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RESEARCH ARTICLE

INDICATORS OF PRODUCTIVE CLASSROOM TALK AND SUPPORTING DISCOURSE MOVES: A SYSTEMATIC REVIEW FOR EFFECTIVE SCIENCE TEACHING

Yılmaz SOYSAL[*]

ABSTRACT

This study intended to delve into productive classroom talk (PCT) typologies and sets of teacher discursive moves (TDMs) or talk moves supporting yielding dialogues in the context of teaching science. This study was arranged as an extended systematic review in which a content-based and thematically-oriented analysis of the selected works were carried out. Two frameworks; conceptual and technical, were invented and applied to the pooled studies. 67 research articles were selected from a larger pool and examined in a fine-grained manner. Five themes or indicators of the PCT were extracted. These are "clarity and intelligibility of the talks", "critiques in the talk", "accountability-justification-authority", "intense discursively-oriented metacognitive activity" and "teacher as the discursive role model". In addition, six sets of TDMs were extracted from the literature that are thought as supporting for the actualisation of a PCT indicator. These are "communicating", "challenging", "evaluating-judging-critiquing", "monitoring-framing", "seeking for evidence" and "modelling-rehearsing aspects of processes of science". The relations between indicators of the PCT and supporting TDMs were reinterpreted by making concrete combinations and presenting in-class instances. It was concluded that several scholars worked through the generic lines of the PCT; however, within the examined studies, supporting TDMs were not attached to the productivity. One of the salient inferences of the present study is that whether science teachers hold a teacher-noticing pertaining the interrelations between the PCT and supporting TDMs. Several recommendations were offered for science teachers and science teacher educator particularly in terms of triggering and sustaining teacher-led noticing regarding rather sophisticated relationships the PCT and supporting TDMs. Practically, pedagogic noticing requires intentionality that is attainable in the presence of high quality professional development programs.

Keywords: Productive Classroom Talk, Teacher Discourse Move, Systematic Review

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[*]Correspondance Details: **Yılmaz SOYSAL,** Faculty of Education, İstanbul Aydin University, İstanbul, Turkey.
E-Mail: yilmazsoysal@aydin.edu.tr
https://orcid.org/0000-0003-1352-8421

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ARAŞTIRMA MAKALESİ

ÜRETKEN SINIF SÖYLEMİNİN GÖSTERGELERİ VE DESTEKLEYİCİ SÖYLEMSEL HAMLELER: ETKİLİ FEN EĞİTİMİ İÇİN SİSTEMATİK BİR DERLEME

*Yılmaz SOYSAL**

ÖZET

Bu çalışma üretken sınıf söylemi (ÜSS) türlerini ve öğretmenin söylemsel hamlelerini (ÖSH) ya da fen öğretimi bağlamında üretken diyalogları destekleyen öğretmen konuşma hamlelerini derinlemesine araştırmayı amaçlamaktadır. Bu çalışma, seçilen eserlerin içerik esaslı ve tematik yönelimli bir analizinin yapıldığı genişletilmiş bir sistematik derleme olarak düzenlenmiştir. İki çerçeve; kavramsal ve teknik, oluşturulmuş ve havuzda yer alan çalışmalara uygulanmıştır. Bu amaçla 67 çalışma geniş bir araştırmalar havuzundan seçilmiş ve derinlemesine incelenmiştir. ÜSS adına beş tematik gösterge ortaya çıkarılmıştır. Bunlar "sınıf içi konuşmalardaki netlik ve anlaşılırlık", "sınıf içi konuşmalardaki eleştiriler", "sınıf içi konuşmalarda hesap verilebilirlik-gerekçelendirme-otorite", "yoğun söylem-yönelimli üst-bilişsel aktivite" ve "rol model olarak öğretmendir". Bununla birlikte, ÜSS'nin herhangi bir göstergesinin sınıf içinde var edilmesini desteklediği düşünülen altı ÖSH seti ilgili literatürden elde edilmiştir. Bunlar "iletişimsel hamleler", "çeldirici hamleler", "değerlendirmeci-eleştirici-yargılayıcı hamleler", "izleme-çerçeveleme hamleleri", "kanıt için arayışta olmak hamleleri" ve "bilimsel süreçleri modelleme hamleleridir". ÜSS göstergeleri ve destekleyici ÖSH'ler arasındaki ilişkiler maddi birleştirmeler yapılarak ve sınıf içi örnekler sunularak yeniden yorumlanmıştır. Birçok araştırmacının ÜSS'nin genel hatlarını derinlemesine incelediği, ancak incelenen çalışmalarda destekleyici ÖSH'nin üretkenliğe bağlanılmadığı sonucuna ulaşılmıştır. Bu çalışmanın öne çıkan çıkarımlarından biri, fen bilimleri öğretmenlerinin ÜSS ve destekleyici ÖSH'ler arasındaki ilişkilere dair bir öğretmen farkındalığına sahip olup olmadığıdır. Fen bilimleri öğretmenlerine ve öğretmen eğitimcilerine, özellikle ÜSS ve destekleyici ÖSH'ler arasındaki karmaşık ilişkilere yönelik öğretmen farkındalığının oluşturulması ve devam ettirilmesi açısından birçok öneride bulunulmuştur. Pratikte, öğretmen farkındalığı kasıtlılığı gerektirir ki bu yüksek kaliteli mesleki gelişim programları aracılığıyla elde edilebilir.

Anahtar Kelimeler: Üretken Sınıf Söylemi, Öğretmenin Söylemsel Hamlesi, Sistematik Derleme

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*Sorumlu Yazar: **Yılmaz SOYSAL**, Eğitim Fakültesi, İstanbul Aydın Üniversitesi, İstanbul, Türkiye.
E-Mail: yilmazsoysal@aydin.edu.tr
https://orcid.org/0000-0003-1352-8421
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Introduction

This study intended to delve into productive classroom talk (PCT) typologies and sets of teacher discursive moves (TDMs) or talk moves supporting yielding dialogues in the context of teaching science. This study took a theoretical stance in analysing the relationships between the PCT and TDMs. Thus, first, the PCT interventions were extracted, then, empirical observations pertaining sets of TDMs were analysed to make relations between two different but inherently interrelated fields of inquiry regarding classroom discourse enacted in the science classroom.

Theoretical Underpinnings

Productive Classroom Talk and Teacher Discursive Moves

Classroom talk (CT) is the primary tool for effective instruction that fosters the quality of learners' cognitive outcomes (Littleton & Mercer, 2013; van der Veen, van Kruistum, & Michaels, 2015). Student-led talks that are enriched by specifically-oriented teacher-led talks may largely influence what and how students acquire disciplinary knowledge (Alexander 2001; 2008; Nystrand et al., 2003). Not all the teacher-led talks are productive for augmented student-led outcomes. Teacher-led moves materialising rigorous dialogues among the peer community may be more boosting in terms of cognitive outcomes (Alexander, 2008; Mercer, 1995; Gillies, 2013).

In the context of the present study, CT refers to verbal interactions and exchanges among classroom members in two forms: teacher-student, student-student. As Mercer, Wegerif and Dawes (1999) stated, CT incorporates three functions in promoting students' cognitive outcomes. CT can be operated as a cognitive tool by which students externalise, probe, extend, modify or totally alter their ideas on topic under consideration. CT has a social-cultural dimension. This means that norms, tenets or practices of specific cultural entities (e.g., scientific communities) can be shared with and experienced by students via specific talk typologies. CT is also a pedagogical tool that may be used to generate productive instructional teaching sequences in which a teacher may use classroom talk as a pedagogic intervention and all instructional approaches (e.g., inquiry-based, problem-based, argument-based inquiry, cooperative learning, etc.) are surrounded, staged, in turn; materialised through TDMs in the classroom (Leach & Scott, 2002; Soysal, 2018; 2019).

TDMs are analytical or utterance-sized units/agents of talk. When a teacher asks, "What do you mean by this?" s/he tries to grasp underlying meaning that is embedded in the articulation of a student. This is needed for the PCT since the continuity of a progressive talk requires comprehensible and intelligible externalisations. For another example, when a teacher asks, "Did you mean that there is a close relation between wearing up a warm woollen coat and using a thermal insulator?" s/he tries to revoice the uttered opinion to scaffold all students' comprehension regarding thermal mechanics. This example presents a teacher-led reformulation (Chapin, O'Connor, & Anderson, 2003) but in a different form compare to the student's original utterance as s/he articulates "When I wear up a worm woollen coat, I feel rather hot in winters." The student did not conceive a worm woollen coat as a thermal insulator that is embedded in the teacher's teaching agenda or the social language of school science. As a whole, the term TDMs incorporates instructional/pedagogic moves/actions of a teacher.

Featured productive classroom talk interventions observed in the previous studies

In the current literature, several research groups evidently proposed different PCT interventions: exploratory talk (ET) (e.g., Barnes, 1976), collaborative reasoning (CR) (e.g., Anderson et al., 1998; Reznitskaya et al., 2009), accountable talk (AT) (e.g., Michaels & O'Connor, 2002; Michaels, O'Connor, & Resnick, 2008), collective argumentation (CA) (e.g., Brown & Renshaw, 2000; Conner et al., 2014a; 2014b), dialogic teaching (DT) (Alexander, 2006; 2008). In these PCT interventions, student-led cognitive outcomes were ameliorated by virtue of executing above-listed in-class interventions. This study aimed at striving for capturing the parameters of yielding classroom talk. In

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these studies, various measurements were attained pertaining student-led cognitive contributions to classroom discourse as the major indicator of productive classroom talk processes. Thus, these studies attach importance for concretising the indicators of the PCT. However, in-class teaching also requires for fine-grained exploration of the TDMs that are instrumental in materialising the PCT parameters that are visible in the sense of timely and properly enacted discourse moves. For these purposes, above-located talk interventions were summarised below.

Barnes (1976) proposed the ET more than four decades ago. During in-class (science) teaching, a student group or individual students may have an argument pertaining a science topic that may be deficient in some terms and should be tested by the peer community's reasoning. As a pedagogical essence of the ET, all students have discursive opportunities in contributing to others' arguments by a critical but constructive manner. Disputations are not welcomed in the ET that is a specific social mode of interthinking.

The CR mostly incorporates verbalised exchanges among the peer community in addition to teacher-student interactions (Anderson et al., 1998; Waggoner et al., 1995). The CR was indeed originated from reading classes in which students read a text including a big idea about a specific topic. Then, the teacher poses specifically-prepared questions to the community to initiate and maintain open-ended exchanges. Within a democratic or egalitarian instructional atmosphere, students do not aim at falsifying their classmates, instead, the purpose of the discussion is to get somewhere by collective thinking and building on others' ideas (Reznitskaya et al., 2009). The AT is generally related with how students defence their meaning positions against counter arguments. The AT has epistemological orientations regarding argument construction and destruction within a formal in-class setting. Within the AT, students are given authority in addressing their classmates' argumentation, however, their argumentations should be made accountable to others and to disciplinary norms (Michaels & O'Connor, 2002; Michaels, O'Connor, & Resnick, 2008).

The CA has a different nature from abovementioned talk interventions. It was first systematised by different camps of scholars as a talk typology (Brown & Renshaw, 2000; Conner et al., 2014a; 2014b). For the CA, there are two interrelated phases in which students present their argumentations under teacher's guidance by a collectivist manner. The first phase is coined as decontextualisation in which students work in small groups around a challenging or ill-structured (science) topic. Within small groups, students first work individually to address the problematic, then, share their solutions that should be justified or reasoned during group-based negotiations. Eventually, all individual student groups try to convince the other groups that their solutions may be more valid and reliable. This is called as recontextualisation in which validation criteria of proposed meaning positions are crystallised by collective efforts of group members. The DT can be seen as the invention of Alexander (2006; 2008).

In the DT, the science teacher uses his/her talks to act as a discussant, negotiator or challenger to invite students to (re)ponder about thought-provoking processes. As a routine act of the DT, the students have to acknowledge the fact that the truth can be procured via testing, structuring evidence, examining and legitimating alternative points of views (Alexander, 2008). The cognitive quest that may be launched by teacher-led or student-led interrogations is seen as the fundamental source of co-constructing knowledge claims in the classroom.

Purpose of the current study

In the current study, the differences and communalities among the above-located typologies of the talk interventions were deeply and thematically analysed to abstract the indicators of the PCT. As mentioned, this study took a theoretical stance. To put it differently, theory-based or research-based indicators were crystallised to grasp the core components of the PCT in order to attach them to the scaffolding discourse moves. To attain this, a specific thinking tool was applied. To be clear, on one hand, scholars might discern a particular aspect of the PCT phenomenon by excluding others at a given time and within a specific research context. On the other hand, some other scholars might feature more sophisticated descriptions of the components of the PCT. This is mostly related with the breadth of the awareness (Åkerlind, 2012) of the scholars who experienced or conducted a version of the PCT in their own studies. In the present study, two specifications of the PCT indicators were examined: shrinking potentiality (delving into only a few individual aspects of the productivity) and broadening capacity (researching into rather sophisticated and integrated aspects of the productivity) (Åkerlind, 2008). In the context of this study, broadening capacity is more about potential for

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variation regarding the revealed PCT indicators. This clarifies the differences among the selected studies. However, shrinking potentiality refers to the uniformity on the side of the researchers while reporting their research outcomes pertaining the PCT. This signifies the communality (Åkerlind, 2003; 2008).

Justification for the study

Indeed, Khong, Saito and Gillies (2019) extendedly summarised key issues, aspects and typologies of productive classroom talk interventions. However, Khong et al.'s (2019) study does not incorporate the materialising TDMs for triggering and maintaining yielding classroom interactions for the purpose of effective science teaching, purposed in the current study. Through similar research efforts (e.g., systematically reviewing), scholars concretised the nature and structure of productive teacher-led and student-led talk (e.g., çHowe & Abedin, 2013; Khong et al., 2009). Another group of researchers were also in action for determining which TDMs are used for initiating, maintaining and finalising in-class science teaching implementations (e.g., Chin, 2006; 2007; Soysal, 2018; 2019). Apart from the previous studies, this study aimed at intersecting these two intense research fields by undertaking a thematically-oriented analysis of the works in the research pool to redefine which TDMs may be displayed to initiate and maintain the PCT for intellectual gains of students.

In the current study, the TDMs were particularly focused. To explicate, particularly Leach and Scott, (2002) argued that "researchers tend to attribute improvements in students' learning to the effectiveness of the sequence of teaching activities, giving little explicit attention to the teacher's role in staging those teaching activities, in the social context of the classroom." (p. 116). This argument was also supported by recent studies (Soysal, 2018; 2019). There is no room to underestimate the TDMs that surround any teaching sequence (Leach & Scott, 2002). Teaching sequences or interventional typologies are important; however, they are materialised by virtue of diversifying sets of the TDMs (Soysal, 2018; 2019). The science teacher may, for instance, tend to actualise guided inquiry in his/her laboratory. The science teacher therefore establishes an instructional scene staging for implementing the guided inquiry with his/her students. However, to our knowledge, not the all science teachers could be conceived as the better implementers of the guided inquiry approach. To explicate, the guided inquiry, as a teaching sequence, is surrounded by specific sets of the teacher-led talk moves that are essential to handle an authentic guided inquiry implementation in the classroom. As an inference, if the science teacher is able to stage proper TDMs by a good timing, the activity will attain its pedagogical and intellectual goals. The science teacher's surrounding talk moves (the TDMs) has therefore a key role in enlarging the students' intellectual contributions to classroom discourse that is the main indicator of the productivity (e.g., Chin, 2006; 2007; Soysal & Yilmaz-Tüzün, 2019). Thus, it would be considerably vital to reconsider the TDMs staged during any type of in-class implementation (i.e., exploratory talk, accountable talk, dialogic teaching, collaborative reasoning, and collective argumentation) in estimating cognitive pathways of the students as the essence indicator of the productivity.

Methods

This study was designed as an in-depth content analysis in which research-based documents were analysed in terms of their different aspects such the indicators of the PCT and occurrences of the TDMs. The purpose of that type of analysis was to systematically transform a large amount of research outcomes (documents) into a considerably organised and concise summary of key results (Lin, Lin, & Tsai, 2014). As mentioned, this study was conducted to represent theoretical interrelations between the PCT typologies/interventions and accompanying TDMs for materialising the in-class interventions. For this purpose, a two-stage systematic review was conducted and combined by a pragmatic manner to re-consider and re-characterise the interrelations between the indicators of the PCT interventions and actualising TDMs. At the outset, the PCT interventions were surveyed and indicators were qualitatively extracted. In the second phase, the TDMs were also reviewed systematically to ascertain which set of TDMs are more compatible with the each extracted PCT indicator. For this theory-based analysis, two methodological frameworks were devised:

1. Conceptual framework was used for determining and establishing criteria to select or eliminate a study dedicated to classroom talk or classroom discourse,

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2. Procedural framework was developed for more analytical or technical processes in which selected scholarly works were re-examined and re-interpreted.

Stage-1: Establishing the Conceptual Framework

In a multifaceted systematic review as taken in the current study, one of the most essential methodological approach is to locate the eligibility criterion (Abrami, Cohen & d'Apollonia, 1988). The selection or elimination of the studies for the sake of the current study's theoretical purposes depended on the specific operational definitions located at the above sections. This is the essence of the eligibility (Suri & Clarke, 2009). For an illuminating review, it is strongly suggested that one must interrogate which studies hold more potential (eligible) to be included in the pool (Lin, Lin, & Tsai, 2014).

One of the most valid indicators of the eligibility is the operational definitions of concept(s) under examination (Abrami, Cohen & d'Apollonia, 1988). In this study, three overarching concepts were used for collapsing and detailing the eligibility in searching of the related studies. These are "classroom talk (CT)", "productive classroom talk (PCT)" and "teacher discursive move(s)" or "teacher discourse moves (TDMs)". These research-driven concepts were used to frame the boundaries of the current study's inclusion and exclusion criteria. Mentioned conceptions were considered in making decision whether a study, dedicated to classroom discourse, may have capability of getting in touch with the purposes of the present study. This methodological approach, as devising a semipermeable griddle, was used as a filtering system in differentiating relevant studies from the unconnected ones. Three layers of the selected studies were observed:

- Totally unconnected studies: even though their title, abstract or keywords incorporates classroom talk or classroom discourse,

- Partially connected studies (implicitly-overlapped),

- Completely related and proper studies (explicitly-overlapped).

After sorting out entirely unconnected studies, implicitly-overlapped and directly-related studies were considered for different research purposes in the current study. First and foremost, partially connected studies provided conceptual tools, epistemological underpinnings or ontological commitments regarding what-aspects and how-aspects of CT, PCT and TDMs (e.g., Kiemer, Gröschner, Pehmer & Seidel, 2015; Micheals, O'Conner, & Resnick, 2008; O'Connor & Micheals, 2017). Implicitly-related studies were the initial predictors of the explicitly-related studies (e.g., Molinari & Mameli, 2013; Pehmer, Gröschner, & Siedel, 2015; Tytler & Aranda, 2015).

Through a snowball technique, implicitly-connected studies prompted the researcher to strive for capturing more appropriate studies incorporating a clear and concrete investigation of the PCT (e.g., Chin, 2006; 2007), TDMs (e.g., Soysal & Yilmaz-Tüzün, 2019) or both (e.g., Veen, Kruistum, & Micheals, 2015). To put if differently, theoretical (e.g., Vygotskian socio-cultural theory, activity theory) and philosophical terms (e.g., Bakhtinian notions such as internally persuasive dialogue) embedded in the implicitly-related studies (e.g., O'Connor & Micheals, 2007) were serviced as an initial selective lens for the careful selection of the relevant studies. A detailed list of the examined studies can be seen in the "References" section. Studies regarding the PCT are marked by (*) and researches dedicated to reveal out the TDMs are signed by (**). In total, 67 studies (nPCT; bunun30; 44.8%; nTDMs; 37; 55.2%; respectively) were deeply examined to construct an entire picture of the relationships between the PCT and TDMs.

Stage-2: Operating the Procedural Framework for Analysing the Content of the Studies

To reach the most informing studies, a computerised search was conducted. Diverse data bases (e.g., ERIC, ERIC Thesaurus, ERIC via ProQuest, ProQuest Dissertations & Theses Global, JSTOR, PsycINFO) were surveyed for capturing more relevant studies. The search was conducted in 2019 through inserting specific keywords: "classroom talk", "productive talk", "talk typologies", "talk interventions", "cognitive contributions", "classroom discourse", "teacher questioning", "teacher move",

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“discursive move”, “discourse move”, “talk move”, “cognitive outcome”, “review”. In addition, for an advanced or multi-layered survey, some of the couplets were constructed by the above-listed keywords. Both primary and secondary sources were involved in the preliminary pool for a fine-grained selection and elimination. The diversity of the included research journals was kept seeing different scholars’ voices/intellectual contributions in the pool. For including or excluding the research journals, peer-reviewing, higher impact factor and reputation were considered to reach more reliable and valid results on the phenomena under examination. The studies were selected from an extended time interval as 1976-2019.

First, two researchers read the abstracts of the selected works at the least three times for re-selection or re-elimination. There had to be a credible sampling as it was expected to represent the population of the studies dedicated to classroom discourse. Detecting a direct and close relation to core concepts was the fundamental indicator as the studies devoted to improvement the theory of CT, PCT and TDMs were strictly featured during preliminary analysis. Features of the participants of surveyed studies were also an important selection criterion. Studies incorporating participants from primary, elementary, middle and secondary school were inserted into the pool to keep the diversity pertaining participant structures. Discourse analytic techniques were also considered to select a study for in-depth analysis. In some of the studies, more qualitatively-oriented examinations (e.g., episode analysis, conversational analysis) of classroom discourse were taken. For some other, more quantitatively-driven analysis techniques (e.g., lag sequential analysis, systematic observations through coding and counting) were used. Recent studies were also selected for ensuring the state-of-the-art principle.

In-depth reading of each piece of the scholarly works was the first step of data analysis (Erlingsson & Brysiewicz, 2017). An inductive/interpretivist analysis approach was applied for coding and categorising the indicators of the PCT and TDMs. In this phase of the analysis, first of all, meaning units were extracted. During this process, two coding catalogues were structured and used: “coding catalogue for the indicators of the PCT” and “coding catalogue for accompanying TDMs”. Catalogues are both theory-laden. By carefully examining the selected studies, all signs, cues or nuances of the PCT were listed to continuously generate diverse meaning units. To do this, all studies devoted to an examination of the PCT were explored in terms of any analytical indicator of the talk interventions presumably facilitating yielding classroom talks among the peer community. Thus, particularly “Findings” or “Results” sections of the studies were analysed in-depth. Same process was also operated for extracting the TDMs. The coding catalogues were organic. After collapsing repeating codes (indicators), novel codes were continuously added. Once the saturation of the codes was observed, the analysis was completed. After analysing isolated meaning units, condensed meaning units were collapsed, then, the solid codes were emerged (Erlingsson & Brysiewicz, 2017). Higher-order categories characterising the relations between the PCT and supporting TDMs were then established after the codes were pooled around the categories. Inter-coder reliability for the PCT coding was 76.3% and 88.9% for the TDMs coding. Through engaging in rigorous negotiations, conceptual discrepancies among the assigned codes were resolved and secondary inter-coder reliability was improved up to the 85.9% for the PCT catalogue.

Findings

In this section, generic parameters of the PCT and typologies of the scaffolding TDMs are presented. Indicators of the PCT are presented by a sectionalised style (e.g., Indicator-1; Indicator-2, etc.). Within each indicator representation, accompanying TDMs are also exemplified by means of classroom dialogues that were taken from authentic science teaching implementations that were conducted across 5th, 6th and 7th grades. Discourse moves for materialising the PCT in the classroom are interpreted analytically by inserting individual examples for all of the moves. In most of the sub-sections, the PCT indicators and scaffolding TDMs are presented in an interwoven style since these are complementary and compensatory structures of dialoguing therefore cannot be reported by an isolated manner.

As seen in Table 1, five overarching indicators of the PCT were extracted. Moreover, Table 1 represents communalities and differences among the talk typologies regarding the extracted indicators. Table 2 displays the supporting TDMs for carrying out the indicators in the classroom. As seen in Table 2, six sets of TDMs were extracted from the literature that are thought as supporting for the actualisation of a PCT indicator.

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Table 1. *Indicators and descriptors of the PCT*

Indicators	Brief descriptions	Communalities and differences of the indicators stated in the featured PCT interventions				
Clarity and intelligibility of the talks	•All members should be able to ability to make intellectual contributions to classroom discourse. •There should be a clear and healthy communication among peer community in which verbal interactions and exchanges are clearly comprehended and captured.	ET	CR	AT	CA	DT
		#	#	#	#	#
Critiques in the talk	•There should be less disputational and/or cumulative talk among peer community •During classroom discourse, there should be critical but constructive talks. •Conceptual, epistemological and ontological cognitive conflictions, contradictions and challenges should be made visible, public and explicit and rigorously negotiated.	ET	CR	AT	CA	DT
		#	#	#	#	#
Accountabil-ity-Justifica-tion-Authority	•Students should hold accountability to learning community, accepted standards of logic and theories/notions in a specific field of inquiry. •Student-led predicates should be justified, or classroom talk should promote students to warrant their meaning positions by reasoned discourse or justified reasoning. •Students should be assigned as social and epistemic authorities of classroom discourse. •There should be a dialogic space as an inclusive space of dia-logue within which self and others mutually construct and re-con-struct each other.	ET	CR	AT	CA	DT
		#	#	#		#
Intense discursively-oriented meta-cognitive activity	•Occurrences of classroom discourse should be monitored by all students. •Classroom talk should incorporate coherent lines of reasoning and joint/shared/collective understanding. •Classroom talk should incorporate conceptual agreements before taking further actions as opening a new topic up for discussion.	ET	CR	AT	CA	DT
		#	#			
Teacher as the discursive role model	•Teachers should model disciplinary thinking such as explicitly demonstrating multivariable reasoning. •Classroom talk should include teachers' modelling ways of argument construction, refutation and protection. •Teachers should model active ways of listening.	ET	CR	AT	CA	DT
			#		#	

*ET: Exploratory talk; CR: Collaborative reasoning; AT: Accountable talk; CA: Collective argumentation; DT: Dialogic teaching

Indicator-1: Clarity and Intelligibility of the Talks

The first theme of the PCT is the clarity and intelligibility of the talks during verbal exchanges and interactions. As seen in Table 1, within all talk interventions this indicator was acknowledged as the sine qua non aspect of generative classroom discourse. This indicator refers that there should be healthy and elaborated intellectual exchanges among peer community (e.g., collaborative reasoning; Reznitskaya et al., 2009). This requires a complete clarity in the idea sharing (e.g., exploratory talk; Mercer, 1995). The dialogues among peer community should be comprehended by the all members then this provides a clear communication in which everyone will be able to comprehend, follow and contribute to classroom discourse (e.g., accountable talk; Michaels & O'Connor, 2002). This is not a simple exchange of the propositions during discussing a topic. A clear and authentic communication refers that all members should strive for capturing what others utter to progress in the discourse (e.g., dialogic teaching; Alexander, 2006; 2008). As seen in Table 2, three talk moves that scaffolding healthy and elaborated communication in the classroom were extracted from the related studies. These are requesting for clarification, probing and reformulating.

Requesting for clarification: A teacher should request students for clarifying their meaning positions during classroom discourse by uttering, "What do you mean by X?" (e.g., Pimentel & McNeill, 2013). This can be conceived as an explicit attempt of teachers in capturing the basic thematic content of the student-led response. Once the science teacher stages that talk move, not only the teacher, but the all students would grasp their classmates' meaning position's content that is the initial instructional condition for a more progressive classroom discourse (e.g., Leach & Scott, 2002).

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Elaborating: Only requesting for clarification may not be sufficient for further social negotiations of meanings or the PCT. Teachers should therefore elaborate on the given student-led answers ("Why do you think that the energy is something that flows continuously?"). Teachers should not see their students as great debaters since the students may need to be guided for deepening and expanding their incomplete responses (e.g., Chin, 2007; Hogan, Nastasi & Pressley, 1999). A student may not fully externalise his/her intention regarding topic under discussion. To disclose the background meaning position of a respondent, probing/expanding/eliciting moves will be instrumental ("How is it possible to think that different masses will be hit to the ground at the same time when they are dropped from the same height?"). When a science teacher displays elicitations deliberately during classroom discourse by forcing students to amplify their externalisations, there would be more cognitive effort on the side of the students (e.g., Soysal, 2018). This, as a chain reaction, may pave the way for the PCT since students are strictly required for materialising their utterances' background meanings (e.g., Tytler & Aranda, 2015).

Revoicing: For an intelligible talk, teachers should also enact reformulating moves. As it is known that there may be students who have difficulties in verbalising their meanings and they may need for verbal scaffolding for clearly articulating their answers in the presence of teacher-led questions (Chin, 2006; 2007; Soysal, 2019). This move was also named as revoicing (e.g., diSessa, Greeno, Michaels, & O'Connor, 2016). For revoicing, a teacher modifies a student-led response to make it more comprehensible for the students (e.g., Oh, 2005; 2010; Oh & Campbell, 2013; see also below located dialogue).

Teacher: What is the difference between heat and temperature?
Student: Wearing a warm woollen coat!
Teacher: Your classmate said that there is a relation between heating up and dressing a warm woollen coat.

For a reformulation, teachers should not entirely alter the core conceptual meaning in the utterance. Reformulations should purpose to enhance the understandability of an utterance given by a student who may have verbal weaknesses in idea delivering (Soysal, 2019). When this is the case, all students, regardless their verbalisation capabilities and capacities, will have opportunities to intellectually contribute to classroom talk as the basic indicator of the PCT (e.g., collective argumentation; Corner et al., 2014a; 2014b).

Table 2. *Supporting TDMs for actualising the PCT in the classroom*

Supporting set of the TDMs	Sub-categories as TDMs	Descriptions	Relation to the themes of the PCT
Communicating	Probing	Expanding and enriching student-led responses	Clarity and intelligibility of the talks
	Requesting for clarification	Clarifying student-led responses	
	Reformulating	Revoicing responses to eliminate any clarity issue	
Challenging	Playing devil's advocate role	Pointing out counter-arguments, contradictions and flaws in student-led responses	Critiques in the talk
	Praising	Reinforcing student-led counter arguments	
	Striving for internal consistency	Guiding students for analysing and modifying their internally inconsistent reasoning	
Evaluating-Judging-Critiquing	Asking for evaluation (student-led)	Inviting students to evaluate, judge or critique their classmates' predicates	Accountability-Justification-Authority
	Asking for evaluation (case-based)	Promoting students to analyse and evaluate a given case (e.g., pedagogical/instructional)	
	Asking for evaluation (teacher-led)	Guiding students to evaluate, judge or critique teacher's meaning position	

Table 2 (Cont.). *Supporting TDMs for actualising the PCT in the classroom*

Monitoring-framing	Focusing	Capturing students' attention to a particular response, event, occurring that is important for the progression of classroom discourse	Intense discursively-oriented metacognitive activity
	Monitoring (type-1: on-moment)	Prompting students for monitoring what is happening in classroom discourse (now)	
	Monitoring (type-2: prospective)	Prompting students for noticing what will be happening in the discourse (future)	
	Monitoring (type-3: retrospective)	Promoting students to reconsider previous conversations by referring previous happenings (past)	
	Summarising-consolidating	Summarising featured ideas to show the progression in the classroom dialogues	
	Selecting (ignoring, excluding, including)	Ignoring (excluding) or including particular student ideas during classroom discourse	
	Asking about mind-change	Asking students whether they will change their claims after/during conversations	
Seeking for Evidence	Prompting for EBR	Forcing and pressing students for reasoned discourse	Accountability-Justification-Authority
	Praising the use of evidence	Motivating students to defend their positions by reasoned discourse	
	Referring in-text information	Promoting students to consider available evidences and/or data to support their arguments	
Modelling & rehearsing aspects of processes of science	Modelling and rehearsing aspects of processes/procedures/operations of science	Modelling how a person controls variable in experiments	Teacher as the discursive role model
		Modelling how a person acts multivariable thinking	
		Modelling how a person makes reliable and valid measurement	

Indicator-2: Critiques in the Talk

The second indicator of the PCT is the continuous existence of the critiques in classroom discourse. This indicator indicates that alternative points of views should be considered and rigorously negotiated during classroom discourse. This is considerably different from disputational or cumulative talk. In disputational talk, members of the learning group do not take their friends' meaning positions seriously or within cumulative talk, teacher pools diversifying ideas through low interanimation of ideas (Mortimer & Scott, 2003) by not creating an argumentative/evaluative discursive context in which there would be a talk that is critical and constructive (e.g., exploratory talk: Mercer, 1995; 1995). To do this, teacher and students first acknowledge alternative thinking and talking for explicating the phenomenon under consideration (e.g., dialogic teaching; Reznitskaya, 2012; Reznitskaya & Gregory, 2013). In addition, teachers should clarify and make public student-led conceptual, epistemological and ontological contradictions for inviting and convincing them that other/alternative types of thinking and talking (theories of science, a more credible student-led reasoning, etc.; e.g., collective argumentation; Brown & Renshaw, 2000) may be more instrumental in explaining natural or social phenomenon. All these processes are functional in creating and sustaining a rigorous learning setting in which students must defence their positions against counter arguments or refutation attempts. When this is the case, students must generate alternate ways of thinking and talking that will be expanded their prior reasoning (e.g., accountable talk; Wolf, Crosson & Resnick, 2006). This is closely related with the PCT since when advocating their points of views, students must produce more persuading arguments for preserving them from counter argumentations or falsifications, which requires more cognitive demand(s) on the side of them (Soysal, 2019), resulting in enriched cognitive outcomes for the students (Soysal & Yilmaz-Tuzun, 2019) as the indicator of the PCT. In addition, within a learning environment filled by authentic critiques, students must defence their propositions against novel ideas or notions (e.g., collaborative reasoning; Anderson et al., 1998) proposed by the teacher who often holds an instructional agenda favouring canonical science knowledge (Mortimer & Scott, 2003). As seen in Table 1, this indicator was accepted as a common aspect of the PCT. Table 2 displays three teacher-led moves supporting the PCT in the sense of critiques in the talk. These were playing devil's advocate role, praising student-led challenging and striving for internal consistency.

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Teacher: What is the difference between heat and temperature?

Student: I think when something is heated up, then, its temperature is increased. Thus, these are same.

Teacher: Suppose that there is a flaming candle in the classroom. Then, we try to heat the classroom up with the candle. Is it possible? I think it is not. However, a radiator that is considerably colder than the flaming candle heat the classroom up easily in winter days. The flaming candle is rather hotter than the radiator, however, it cannot heat the room up. How is this possible?

Playing devil's advocate role: For creating learning environments fostering authentic acquisitions, science teachers should play devil's advocate role through thought-provoking dialogues and persuading students regarding there should be more credible ways of explicating the phenomenon under discussion than the students' propositions (Simon, Erduran & Osborne, 2006). When a science teacher acts as a discussant or challenger, students have to modify, enlarge or rephrase their predicates for defencing their points of views against a rigorous debater (e.g., Christodoulou & Osborne, 2014). This therefore needs more intellectual endeavours on the side of the students in responding to a negotiator who may not be easily convinced and that would be cognitively demanding on the side of the students (e.g., McMahon, 2012; Soysal, 2019). As seen in the dialogue located below, the science teacher tries to show the conceptual contradiction embedded in the student-led predicate advocating the idea that the heat and temperature should be same. By playing devil's advocate role, the teacher proposed an instance that may not be explicated by the student's prior understanding. Thus, the student has to exceed the boundaries of his/her previous thinking pertaining the relation between the heat and temperature by enlarging, modifying or completely altering his/her less explanatory reasoning.

Praising student-led challenging: In addition to acting as a rigorous negotiator, science teachers should maintain an instructional harmony in which students employ a set of cultural practices favouring critical but constructive intellectual exchanges (e.g., Soysal, 2019). To do this, by an explicit and deliberate manner, science teachers may foster challenging thinking and talking among learning community for the sake of the PCT. Science teachers may deliberately praise or reinforce counter-arguing among the peer community for academic rigor (e.g., Soysal, 2019). This will be a routine acting of the class members during a longitudinal process when the science teacher continuously reinforces and makes featured alternative points of views by uttering that, "Thank you Lily, I realised that you have a different position compare to Wendy, and it sounds reasonable. Wendy, do you want to say something to that?" When these types of teacher-led praises are injected into classroom talk, acting as a counter-arguer will be valued and accepted as a norm of classroom discussions that will improve talk quality (e.g., Jadallah et al., 2011).

Striving for internal consistency: In order to amplify critiques in classroom discourse, the science teacher should strive for conceptual, epistemological and ontological consistency among the propositions of students. This refers that the science teacher has to monitor and be aware the retrospective and on-moment student-led propositions that may be discordant with each other, causing conceptual dilemmas for students. This may therefore distort meaningful acquisition of scientific terms. Prior to taking a further action within the dialogues regarding science concepts, the science teacher has to criticise the streaming of reasoning to detect any conceptual disharmony (Mercer, 1995) by articulating that, "I truly remember that we had accepted the idea that there is a relation between the heat and temperature, however, these are different things in detail. Please, provide your responses based this consensus we had reached."

Indicator-3: Accountability-Justification-Authority

One of the most significant and determining indicators of the PCT is the accountability-justification-authority. This indicator stands for that student-led or teacher-led talks should incorporate a version of accountability or epistemic responsibility (e.g., accountable talk; Michaels & O'Connor, 2002; Reznitskaya & Gregory, 2013). In the context of effective science teaching, it may not be sustainable to progress in the discourse by not taking others' opinions into account or building on the others' propositions (e.g., collaborative reasoning; Reznitskaya et al., 2009). Accountability in classroom talk means that students do not have a tendency in featuring their own ideas by underestimating others' reasoning (e.g., exploratory talk; Mercer & Littleton, 2007). This may ensure the ethos of mutual respect in dialoguing and philosophising of the science concepts (Boyd & Rubin, 2006). There should be an interthinking among the peer community resulting in continuously re-created joint co-construction of knowledge claims (e.g., collective argumentation; Conner et al., 2014a; 2014b). In a sense, when there is an accountability in classroom discourse, there would always be spaces for inter-thinking or inter-knowing that is the premier indicator of the PCT (e.g., dialogic teaching; Alexander, 2006; 2008). Students and the science teacher should feel the accountability pertaining three dimensions of classroom talk: accountability to peer community, accountability to accepted norms and styles of logical/scientific reasoning and attitudes, accountability to canonical science knowledge (e.g., Michaels et al., 2008). For the purpose of effective science teaching, accountability requires student-led justified reasoning. Every individual in the classroom should hold a responsibility in warranting their claim-like opinions to generate justified arguments or reasoned discourse. To put it differently, the science teacher should promote students for making concrete coordination between their claims and experiential/observational data as the basic configuration of an argument structure.

Furthermore, for accountable classroom discourses, there should be an authority sharing process. This means that the science teacher should assign students as social and epistemic authorities. To be clear, by scaffolding talk moves of the science teacher, the students employ criticisms, evaluations, judgements and legitimisations for their classmates' ideas. When this is the instructional case, not only the teacher, but also the students as co-evaluators, co-judgers or co-legitimators have rights for revising, modifying, enriching or refuting peer-led or teacher-led predicates. When students are assigned as co-legitimators of the proposed ideas, there would be an inclusive space for dialoguing by which self and others mutually construct each other's mental states as the primary indicator of the PCT, reported by several researchers (e.g., Wegerif, 2008; Soysal, 2019).

This indicator of the PCT was directly emphasized by the four PCT interventions (Table 1). Within collective argumentation, of course, accountability-justification-authority indicator is recognised, however, it is implicitly referred compare to other talk interventions. As seen in Table 2, two sets of the TDMs are supporting and scaffolding in actualising accountability-justification-authority in the science classroom. These moves are coined as evaluating-judging-critiquing and seeking for evidence.

Evaluating-judging-critiquing: By this set of talk move, the science teacher may prompt students for evaluating, judging, critiquing and legitimating proposed utterances' validity, plausibility and credibility (van Zee & Minstrell, 1997b; Crawford, 2000; Pimentel & McNeill, 2013). These moves may be enacted within three formats (Soysal, 2018; 2019). A science teacher may encourage students to comment on a speaker's externalisation to revise or expand the content and scope of the response ("She mentioned that the mass will not affect the time of an object's arriving time to the bottom of inclined plane. Do you want to say something on it? Is it possible to believe?"). In addition, the science teacher may invite students to judge his/her own predicate ("I (the teacher) am of the idea that there may be other things that may change the motion of an object on an inclined plane in addition to angle of the inclined plane and surface or friction force. How about that?"). Moreover, the science teacher may guide students to criticise a case that is proposed by the teacher ("Imagine that I hang up my wet dresses to the clothesline that is in the balcony of the home. It is outside of my home. Then, in a winter day, would the clothes be dry after a while… Or what is your interpretation?"). The mutual point in these talk moves is to provide an intellectual opportunity for the student to evaluate one another's reasoning by applying his/her pre-theories or disciplinary norms by transcending his/her own interpretation's limits (van Zee & Minstrell, 1997b; Crawford, 2000; Pimentel & McNeill, 2013). In a sense, when a teacher displays evaluating-judging-critiquing moves, students will have a tendency to test their classmates' ideas by applying their own logic system, thus, there would be a PCT in which every member has an intellectual responsibility for contributing to others' meaning positions by revising, extending, modifying, refuting and supporting them (Barnes & Todd, 1977; Gadamer, 2004; Mercer, 2000; Molinari & Mameli, 2013; Wegerif, 2008).

Seeking for evidence: This talk move indicates the teacher-led attempts for inviting students to present justifications for their propositions. Through seeking for evidence, the science teacher guides students to ponder about specific questions such as "how do we know?" and "why do we believe?" By doing this, the science teacher press students to decide what is correct and why in the negotiati-

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ons by promoting justified (Cazden, 1986; Lemke, 1990) or evidence-based reasoning (Christodoulou & Osborne, 2014; Jadallah et al., 2011; Simon et al., 2006) ("Do you have a concrete example proving that the heat is just a form of energy and it streams all the time from one object to another?"). As seen in Table 2, inviting students for providing evidence is also possible by praising the use of it ("It is very reasonable to accept a warm woollen coat as an thermal insulator since as you mentioned it keeps our body heat from the external, or cold environment."). Once the evidence-based reasoning is reinforced by praising, this will be rehearsed by other students and become a rule of idea sharing processes (Jadallah et al., 2011). The science teacher should also promote students to find the sources of evidences, for instance, by referring to textbooks or experts ("We observed a very clear and close relation between the height of the inclined plane and friction force. Let's look at our physics book to find out how this relation is considered.").

Indicator-4: Intense Discursively-oriented Metacognitive Activity

The forth indicator of the PCT is found as meta-cognitive activity of peer community during classroom discussions. This indicator refers that there may be desynchronizations between the science teacher's and students' mental states. All interactions should be synchronised or paralysed during discussions for meaningful learning. This would be possible when students are (meta)cognitively engaged in the discussions. The occurrences of the classroom discourse should be monitored by the all members for a complete synchronisation. The happenings of the classroom discourse should be followed by the all members to involve consciously in the verbal exchanges. This requires a metacognitive awareness (activity) or conscious noticing pertaining conceptual and/or procedural streaming/flow that is continuously (re)emerged and may constantly be altered during classroom talks. Once students are involved in classroom talks metacognitively, they will act as stimulated respondents who would be able to provide more contextualised and proper answers that is the indicators of the PCT (e.g., Soysal, 2018; 2019) This indicator was focused by scholars who proposed exploratory talk (e.g., Mercer, 1995) and collaborative reasoning (e.g., Reznitskaya et al., 2009). In other productive talk interventions, this indicator was not emphasized directly. As seen in Table 2, seven types of TDMs were observed in the related studies for this indicator.

Focusing: One the teacher-led moves that scaffolds meta-discursive activity in the science classroom is focusing. By that move, the science teacher gathers students' attention to a specific response or occurrence in the classroom that would be invaluable for the sake of the classroom discourse ("Did you hear what your friend say that is very interesting according to me?"). This is instrumental for students to differentiate relevant points from irrelevant ones during classroom talks when their attentions are directed to a specific point of view supporting more elaborated discussions (Kawalkar & Vijapurkar, 2013; Oh, 2010).

Monitoring (type-1: on-moment; type-2: prospective; type-3: retrospective): In addition to focusing move, monitoring is also scaffolding for inviting students to re-think regarding classroom happenings. This move is staged when the science teacher invites students to be cognizant of retrospective, on-moment and prospective conversational contents (Christodoulou & Osborne, 2014; van Zee & Minstrell, 1997a). These processes require a metacognitive activity since once the science teacher asks about the format of the retrospective conversational context and content, students have to reconsider their thinking and talking and reflect on them (Bansal, 2018; Tabach et al., 2019) (e.g., "I remember that we accepted that the heat and temperature is different, however, they are also considerably related. Thus, we have to consider that before proposing something else since it is your acceptance."). This is also valid for the on-moment monitoring by which the science teacher promotes students to reconsider their emerging thinking's meaningfulness as a metacommunicative activity (e.g., "Right now, we are only talking about the change of the heat transfer in terms of different variables, please do not refer any other topic please."). In addition, the science teacher may encourage students to hypothetically ponder about future conversational contents (e.g., "We will be attaching the heat phenomenon to the energy phenomenon after a while."). As seen in the examples given in the parenthesis, there is an emphasis on the "we-voice" as an indicator of collective or joint thinking or co-construction of knowledge that is central to the PCT (Soysal & Yilmaz-Tuzun, 2019).

Summarising-consolidating: In increasing metacognitive activity in science classroom, the science teacher may make extended summaries regarding what are discussed and considered in classroom dialogues (Louca, Zacharia, & Tzialli, 2012). Summarising-consolidating is not a simplified presentation of the pooled responses as a rehearsing format. Analytical student-led utterances are continuously categorised and represented as a clustered version for reducing the student's cognitive load. This gives students the chance of following classroom conversations' streaming (van Booven, 2015). To put it differently, this will create more trackable classroom conversations. To advocate, by summarising-consolidating, the science teacher will present a aggregated form of classroom talks based on analytical answers of students and that would be more comprehensible; in turn productive (Oh & Campbell, 2013). To support, based on teacher-led summaries, students may realise their progressions in classroom talks and try to find other ways of contributing to the talks in an enriched manner. (e.g., "We proposed many variables that are thought to change the amount of heat transfer from a system to another and these are, based on your sayings, mass, temperature, time. Do you want to add some variables to the list, or will we continue only with these ones in the phase of experimenting?").

Selecting (ignoring, excluding, including): The science teacher may proliferate the PCT by intense metacognitive activity through intentionally ignoring or accepting the student responses. By this talk move, the science teacher may implicitly/explicitly exclude or include some specific student-led responses (Soysal, 2018; 2019). By doing so, the science teacher gives a metamessage to students that some responses are more plausible/proper for classroom discussions while some others are not credible/improper for the content under consideration (Grinath & Southerland, 2018). When the science teacher ignores/excludes a given response, students will try to find out a more logical/proper one to contribute to classroom negotiations (e.g., I totally agree with you about the effect of the power of the heater when it comes to explicate the amount of the heat transfer, however, we are trying to relate this to increasing or decreasing time intervals during we run the heater. These may be different, OK?). By eliminating a student-led response, the science does not make a total rejection of the response. Instead, discursive purpose of the science teacher is to feature a more relevant response for the sake of the discourse (Mortimer & Scott, 2003).

Asking about mind-change: Another way of prompting students for being aware and cognitively engaged for classroom happenings, the science teacher may ask about mind-change (e.g., "Have you still been of the idea that the heat and temperature are the same things?"). When a science teacher asks about mind-change, students will juxtapose their previous claims with novel ones to make a comparison (Van Zee & Minstrell, 1997a). This will scaffold students to follow their conceptual change processes emerged continuously during classroom discourse (Simon, Erduran & Osborne, 2006). When the science teacher stages ask about mind-change move, students would notice that they now hold a different understanding about what- and how-aspects of science content under negotiation that is one of the indices of the PCT (Soysal, 2018; 2019).

Indicator-5: Teacher as the Discursive Role Model

For the last indicator of the PCT, educational scholars have accepted the science teacher as a discursive role model in scaffolding students' scientific practices. In-class science inquiry environments often include students who have restricted prior knowledge and skills of disciplinary thinking. This is sometimes coupled with the augmented cognitive demands of problem-posing and problem-solving procedures that are the essence of in-class science inquiry. While doing science in their classroom, students may therefore feel exhausting loads of cognitive work (Kirschner, Sweller, & Clark, 2006). This presumably disadvantageous cognitive load of students emerged especially during experimenting can be reduced when the science teacher explicitly rehearses/models aspects of processes of scientific practices. This indicator was specifically made salient in the two types of the PCT interventions as collaborative reasoning (e.g., Reznitskaya et al., 2009) and collective argumentation (e.g., Conner et al., 2014a; 2014b). The science teacher may model how one attains controlling variables for a fair scientific testing (McMahon, 2012) ("e.g., If I were you, I only change the height of the inclined plane to see how this would affect the arriving time of the object to the bottom of it."). In addition, modelling multivariable thinking is acknowledged as an indicator of the PCT (Crawford, 2000) (e.g., "I suppose that there are more variables effecting an objects arriving time to the bottom of the inclined plane in addition to friction of the inclines plane as you had proposed and this would be more informative if you will be able to add them into your observations."). Moreover, the science teacher may model how an individual achieve valid and reliable observations during a routine data gathering process (Soysal, 2018; 2019) (e.g., "Now, I am trying to do my best while collecting data

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by making at the least five measurements if I can do with the chronometer through free dropping a half-filled and empty plastic bottle from the same height to the ground in the same environment.")

Discussion

This study presents novel thinking tools for external readers (science teachers, science teacher educators). In the present study, two theory-based and data-driven catalogues or check lists are presented. These may service delving into classroom talks by a fine-grained manner. A science teacher may systematically observe and analyse his/her classroom talks through indicators of the PCT extendedly examined in the current study. More importantly, the science teacher may analyse his/her talk moves to make pedagogic decisions whether s/he implements a science activity in an intended or productive manner.

When the indicators of the PCT are associated with the surrounding TDMs in a science teacher's classroom, students may reach higher degrees of reasoning (e.g., Rojas-Drummond et al., 2013), problem-solving (e.g., Rojas-Drummond & Zapata, 2004) or scientific thinking (Rabel & Wooldridge, 2013). Thus, by taking the indicators of the PCT and materialising TDMs into account, science teachers may make rigorous quality controls of their in-class implementations.

As presented, clarity of the talks was found as an indicator of the PCT. Previous studies showed that probing teacher-led talks are always more cognitively-demanding and open pedagogical rooms for students to contribute classroom discourse (e.g., Edwards-Groves et al., 2014; Kyriacou & Issitt, 2008). By probing, requesting for clarification and revoicing, the science teacher may provoke student-led deeper explanations as an indicator of the PCT, found in the previous studies (e.g., Herrenkohl, Tasker & White, 2011; van Zee, Iwasyk, Kurose, Simpson & Wild 2001) and abstracted in the present study.

In order to emphasize the essential place of the communicating TDMs, Sfard (2007; 2008) proposed commognition term. Commognition is a combination of cognition and communication. According to Sfard (2007; 2008) communication and cognition cannot be disintegrated or should be thought as indivisible entities. To support, Sfard (2007; 2008) proposed that science and mathematics knowledge can be best acquired through engaging in and contributing to classroom talks. This is indicator of cognitive productivity and is more possible when a teacher frequently enacts communicating TDMs (Soysal, 2018; 2019). Sfard (2008) also found that commognition should be centralised during classroom talks since building on other' ideas require to comprehend what others actually mean and this guarantees knowledge acquisition.

Sfard's (2007; 2008) argumentation is also recognised by other scholars (Martin & Hand 2009; McNeill & Pimentel, 2010) in the context of teaching science concepts. Cognitive productivity in science classroom discourse is considerably related with increasing frequencies of student-led talks. Once speaking time of students are augmented, there would be more intellectual opportunities for them to contribute to classroom talks. This does not mean that when students speak more, cognitive productivity is warranted. As detected in this study, there should be additional indices for generative talks. Healthy communications can be therefore seen as a pre-condition of intellectual productivity.

One of the complementary or compensatory teacher-led move was detected as the monitoring-framing initiations that may promote discursively-oriented metacognitive activity. There should be a healthy communication in the classroom talks, however, students should also be aware of discursive happenings. By the monitoring-framing moves, students are guided to analyse or closely track what is that happening in the classroom talks. Cognitive productivity requires an organic intellectual attachment into classroom talks that seems to be more attainable by virtue of monitoring-framing moves, as observed in previous studies (Berland & Hammer, 2012; Hutchison & Hammer, 2010). Metacognitive activity in the classroom talk is a source of cognitive productivity (Zohar & Barzilai, 2013) entailing monitoring-framing moves. For instance, when the science teacher asks about mind-change, students will juxtapose and compare their preliminary reasoning and secondary understandings as an explicit metacognitive activity which shapes and frames their minds. Once students are promoted to contrast their prior and post views on the topic under consideration, by displaying a cognitive effort, they will establish coherent lines of reasoning as an indicator of the PCT supported by previous studies (Brown et al., 2010a; 2010b; Furtak et al., 2010; Hardy et al., 2010; Shemwell & Furtak, 2010).

There should also be a challenging learning environment in which critiques are welcomed and valued in terms of fostering cognitive activity and productivity. Challenging learning environments refers that there should be rigorous critical argumentations that may be launched by either the science teacher or students, however, all counter arguing initiations should be constructive and progressive. As previous studies showed, when a student is challenged by other students or teacher, the student has to re-think on his/her meaning position profoundly. Then, the student may enrich his/her articulation to a certain extent. Herein the purpose of the student is to convince others that his/her argument(s) is valuable, defensible and contributing (Lee & Kinzie, 2012; Walshaw & Anthony, 2008). Indeed, when the science teacher opens the ways of presenting alternative points of views, students are transformed into debaters, negotiators or discussants like expert scientists. This new role; acting similar to individual members of scientific communities, requires more cognitive demand on the side of the students (Soysal, 2019) since they have to understand, analyse, examine or refute others' arguments if it is needed. This may result in higher scores on follow-up reasoning and problem-solving activities found in Gillies and Khan's (2008) study.

Within a challenging learning environment, students may have two intellectual responsibilities: evaluating others' reasoning and justifying their own thinking. These indices of the PCT were detected in the current study under the theme of accountability-justification-authority. Challenging learning environments provide the very means of a problematized science inquiries (Hiebert et al., 1996; Warren & Rosebery, 1996; Soysal & Yilmaz-Tuzun, 2019). However, as seminally explicated in the work of Engle and Conant (2002) who evidently established the norms and notions of fostering productive disciplinary engagement, during classroom discourse, students should be given epistemic authority in addressing teacher-led or student-led problematisations or challenges (Candela, 2005; Scardamalia, Bereiter, & Lamon, 1994; Soysal, 2018). This is not a representation of fully productive classroom discussions. There is therefore more on the side of the students as their sayings should be accountable to others and to disciplinary norms in the presence of teacher-led prompts requiring evidence-based reasoning (Resnick & Hall, 2001; Resnistkaya & Gregory 2013; Soysal & Yilmaz-Tuzun, 2019; Soysal, 2019).

Conclusions

In the current study, it was concluded that not only the talk interventions are required for enhancing cognitive activity in the science classroom, but also, discourse moves should be clarified or investigated in a fine-grained manner to complement or compensate the influences of the PCT on the student-led cognitive contributions. It would be a better way of portraying a broader picture of the interrelations between the PCT and the TDMs. The indicators of the PCT were extracted by deeply scanning the research works produced within the last six decades. In conclusion, it was evidently detected that two of the indicators were sine qua non for the PCT. In a science teacher's classroom, there should be a healthy; clarified and elicited, communication among the all members in producing alternative points of views by virtue of critiques in the dialoguing as this turns the simplified student-led verbalisations into more complicated and internalised ones by philosophising the contents under negotiations. Critiques in any student-led talks are only be visible and doable once science teacher assign students as co-legitimators by quitting their primary knower, evaluator, judger or legitimators roles. Critiques in any student-led talks should also be accountable to other logical systems (e.g., other minds, disciplinary norms, etc.) and this requires justified or evidence-based reasoning that should be encultured as an imperative norm of the classroom discourse through teacher-led discourse moves outlined in the current study. Moreover, science teachers have to manage the classroom discourse for synchronized individual-based mental states by ensuring the intense discursively-oriented metacognitive activity that is an indicator of the PCT. Finally, as evidently concluded, above-stated classroom interactions may only be possible and reachable under the guidance of an intellectual role model teacher.

Educational Remarks

As mentioned earlier, concrete indicators of the PCT and accompanying TDMs were tried to be make visible to teachers and teacher educators. Beyond, it was also interrogated whether the science teacher holds a teacher-noticing pertaining the PCT and reinforcing TDMs. The term teacher-noticing refers to teacher-led pedagogic consciousness or stimulated cognition (Erickson, 2011), for instance, regarding norms and notions of the interrelations between the PCT and TDMs. One of the vital ways of enhancing teacher noticing is to guide teachers to observe and analyse their own classroom practices' productivity (Erickson, 2011). However, there is a thought-provoking question that why the science teacher tends to analyse, examine and interpret; in turn, notice the interrelations between the PCT and supporting TDMs? A satisfactory response is that science teachers may have an internally-oriented motivation in monitoring, analysing and modifying their in-class discourse processes if tangible evidences are presented pertaining increasing student-led cognitive outcomes. Certain cognitive awareness on the indicators of the PCT and supporting TDMs may be insufficient in motivating science teachers to practice the productivity indices in their classrooms (Soysal & Yilmaz-Tuzun, 2019). Beyond, science teachers must experience or witness that the indicators and supporting talk moves are indeed instrumental in fostering their students' cognitive productivity (Guskey, 2002).

It can be therefore concluded that science teachers should be able to explore their discourse moves' productivity on the side of students to improve their pedagogical vision by referring to the indicators of the PCT. Schön (1983; 1987) proposed a functional term as teachers as reflective practitioners. Within the rationality of the Schön's propositions, science teachers should have understanding and practical capacity and capability in analysing and interpreting what is that occurring in the classroom discourse at the intersection of the PCT and TDMs. This is not a simple professional duty for science teachers as they have to be involved in the longitudinal professional programs introducing core aspects of the PCT and TDMs. One of the most illustrative ways of engaging science teachers in a discursively-oriented professional development program may be stimulated-recall sessions or video-based case analysis processes (e.g., Dempsey, 2010; Haw & Hadfield, 2011) by which science teachers may observe, analyse and interpret the variances within their discourse talks with the aid of an educator.

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