Supporting Pre-Service Science Teachers' Planning of Task-Based Classroom Discussions

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Abstract: This study focuses on a set of core, or high-leverage, practices in teacher education in order to allow pre-service teachers to begin to develop a set of necessary skills to successfully support student learning through inquiry (Grossman et al., 2009b). Specifically, in the secondary science teacher preparation program teacher educators adopted a practice-based focus in which secondary pre-service science teachers participated in the high-leverage practice of engaging students in task-based science discussions and the planning of those discussions. The results suggest that pre-service teachers are able to incorporate aspects of these instructional models in their discussion planning practices. The results also suggest a shift in focus on different aspects of planning over time and across science disciplines that open the possibilities for future work.

Background and Significance of Work

Teachers will face many challenges as we move forward into the age of the *Next Generation Science Standards (NGSS)* (Achieve, 2013). The *NGSS* aim to develop a population of scientifically literate and talented students who can participate in the "innovation-driven economy" (p. 1). In order to meet these goals, teachers must provide students with opportunities to engage in science and engineering practices (SEPs), e.g., interpreting data, engaging in argument, and learning core ideas of these disciplines.

In classrooms where students are engaged in the practices of scientists and engineers, teachers face the additional challenge of designing instruction so that students have opportunities to wrestle with the underlying science ideas at a high level (Engle, 2011; Engle & Conant, 2002; Smith & Stein, 2011). To design instruction in this way, a teacher must first identify key learning goals to focus the lesson and then choose a task that is robust enough to support students' thinking and learning in the discipline. After selecting (or designing) a task, the teacher must then imagine in detail the ways in which her students might engage with the task, design appropriate tools and scaffolds to support and direct that engagement, and plan for ways to monitor students' work during the task, also know as the Five Practices model (Cartier, Smith, Stein, & Ross, 2013). We assert that this type of planning is both sophisticated and teachable. In this study, we describe our approach to helping pre-service secondary science teachers (PSTs) adopt effective (high-leverage) planning practices. We investigate the impact of engaging PSTs in a series of carefully scaffolded exercises focused on helping them to learn how to anticipate and support students' engagement in challenging science tasks and subsequent discussions about those tasks. Specifically we examined:

(1) To what extent do PSTs use the Five Practices instructional model in their planning?
(2) In what ways do PSTs' use of the Five Practices instructional model change over time?

Importance of Classroom Discourse in Science

Students in today's science classrooms must have opportunities to develop the practices and skills used in science and engineering professions in order to be productive members of our technologically advanced society (Achieve, Inc., 2013; Duschl, 2008). Discourse – or students engaging in talk with one another around disciplinary concepts – is a key component of classrooms where students are engaged productively in science and engineering practices (SEPs). While discourse is necessary to achieve the *NGSS* goals, it is also a challenge for teachers to orchestrate (Grossman et al., 2009a; Stein, Engle, Smith, & Hughes, 2008).

As teacher educators, our goal is to provide novice teachers with conceptual and practical tools to support their learning and teaching (Grossman, Hammerness, & McDonald, 2009b), and we are particularly interested in supporting the practices related to orchestrating productive classroom discussion. Researchers have identified many different pedagogical strategies designed to aide teachers in supporting robust discussions and supporting students in the types of discourse that increase deep understanding. Pedagogical frameworks, such as Investigating and Questioning our World Through Science and Technology (IQWST) (Berland & Reiser 2008; McNeill, Lizotte, Krajcik, & Marx, 2006), the evaluate-alternatives model (Sampson & Grooms, 2009), the Accountable Talk framework (Michaels, O'Connor, & Resnick, 2008), and the Five Practices model (Cartier, Smith, Stein & Ross, 2013; Smith & Stein, 2011; Stein et al., 2008) present teachers with micro-practices that support student learning through discussion. These frameworks have several features in common. Specifically, each emphasizes the need for teachers to (1) choose appropriate instructional content that promotes discourse, (2) guide and support students through scaffolding, and (3) hold students accountable to classroom and scientific norms.

Expert teachers have established routines and plans that help to support such ambitious instruction. Many of their moves have been developed and practiced over time and are often not taught to beginning teachers (Leinhardt & Steele, 2005). However, we assert that because novice teachers struggle to support productive student engagement in science discussion, and because this type of instruction shows so much promise for enabling learners to engage in SEPs and master core content, teacher educators should provide pre-service teachers with conceptual and practical tools to support this practice (Grossman, Hammerness, & McDonald, 2009). Consequently, we have designed pedagogy courses for PSTs that include explicit opportunities to learn about and practice elements of the Five Practices instructional model (Cartier et al., 2013; Smith & Stein, 2011). By supporting teachers in learning how to *anticipate* student thinking, *monitor* student responses to tasks, *select* students to present their work, purposefully *sequence* these presentations, and *connect* the ideas through discussion, this model guides teachers through the processes of preparing for and supporting whole class discussions (Cartier et al., 2013; Smith & Stein, 2011). We leveraged these five practices in the design of the secondary science methods course.

Theoretical and Methodological Approaches

In order to make PSTs more comfortable with enacting discussions in their classrooms, we chose to attend to specific aspects of this practice and designed learning experiences to help them develop the skills to enact productive discussions in their own 7^{th}-12^{th} grade classrooms. We utilized the framework developed by Grossman and colleagues (2009a), to design cycles of decomposition, representation, and approximation of planning practices related to task-based discussions. By separating complex practices in subsets, or micro-practices, such as the critique and analysis of lesson planning and discussion facilitation, into its component parts, we reasoned that PSTs would feel more comfortable enacting the practices in their own classrooms, leading to consistent implementation of these practices over time (Grossman et al., 2009a; Stein et al., 2008). What follows is a detailed example of how we utilized this framework within the context of the pedagogy courses for secondary science PSTs at the Midwestern university where this study occurred (see Table 1).

We divided the fall semester into lessons in which the PSTs engage in science as learners and as practitioners through iterative cycles of decompositions, representations, and approximations of practice (Grossman et al., 2009a). More specifically, in addition to other practices, the PSTs observed teacher educators decompose and represent the practice of the Five Practices model by having the PSTs approximate components of this model by planning discussion-based lessons using this model, and rehearsing and formally teaching instructional episodes with peers. Through varying levels of authenticity the teacher educators guided the PSTs to examine specific planning and instructional practices and certain teacher moves that help to support discussion orchestration. Once the PSTs had the opportunity to unpack these instructional micro-practices, they were better able to use them in their own planning and teaching (Grossman et al., 2009a).

Decomposition

Enacting productive task-based discussions in any discipline is a complex practice in which teachers employ a variety of moves, micro-practices, and routines during instruction (Leinhardt & Steele, 2005). In order for PSTs to begin to engage in this or any practice, Grossman et al (2009b) posit that PSTs may need varying opportunities to recognize and then enact small components of professional practice after which they can then begin to integrate each micro-practice completely.

By decomposing the Five Practices model into its distinct practices, we provided PSTs with an opportunity to focus on certain fundamental skills, e.g. anticipating student thinking, that will help them to prepare for and facilitate productive science discussions (Grossman et al., 2009a). This decomposition allowed the instructor to call attention to as well as provide immediate feedback to students as they analyzed and reflected upon these components. Through this feedback, the PSTs attend to particular teacher moves and aspects of the instructional model that help support their discussion planning and facilitation. By focused attention on certain aspects of student thinking, student work, and important teacher moves, these aspects of discussion typically viewed as improvisational by many beginning teachers seem less so (Smith & Stein, 2011; Stein et al., 2008). By giving the PSTs this instructional planning tool and facilitating a discussion, our goal was to help them feel more comfortable standing to the side of the dialogue and allowing students' opportunities to engage with each other.

In order to support the development of the PSTs' planning for lessons where students engage in science discussions, we selected particular practices based on past research (Smith & Stein, 2011), namely: writing specific learning goals, anticipating student thinking, planning for monitoring, selecting and sequencing student approaches, and connecting student ideas and disciplinary ideas. We believe that the development of these practices in PSTs' repertoires will best support the development of their capacity to design task-based science discussions.

Representation

The PSTs observed expert teachers utilizing the model, read written cases, as well as analyzed evidence of student work. Through varying levels of authenticity we guided the PSTs to examine specific practices or certain teacher moves that help to support the instructional dialogue that might otherwise go unnoticed. By drawing attention to particular details, the PSTs began to notice and learn ways in which they might begin to build their own teaching repertoire.

Once the PSTs analyzed these micro-practices related to planning science discussions, they have a model, or representation, by which to analyze this complex practice (Stein et al., 2008). For example, by providing PSTs with examples of student work and a case study of how a classroom teacher implements her classroom discussion, we foregrounded salient aspects of anticipation, monitoring, selecting, sequencing, or connecting the teacher used. Through these various representations, we supported the PSTs in visualizing ways in which they can begin to use and develop their own identity as a classroom teacher (Grossman et al., 2009a).

Approximation

By simulating and role-playing a Five Practices discussion in the methods classroom, the PSTs engaged in approximations of practice similar to those identified by Grossman et al (2009a). As they gained experience, they engaged in varying levels and iterations of authentic and complex discussion practices, thereby developing the knowledge and skills necessary to begin to integrate the decomposed pieces of the model. Through this public practice and feedback provided to the PSTs, we highlight particular aspects of the model, while other, less important, aspects of discussion facilitation are ignored. By drawing PSTs' attention to these important aspects and allowing them to engage in opportunities to practice, they can begin to develop their PDC to design tasks necessary to facilitate productive, engaging science discussions with students.

In designing the secondary science methods courses, we adopted Ball and Forzani's (2009) practice-based focus to design a Teaching Laboratory course for secondary science pre-service teachers in which they participate in the high-level practice of supporting productive classroom discourse. We designed role-play scenarios that enabled our PSTs to engage in approximations (Grossman et al., 2009a) of these Five Practices in the context of the Teaching Laboratory course. Here, we provide examples of our approximation scenarios and described the principles underlying the design (see Figure 1).

Grossman et al.'s framework Component	*Description*	*Example from Teaching Lab course*
Decomposing the Practice	Breaking down the overall practice into component parts is necessary in order for the practice itself to be accessible to learners. **Thus, a complex practice like "orchestrating classroom discussion" can be viewed as consisting of several smaller practices.**	Smith and Stein (2011) decompose the practice of orchestrating discussion into five sub-practices: (1) anticipating students' ideas and/or problem solutions related to an instructional task; (2) monitoring students' work during the task and taking note of which ideas emerge; (3) selecting examples of students' work to highlight in whole-class discussion; (4) planning the sequence in which you will discuss these work samples; and (5) planning questions and talk that will elicit key ideas and help learners connect their ideas to one another and underlying canonical disciplinary ideas.
Representing the Practice	Representations should be chosen or created to highlight certain aspects of practice while backgrounding others. Representations may be teaching artifacts like lesson plans or excerpts from curriculum materials, or they may be videos, transcripts, or examples of student work.	In our work, we developed "sample stories" that are partial transcripts of classroom discussions. These transcripts are accompanied by meta-language that reveals the teacher's rationale for decision-making during the discussion.
Approximating the Practice	Learners develop facility with a practice only through participation in approximations of that practice. **Initial approximations are usually constrained and simplified**. Later, learners encounter the practices in more complex and realistic contexts.	We developed elaborate role-play scenarios related to various science ideas (e.g. kinetic molecular theory, the theory of natural selection, mathematical modeling of radioactive decay). The materials that support each role-play scenario include: (a) a description of the instructional activities in which students would participate; (b) samples of student work that have been selected or invented such that typical alternative conceptions are represented; (c) background information for the person playing each student's role; and (d) tools to support teachers' monitoring, selecting, sequencing, and question planning. The role-play scenarios provide opportunities for pre-service teachers to engage in approximations of all five sub-practices related to orchestrating discussion. They take turns adopting the role of student and teacher throughout the scenarios and have multiple opportunities to offer and receive feedback on their teaching performance and decision-making throughout the each scenario.

Figure 1. Description of the Approximation Scenarios From the Teaching Laboratory Course (Ross, Cartier, Forman, & Walker, 2011).

Participants

A total of 18 teachers enrolled in the 2011-2012 secondary science Master of Arts in Teaching and professional year teacher certificate year program. The 14 subjects (5 males and 9 females) of this study were a sample of convenience because they were all enrolled in the science methods course and required to participate in the coursework. The majority were 22-26 years old and Caucasian. Two instructors taught the Teaching

Laboratory during this time using a common syllabus and identical classroom learning tasks and course assignments.

Data Corpus and Coding

Over the course of 10 weeks during the fall 2011 term, the PSTs completed two instructional planning (IP) assignments in which they planned and designed their own lessons focusing on whole class discussion around data (see Figure 2). Each PST implemented their lesson at the secondary science placement in which they were assigned. Upon completion of the lesson, PSTs completed a reflection on the lesson and posted all relevant materials (e.g. lesson plan, tasks, reflection, etc.) to a shared online planning tool that the research group had access. In service of this study's goals we focused the analysis specifically on the PSTs planning documents.

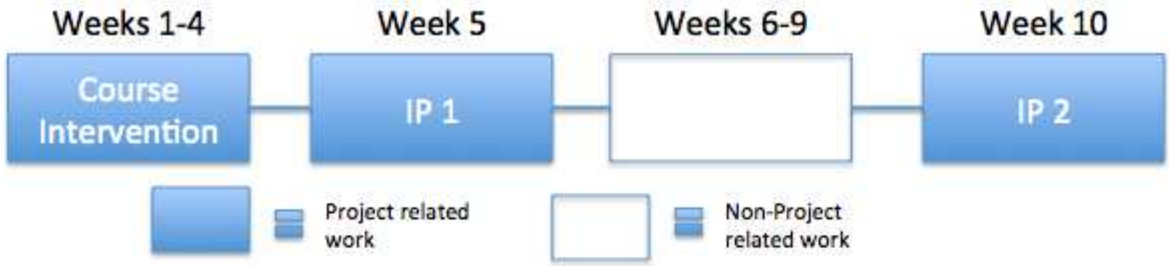

Figure 2. Intervention and instructional planning timeline.

Recall that the purpose of this study is to understand what features of the Five Practices (Stein & Smith, 2011) the PSTs, who had participated in the role-play scenarios around these practices, utilize when planning for a discussion lesson. We coded each lesson plan for instances of anticipating, monitoring, selecting, sequencing, and connecting as defined by Stein and Smith (2011). Twenty-five percent of the data set was double coded with an interrater reliability of 85%. In areas where there was disagreement, we discussed the disagreements and reached consensus.

Major Findings

Use of the Five Practices Model in Planning

In both lesson plans, PSTs showed evidence of using the Five Practices in their lesson planning. Coding for use of the Five Practices included a variety of different ways that the PSTs used this instructional model. PSTs anticipated, monitored, selected, sequenced, and connected in their planning. Exemplars of each of these practices are below (Table 2).

Table 2. Examples of Use of the Five Practices in the PSTs' Lesson Planning.

Anticipating	"Based on the surveys I had students complete in the last class, I have already organized them into groups specific groups with similar thinking patterns (though not 100% the same, because differences will help to facilitate a discussion)." Details misconceptions and groups and what their underlying misconceptions are for each group."
Monitoring	Plans questions and prompts to address to students and probe their thinking in order to generate a discussion. Creates a completed monitoring tool based on student work from previous day.
Selecting	"I will ask for volunteers if students fail to volunteer I will ask for group 2 to start." They had the q2m2 then group 5 can offer alternative explanation of lab data then group 1 with the alternative form of sugar (I will privately ask Brittney from group 4 if she would come up she will wrap up this discussion b/c she had most complete and well thought out response"
Sequencing	"I will ask for volunteers if students fail to volunteer I will ask for group 2 to start." They had the q2m2 then group 5 can offer alternative explanation of lab data then group 1 with the alternative form of sugar (I will privately ask Brittney from group 4 if she would come up she will wrap up this discussion b/c she had most complete and well thought out response"
Connecting	Plans questions that prompt students to make comparisons to the affordances and drawbacks of sickle cell anemia.

In the first set of lesson plans (Instructional Performance 1), coding for use of the Five Practices model showed that PSTs did utilize part of the model in their planning. Of the 14 PSTs, evidence of anticipating and monitoring occurred the most in their planning practices with 8 out of 14 anticipating and 11 out of 14 monitoring to some degree (see Table 3). Half of the teachers (7) showed evidence of selecting students' work to present in their planning, with sequencing and connecting used by only 5 teachers.

In Instructional Performance 2 (IP 2) planning, PSTs show evidence of using connecting in their planning most frequently, 10 out of 14. Selecting and sequencing use occurred the least in their planning, 4 and 2 PSTs, respectively. However, use of anticipating and monitoring practices decreased compared with IP1, 6 PSTs and 7 PSTs respectively (see Table 1). Overall, there is not evidence that the PSTs use the Five Practices model as intended, incorporating all of the Practices in their planning. Instead, PSTs show evidence of using selective practices in each lesson plan

Table 3**:** Total number of pre-service teachers' use of features of the five practices instructional model in their lesson planning assignments.

	Anticipating	Monitoring	Selecting	Sequencing	Connecting
IP1					
No Evidence	6	3	7	9	9
5P Use	8	11	7	5	5
IP2					
No Evidence	8	7	10	12	4
5P Use	6	7	4	2	10

Use of the Five Practices Model in Discussion Planning Over Time

In looking at the way PSTs planning changed over time, we see two patterns emerge. First, there is a shift in anticipating and monitoring use in IP1 with minimal attention paid to planning for connecting to clear evidence in IP2 where connecting is a focus of the PSTs' planning attention (see Table 1). This finding suggests that PSTs recognized the importance of planning for connecting and discussion orchestration after implementing IP1 and made that planning a focus in their subsequent lesson plans. Moreover, evidence suggests that PSTs attend to particular aspects of their planning at certain times. For example, immediately after coursework focusing on the importance of using the Five Practices, 51% of the PSTs used elements of the Five Practices model in their planning. As time passes, only 41% of the PSTs used elements of the Five Practices model in their planning. This finding suggests: (1) PSTs recognized the importance of planning for connecting in their discussion, (2) PSTs focused on other elements of their planning as they continue teaching in their field placements.

Second, in an effort to determine if any content specific variations occurred in the PSTs planning, we analyzed the data with respect to content area (see Tables 4 and 5). Although the sample size is low (n=14), a pattern emerges between Physical Science and Biological Science. For IP 1, both content area PSTs plan using features of the Five Practices at some level. However, for IP 2, there is a significant drop in the General Science PSTs that plan using the Five Practices model. The Biological Science PSTs plan using the Five Practices across IP 1 and IP 2, while planning in the Physical Sciences drops noticeably. This finding indicates a possible connection between planning and using the Five Practices model in the two science areas. We cannot speak to specifics without further research, but there may be a connection between content area and curriculum and ease or feasibility of using the Five Practices model. Moreover, there may be differences in the way the PSTs understanding of the Nature of Science or learning of science. For instance, if a PST has an understanding that Chemistry is learned through doing experiments and completing problems, then it might be difficult to conceptualize a robust whole class discussion around Chemistry content.

Table 4: Total number of pre-service teachers' use of the five practices model in planning for instructional performance 2 by content area.

<table>
<tr><th></th><th></th><th colspan="5">IP1</th></tr>
<tr><th></th><th></th><th>Anticipating</th><th>Monitoring</th><th>Selecting</th><th>Sequencing</th><th>Connecting</th></tr>
<tr><td rowspan="3">Physical Science</td><td>No Evidence</td><td>4</td><td>2</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>5P Use</td><td>6</td><td>8</td><td>5</td><td>4</td><td>3</td></tr>
<tr><td>Total</td><td>10</td><td>10</td><td>10</td><td>10</td><td>10</td></tr>
<tr><td rowspan="3">Biological Science</td><td>No Evidence</td><td>2</td><td>1</td><td>2</td><td>3</td><td>2</td></tr>
<tr><td>5P Use</td><td>2</td><td>3</td><td>2</td><td>1</td><td>2</td></tr>
<tr><td>Total</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td></tr>
</table>

Table 5: Total number of pre-service teachers' use of the five practices model in planning for instructional performance 3 by content area.

		IP2				
		Anticipating	**Monitoring**	**Selecting**	**Sequencing**	**Connecting**
Physical Science	No Evidence	7	6	8	9	4
	5P Use	3	4	2	1	6
	Total	10	10	10	10	10
Biological Science	No Evidence	1	1	3	3	0
	5P Use	3	3	1	1	4
	Total	4	4	4	4	4

Conclusions and Implications

These findings suggest that the Five Practices role-play approximations in the Teaching Laboratory course plays a role in supporting PSTs as they plan for robust science discussions using this instructional model. Over time, the PSTs appear to focus on other aspects of their teaching, e.g., classroom management, and less focused on planning related specifically to discussions using the Five Practices model. It might be necessary to design supports methods courses to further unpack the importance of student talk and discussion in science. In addition, we are currently designing ways to support PSTs planning and teaching through discussion throughout their teacher preparation coursework. This study provides evidence that the Five Practices model and teaching of this instructional model provides a useful framework for PSTs as they plan discussions. By simulating and approximating a Five Practices discussion in pedagogy courses, the PSTs engaged in approximations of practice similar to those identified by Grossman et al (2009a) as effective. As the teachers gained experience, they engaged in varying levels of authentic and complex discussion practices, thereby developing the knowledge and skills necessary to begin to integrate the decomposed pieces of the model as they planned lessons for their own 7-12 students. Through the public practice and feedback, we highlighted particular aspects of the Five Practices important for planning a productive discussion. By drawing PSTs' attention to these important aspects and allowing them to engage in opportunities to practice, they showed evidence of using these practices as they planned to engage their students in science discussions.

Additionally, these findings suggest that the role-play scenarios in which the PSTs participated in the pedagogy courses are effective in the PSTs learning. Providing the PSTs with opportunities to engage in the approximations of practice (Grossman et al., 2009) allows for greater traction and understanding of the strategies presented in the role-play. Problematizing the issues that arise as teachers enact discussions in the familiar and comfortable setting of their own classrooms allows the PSTs to notice these issues and practice ways to address them.

In addition, findings from this study indicate the importance of grounding Five Practices discussions in high-levels tasks (Smith & Stein, 2011). Although not a focus of this study, anecdotal data reveals that designing and planning discussions around tasks that are not cognitively demanding for students can hinder the ways in which the PSTs plan and implement these discussions. As such, we continue to work on designing ways in teacher preparation to support PSTs development as instructional designers.

In order for the ambitious vision of science instruction presented by the *NGSS* (Achieve, Inc., 2013) to become a reality in secondary schools, teachers must design instruction with these goals in mind. By using various curriculum resources (e.g. texts, online lesson plans and resources, standards, curriculum materials, etc.), teachers can design instruction that supports students' engagement in SEPs and their sense making related to key disciplinary phenomena. The ability to navigate through the vast number of these resources and to design instruction appropriate for each group of students is the essence of what Brown (2009) terms *pedagogical design capacity (PDC)*. Thinking about the task, or thinking through the lesson, in critical ways can support teachers' as they design their planned curriculum (Smith & Stein). Analyzing tasks through the student lens allows teachers to understand their value in supporting students' learning and support teachers as they build upon individual tasks to create lesson arcs and curriculum units (Remillard, 2000).

Theoretically, we will continue to learn more about teacher learning and the mechanisms behind learning to orchestrate discussions through the continued use of the Five Practices model and the iterations of representation, decomposition, and approximation of practice through design research that continues in these courses (Grossman et al., 2009a). The potential learning ecologies and theories that emerge from this research will enhance teacher education across disciplines. Practically, it directly impacts the secondary science pre-service teachers in this teacher preparation program yearly. Ultimately, teachers impact secondary science student learning greatly through participating in task-based discussions regularly. This study lays the foundation for generalizability to other disciplines. The features of the role-play instructional model based on the Five Practices (Stein et al., 2008) can be used in teacher education course in all disciplines. Through the identification of important features of the model that are essential for PST learning, teacher educators can design instruction to incorporate similar role-play instructional models in their disciplines.

The work associated with preparing pre-service science teachers to incorporate science and engineering practices into their instruction is something everyone should be concerned with, especially given the release of the *Next Generation Science Standards*. As the demands on teachers' instruction increases, beginning teachers need to be able to incorporate high-leverage practices effectively in order to engage students. This work describes a feasible way to prepare PSTs to engage students in task-based science discussions and the planning of those discussions through a set of decompositions, representations, and approximations. Additionally, this work addresses what these practices can look like in real environments, suggests one possible way to frame these practices in established instructional theory, opens the doors for discussions around practices, and has some clear avenues for further research including lesson implementation and student learning.

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