encompasses traditional teacher-centred methods, and the second constructivist student-centred approaches (Norton et al. 2005; Trigwell and Prosser 1993). The first framework is characterised by transmissive beliefs, or the idea that teachers can transmit knowledge. In contrast, student-centred approaches comprise constructivist beliefs, which are based on the idea that learners are individual constructors of their own knowledge. For teachers holding constructivist beliefs, the teacher's role is that of a facilitator of knowledge construction (Duit and Treagust 2003). In addition, they assume that the learner constantly evaluates new information in terms of the degree to which it fits past knowledge and experience (Driver 1989).

Teaching and learning beliefs can vary with respect to context. For example, the beliefs of teachers who teach science and language differ significantly from those who teach science and philosophy (Neuhaus and Vogt 2012). Additionally, teachers' beliefs are generalised to a greater or lesser extent depending on their subject specification and subject domain (Buehl et al. 2002). They range from beliefs referring globally to learning and teaching to those dealing with a specific subject or domain (Kleickmann 2008). The latter in particular appear to play an important role in the development of subject-specific content (Kleickmann 2008). Teaching science is a complex process determined by prior

knowledge and experience (Brown et al. 2013; Russel and Martin 2007). Scientific concepts can be taught by means of various phenomena (Kleickmann 2008). It is important to choose phenomena the students might already be familiar with. To better support students' learning, their pre-concepts should be connected to the subject taught (Kleickmann 2008). In order to teach science successfully, it is important for science teachers to have developed an adequate belief structure (Lederman 1992). Examples of domain-specific beliefs are the role of experiments, epistemological beliefs and beliefs about the function of (prior) knowledge and experience, such as those involving connectivity and taking pre-concepts into account (Widodo and Duit 2004). Beliefs regarding connectivity refer to the involvement of previous coursework (Möller 2010). Beliefs about pre-concepts involve the students' familiarity with non-scientific concepts developed from students' everyday experiences and speech (Möller 2010). The importance of these beliefs is shown when comparing experts and novices: Experts use principle-oriented, abstract knowledge structures whereas novices tend to develop knowledge structures that are interconnected with a topic-oriented structure (Chi et al. 1981). Taking this into account, the science curriculum should give students the opportunity to investigate the practical, social, contextual, and political dimensions of science and it should be taught in contexts (Fensham 1992; Huibregtse et al. 1994). Hence, by contextualising information, students are enabled to apply their knowledge and make connections between their everyday life and prior knowledge. This approach can serve to break down the distinction between academic scientific knowledge and everyday knowledge (Driver 1989). Regarding science as an organised and deductive system of laws and rules, on the other hand, emphasises the transmission of knowledge (Fensham 1992; Huibregtse et al. 1994).

In order to analyse science pre-service teachers' beliefs about learning, we focused first on their general beliefs about *transmissive* and *constructivist* learning. Secondly, we investigated their domain-specific beliefs about the role of (prior) knowledge, specifically those about taking *pre-concepts* into account and *connectivity* in teaching science.

Research Question and Objectives

Pre-service teachers come to pre-service teaching programmes with beliefs influenced by their experiences with pre-university education. These individual experiences are transferred to their teaching. Furthermore, pre-service teachers may project their own experiences onto their students and assume that the students learn in the same way they do. Pre-service teachers, unsurprisingly, tend to favour the teaching approaches they most enjoyed when they were at school themselves. Teachers valuing traditional learning approaches assume that efficient learning is realised when teachers transmit knowledge. Consequently, pre-service teachers may struggle with the constructivist approach, which is currently prevalent. In order to develop adequate learning beliefs, pre-service teachers must first become aware of the beliefs they hold.

We focused on whether pre-service teachers' beliefs about their students' learning were related to their beliefs about their own learning. In particular, we were interested in the question of whether the general transmissive and constructivist beliefs pre-service teachers hold about their student's learning correspond with those about their own learning. Analogously, we investigated whether specific beliefs involving connectivity and pre-concepts also followed this pattern. Furthermore, we were interested in the longitudinal

perspective of teacher beliefs and explored the development of pre-service teachers' beliefs by comparing students at the beginning with students at the end of their bachelor's study programme.

Methods

Overview and Sample

The sample consisted of 224 pre-service science teachers who studied at four different universities in Germany. In Germany, pre-service teachers first accomplish a mainly theoretical university training. All students in this study were in the first phase of teacher education. The number of semesters of tertiary study (university) completed by students was captured ($M_{\text{semester}} = 3.82$, $SD_{\text{semester}} = 1.64$; $M_{age} = 23$, $SD_{age} = 3.95$). The study took place at universities that offer primarily formal learning opportunities, although some also offered informal (team-) learning opportunities. All instructors received a manual to standardise data collection. In order to analyse the development of general and specific beliefs, we divided the sample into two groups. The first group included students studying in the first to third semester, the second students in their fourth to sixth semester. Students of both groups attended the same courses during data collection, independent of their semester. Both groups were similar regarding gender ratio and academic training. The study design was quasi-longitudinal and used two questionnaires (32 items in total) developed specifically for this study by adapting parts of other previously tested questionnaires (Brauer et al. 2015; see Table 1).

Test Instruments

The first instrument, the TraC-questionnaire, measured the beliefs about general learning processes on the transmissive and constructivist dimensions. We used items from Peterson and colleagues (1989) and from Staub and Stern (2002). The instruments were designed to capture espoused beliefs the participants might not be aware of (Schön 1983; Strauss et al. 1998). The two scales regarding transmissive and constructivist learning processes consisted of four and three items, respectively. The second instrument, the CoP-questionnaire, covered the science-specific dimensions of connectivity and pre-concepts. The *connectivity* scale focused on the integration of previous course content into science lessons (four items), and the *pre-concepts* scale (five items) on the integration of individual explanations about biological phenomena with respect to everyday experiences (Brown et al. 2013). The items from these four scales were randomised across the

Table 1 Overview of the subscales evaluated at both measuring points

Perspective	Pre-service teachers' beliefs about their students' learning		Pre-service teachers' beliefs about their own learning	
Beliefs	General	Specific	General	Specific
	Transmissive	Pre-concepts	Transmissive	Pre-concepts
	Constructivist	Connectivity	Constructivist	Connectivity

questionnaire to disrupt a response set. The items involving student learning used the third person singular (see Table 2).

The pre-service teachers were asked to indicate their agreement using a 5-point scale. The factorial structures of all four scales have been previously validated (Brauer et al. 2015). In the current sample, exploratory factor analyses with default factors were conducted. The extraction was based on an eigenvalue > 1. As a precondition for the exploratory factor analysis, the Bartlett's test was conducted in conjunction with testing of the Kaiser-Meyer-Olkin (KMO)-criterion. The KMO-criterion was not lower than .7; the Bartlett's test was always significant (see Table 3). The exploratory factor analyses show that the four dimensions of beliefs about students' learning and the pre-service teachers' own learning can be separated from each other.

In addition, for each scale we analysed whether the items regarding beliefs about students' learning could be separated from those involving the pre-service teachers' own learning. For this reason, an exploratory factor analysis was also conducted for each scale from both perspectives (see Tables 4 and 5). Results show that for each scale, beliefs about students' learning and the pre-service teachers' own learning can be separated.

Results

The descriptive statistics suggested that pre-service teachers tend towards a constructivist approach for their own and their students' learning. Additionally they do not support a transmissive approach for either their own learning, or students' learning. The pre-service teachers' specific beliefs were also in line with a constructivist approach. They agreed with supporting connectivity and taking their students' pre-concepts into account when teaching. Similarly, they approved of this kind of learning for themselves (see Table 6).

Table 2 Item examples for the TraC- and CoP-questionnaire

	Beliefs about students' learning	Beliefs about pre-service teachers' their own learning
	Item examples from the TraC-questionnaire	
	It is important for the pupils' learning process that…	It is important for my own learning process that…
Transmissive (four items)	…all students can reproduce the content verbatim.	…I can reproduce the content verbatim.
Constructivist (three items)	…students can develop their own approach.	…I can develop my own approach.
	Item examples of the CoP-questionnaire	
	It is important for the pupils' learning process that…	It is important for my own learning process that…
Connectivity (four items)	…they can integrate their knowledge.	…I can integrate my knowledge.
Pre-concepts (five items)	…they can bring in everyday experience.	…I can bring in everyday experience.

Table 3 PCA rotated factor matrix for pre-service teachers' beliefs about their students' and their own learning processes

	Beliefs about students' learning					Beliefs about their own learning			
	Trans	Cons	Conn	Pre		Trans	Cons	Conn	Pre
Trans_1	0.79				Trans_1	0.84			
Trans_2	0.79				Trans_2	0.85			
Trans_3	0.68				Trans_3	0.74			
trans_4	0.79				Trans_4	0.84			
Cons_1		0.81			Cons_1		0.82		
Cons_2		0.81			Cons_2		0.83		
Cons_3		0.50			Cons_3		0.61		
Conn_1			0.73		Conn_1			0.79	
Conn_2			0.81		Conn_2			0.76	
Conn_3			0.79		Conn_3			0.85	
conn_4			0.55		Conn_4			0.79	
Pre_1				0.67	Pre_1				0.83
Pre_2				0.66	Pre_2				0.55
Pre_3				0.69	Pre_3				0.73
Pre_4				0.63	Pre_4				0.68
Pre-5				0.60	Pre-5				0.69
Eigenvalue	2.55	1.95	2.52	2.35	Eigenvalue	2.83	2.19	2.97	2.72
Variance	15.86	12.20	15.01	14.82	Variance	17.56	12.61	17.86	16.83
Cronbach's α	0.77	0.77	0.78	0.68	Cronbach's α	0.84	0.74	0.84	0.84
Item discrimination	0.47–0.62	0.38–0.60	0.43–0.61	0.35–0.50	Item discrimination	0.56–0.74	0.45–0.69	0.66–0.77	0.46–0.65

Only loadings higher than |0.40| are reported

Trans transmissive, *Cons* constructivist, *Conn* connectivity, *Pre* pre-concepts

KMO = .76; ***$p < .001$; 58.6 % explained variance

KMO = .81; ***$p < .001$; 64.8 % explained variance

Table 4 PCA rotated factor matrix for the transmissive and constructivist beliefs

Students' learning	Students' learning	Own learning	Students' learning	Students' learning	Own learning
Trans_4	0.80		Cons_1	0.85	
Trans_1	0.74		Cons_2	0.82	
Trans_3	0.69		Cons_3	0.64	
Trans_2	0.68				
Own learning			Own learning		
Trans_2		0.86	Cons_1		0.87
Trans_1		0.85	Cons_2		0.77
Trans_4		0.81	Cons_3		0.73
Trans_3	0.47	0.51			
Eigenvalue	2.50	2.65	Eigenvalue	2.65	2.50
Explained variance	31.24	33.12	Explained variance	31.91	32.80
Cronbach's α	0.77	0.84	Cronbach's α	0.77	0.74
Item discrimination	0.47–0.62	0.56–0.74	Item discrimination	0.38–0.60	0.45–0.69

Only loadings higher than |0.40| are reported

Trans transmissive, *Cons* constructivist

KMO = .837; ***$p < .001$; 64.3 % explained variance

KMO = .713; ***$p < .001$; 64.7 % explained variance

Table 5 PCA rotated factor matrix for the beliefs "connectivity" and "taking pre-concepts into account"

Students' learning	Students' learning	Own learning	Students' learning	Students' learning	Own learning
Conn_2	0.86		Pre_3	0.79	
Conn_3	0.78		Pre_2	0.67	
Conn_1	0.70		Pre_1	0.64	
Conn_4	0.47		Pre_5	0.57	
			Pre_4		0.47
Own learning			Own learning		
Conn_4		0.84	Pre_5		0.80
Conn_3		0.80	Pre_2		0.75
Conn_1		0.78	Pre_1		0.67
Conn_2		0.75	Pre_3		0.61
			Pre_4	0.51	0.46
Eigenvalue	2.55	2.54	Eigenvalue	2.29	2.12
Variance	31.88	31.79	Variance	28.64	26.47
Cronbach's α	0.78	0.84	Cronbach's α	0.68	0.84
Item discrimination	0.43–0.61	0.65–0.77	Item discrimination	0.35–0.50	0.46–0.65

Only loadings higher than |0.40| are reported

Conn connectivity, *Pre* pre-concepts

KMO = .862; ***$p < 0.001$; 63.7 % explained variance

KMO = .759, ***$p < 0.001$; 55.1 % explained variance

Table 6 Descriptive statistics of the TraC- and CoP-questionnaire including means (M) and standard deviation (SD); minimum = 0, maximum = 4

	Beliefs about students' learning		Beliefs about own learning	
	M	SD	*M*	SD
Transmissive	1.22	0.75	1.43	0.88
Constructivist	3.45	0.54	3.21	0.65
Connectivity	3.32	0.52	3.33	0.59
Pre-concepts	3.30	0.67	3.35	0.67

Relation Between the General Beliefs of Pre-Service Teachers About Their 'Students' and Their Own Learning

We used a repeated measures ANOVA to compare the general constructivist and transmissive belief frameworks from the perspective of the students' and the pre-service teachers' own learning. The results showed significant differences between general beliefs about the students' and the teachers' own learning for the constructivist ($F(1,210) = 31.62$, $p < 0.001$, $\eta^2 = 0.131$) as well as for the transmissive scale ($F(1,208) = 14.5$, $p < 0.001$, $\eta^2 = 0.065$). Hence, pre-service teachers seem to differentiate between beliefs about the learning of their students and their own learning both for the constructivist and the transmissive dimensions. However, Pearson's coefficients indicated strong correlations between the two constructivist ($r = 0.43$, $p < 0.01$), and the two transmissive scales ($r = 0.57$, $p < 0.01$).

Relation Between the Specific Beliefs of Pre-Service Teachers About Their 'Students' and Their Own Learning

For the specific beliefs, the repeated measures ANOVA showed no significant differences between the perspectives, neither for the connectivity ($F(1,209) = 0.197$, $p = ns$) nor for the pre-concepts scales ($F(1,213) = 1.854$, $p = ns$). Hence, pre-service teachers showed similar beliefs about their students' and their own learning. Similar to the findings about general beliefs, we found that beliefs regarding connectivity ($r = 0.59$, $p < 0.01$) and pre-concepts ($r = .50$, $p < 0.01$) showed significant correlations between the two perspectives.

We also wanted to know whether beginning pre-service teachers held different general beliefs than more advanced pre-service teachers (see Table 7). The MANOVA showed significant

Table 7 Descriptive statistics of the first to third semester students (beginning pre-service teachers) and fourth to sixth semester students (advanced pre-service teachers) for general beliefs. Means (M) and standard deviations (SD) are reported; minimum = 0, maximum = 4

	Beliefs about students' learning *M* (SD)	Beliefs about own learning *M* (SD)	Beliefs about students' learning *M* (SD)	Beliefs about own learning *M* (SD)
Semester	Transmissive		Constructivist	
First to third	1.37 (0.81)	1.56 (0.93)	3.47 (0.53)	3.21 (0.62)
Fourth to sixth	1.11 (0.69)	1.31 (0.81)	3.44 (0.56)	3.19 (0.67)

differences for both groups regarding transmissive beliefs; more advanced pre-service teachers reported a less transmissive orientation: $F(1,202) = 6.144$, $p < 0.05$, $\eta^2 = 0.030$ in relation to students' learning; $F(1,202) = 4.192$, $p < 0.05$, $\eta^2 = 0.020$ in relation to their own learning. Regarding constructivist beliefs, the MANOVA, however, did not show any significant differences between the pre-service teacher groups in relation to either students' learning: $F(1,202) = 0.099$, $p = ns$; or own learning: $F(1,202) = 0.035$, $p = ns$.

Analogously to the question above, we wanted to know whether the beliefs held by beginning pre-service teachers about domain-specific beliefs differed from those of pre-service teachers nearing the end of their bachelor studies (see Table 8). For specific beliefs, the MANOVA showed no significant differences between the student groups in either the connectivity or the pre-concepts perspective (connectivity in relation to /students' learning: $F(1,205) = 0.030$, $p = ns$; connectivity/in relation to their own learning: $F(1,205) = 1.500$, $p = ns$; pre-conceptions/in relation to students' learning: $F(1,205) = 0.218$; $p = ns$; pre-conceptions/ in relation to their own learning: $F(1,205) = 3.672$, $p = ns$).

Discussion

In our study, we focused on understanding the learning beliefs of pre-service teachers. More precisely, we wanted to analyse whether the beliefs held by pre-service teachers about their students' learning were related to the beliefs the pre-service teachers held about their own learning. Our results show that for general beliefs, pre-service teachers differentiated between their own learning and that of their students. Nevertheless, beliefs about students' learning correlated with beliefs about their own learning.

We also detected significant differences between beginning and advanced pre-service teachers in terms of transmissive beliefs in relation to students' learning and their own learning, but not for constructivistic beliefs. For specific beliefs about connectivity and pre-concepts there were no significant differences and they were found to be strongly correlated in relation to both students' learning and the pre-service teacher participants' own learning. Overall, there appeared to be a tendency for the view that transmissive learning is effective to decrease the longer the pre-service teachers attend university, both in relation to their understandings about students' learning and their own learning.

Pre-service teachers' general beliefs are affected by their own schooling and instruction experiences, beginning in early childhood (Richardson 1996). In contrast, specific beliefs are mainly influenced by the experiences pre-service teachers have in their

Table 8 Descriptive statistics of the first to third semester students (beginning pre-service teachers) and fourth to sixth semester students (advanced pre-service teachers) for specific beliefs. Means (M) and standard deviations (SD) are reported; minimum = 0, maximum = 4

	Beliefs about students' learning *M* (SD)	Beliefs about own learning *M* (SD)	Beliefs about students' learning *M* (SD)	Beliefs about own learning *M* (SD)
Semester	Connectivity		Pre-concepts	
First to third	3.32 (0.55)	3.39 (0.56)	3.26 (0.67)	3.45 (0.66)
Fourth to sixth	3.31 (0.50)	3.28 (0.61)	3.30 (0.60)	3.28 (0.67)

tertiary education (Cain 2012). It can be argued that pre-service teachers have had a long time to reflect upon their general beliefs and that they should be able to distinguish between their views in relation to students' learning and their own learning, and not equate their own learning processes with those of their students. However, specific beliefs are relatively newly developed (Cain 2012). Therefore, pre-service teachers may be able to correctly distinguish between the two perspectives only later in their career and not in the time frame we analysed. It would be worth including more experienced teachers or master's students in future studies.

The correlations between the two perspectives (students' learning and their own learning) in relation to the four belief scales were relatively strong. This is not surprising, since this could be due to the normal development of beliefs; pre-service teachers first develop a perspective for their own learning before they develop one for their students (Meyer et al. 1999). Our results indicate that beliefs can develop in parallel for both perspectives. Hence, there might be a connection between the pre-service teachers' beliefs in relation to their own learning and the learning of their students. When comparing the beliefs of beginning and more advanced pre-service teachers, the results showed that the development of beliefs seems to be independent of whether they are specific or general. Beliefs that seem to change during university study are those involving the transmissive framework. In contrast, no significant effects were found regarding the constructivist framework, either on the general level or the specific. This might be the result of a ceiling effect, and therefore not necessarily evidence of a lack of development. There were also limitations to our study. A main factor is the measurement of espoused beliefs. In such analyses, participants might answer in a socially desired way (Kleickmann 2012). This might be especially true for contents discussed in lectures and consistent with contemporary education, such as the transmissive and connectivity scales. Additionally, all scales showed means on the upper as opposed to the lower sides of the scales and were based on a small number of items which could indicate a ceiling effect. A second factor is the quasi-longitudinal design of the study. In future research, the participants should be surveyed several times in order to gain longitudinal data. A third factor is the assumption, that beliefs are developed consistently.

The findings of this study indicate that teacher educators should bear in mind that beliefs regarding learning and teaching can be developed differently. In particular, pre-service teachers may have difficulties differentiating between their own learning processes and those of their students (compare Huibregtse et al. 1994). Accordingly, teacher educators should help pre-service teachers examine their own beliefs in the light of reform-orientated practice (Brown et al. 2013) and especially help them to reflect on different learning perspectives. The beliefs we examined all indicate a correlation between teachers' beliefs about their own learning processes and their students' learning processes. It therefore follows that changes in one perspective might lead to changes in the other. One way to facilitate change of inadequate beliefs might be through the explication and reflection of one's own beliefs. A precondition for all development is a motivation to change. Engaging in this process may well result in the will to develop a more sophisticated belief framework about learning processes. Russel and Martin (2007) suggest that teacher preparation may be viewed as a process of conceptual change. From this perspective, science teacher education should help pre-service teachers become dissatisfied with traditional, transmissive teaching and learning and provide opportunities for students to reflect on the importance of prior knowledge and pre-concepts in learning (Brown et al. 2013).

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