

SCIENCE DISCOURSE AND EPISTEMIC PRACTICES NORMS FOR THE
DEVELOPMENT OF SCIENTIFIC EPISTEMOLOGY IN
PHYSICS LESSONS

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DEDICATION

To all whom suffered most during my PhD journey I owe you more than this world can offer me. Alhamdulillah, I finished my PhD journey.

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I learnt from my mother that as a women and a mother to my children, 'giving up is not an option'.

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ABSTRACT

This study argues that insufficient attention has been focused on explaining the alienation phenomenon toward physics knowledge. The discontinuity towards the physics knowledge requires an exploration about the scientific epistemology development. Scientific epistemology is a study that focuses at nature of knowledge and its acquisition process which treat physics as a way of knowing. The situation of Malaysian physics education is viewed as alarming and a new method of investigation is required to establish a more accurate representation of the current state of physics education. An exploratory study of the norms of science discourse and epistemic practices was therefore conducted to explore the scientific epistemology development through the lens of critical realism. Critical Discourse Analysis (CDA) was used as a methodology to address methodological issues in representing the development of scientific epistemology. The data were obtained from non-participant observations, self-reflexivity, interviews and audio-video recording. Observation and recording sessions were conducted over a period of nearly three months among four physics teachers with different educational backgrounds and their students in Johor Bahru. The analysis identified six elements underpinning the norms of science discourse and epistemic practices: epistemic agency, activity oriented by discourse, discourse moves, epistemic episodes, epistemic operations and epistemic moves. The powers that shape the norms are identified as knowledge authority (epistemic agency), privatizing and publicising ideas (epistemic agency and epistemic moves), epistemic devices and managerial moves (epistemic operations) and social conditions (activity of discourse and discourse moves). Further to this, the implication of the accepted norms is directed to a focus on teachers' confirmation bias and expanding epistemological resources for students. Physics teachers should reflect on their norms so they can support the chain of scientific epistemology development among the students in learning physics.

ABSTRAK

Kajian ini berpendapat bahawa kurang perhatian diberikan untuk menjelaskan fenomena keterasingan yang dialami pelajar terhadap ilmu fizik. Ketakselajaran terhadap ilmu fizik memerlukan penerokaan perkembangan epistemologi saintifik. Epistemologi saintifik ialah kajian yang memberikan fokus kepada sifat ilmu dan proses pemerolehannya yang melihat ilmu fizik sebagai cara mengetahui. Situasi pendidikan fizik di Malaysia dilihat semakin meruncing dan memerlukan penerokaan kaedah kajian yang baharu untuk memberikan gambaran sebenar status terkini pendidikan fizik. Maka kajian penerokaan budaya wacana sains dan amalan epistemik berlandaskan falsafah *critical realism* ini telah dijalankan untuk mengkaji perkembangan epistemologi saintifik. Kajian ini menggunakan metodologi *Critical Discourse Analysis* (CDA) bagi menangani isu metodologi semasa mengkaji perkembangan epistemologi saintifik. Sumber data adalah daripada pemerhatian bukan peserta, refleksi sendiri, temu bual dan rakaman audio video. Sesi pemerhatian dan tinjauan dijalankan selama hampir tiga bulan ke atas empat orang guru fizik dengan latar belakang pendidikan yang berbeza serta pelajar mereka di Daerah Johor Bahru. Hasil kajian mengenal pasti enam elemen yang mendukung budaya wacana sains dan amalan epistemik iaitu: agen epistemik, aktiviti wacana, gerakan wacana, episod epistemik, operasi epistemik dan gerakan epistemik. Kuasa yang membentuk budaya dikenal pasti sebagai autoriti ilmu (agen epistemik), memperibadikan dan menghebahkan idea (agen epistemik dan gerakan epistemik), alat epistemik dan gerakan kepengurusan (operasi epistemik) dan keadaan sosial (aktiviti wacana dan gerakan wacana). Lanjutan itu, implikasi daripada penerimaan budaya tersebut tertumpu kepada kecenderungan pengesahan guru dan mengembangkan sumber epistemologi untuk pelajar. Guru fizik perlu membuat refleksi terhadap budaya yang didukung supaya dapat menyokong rantaian perkembangan epistemologi saintifik pelajar dalam pembelajaran fizik.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENT	vii
	LIST OF TABLE	ix
	LIST OF FIGURES	x
	LIST OF ABBREVIATIONS	xi
	LIST OF APPENDICES	xii
1	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Background of the Study	2
	1.2.1 Science and Technology Education Scenario in Malaysia	3
	1.2.2 Philosophical Consideration in Physics Education	9
	1.2.3 Scientific Epistemology Developmental Relation to Science Discourse and Epistemic Practices	13
	1.3 Problem Statement	17
	1.4 Rationale of the Study	18
	1.5 Research Objectives	19
	1.6 Research Questions	19
	1.7 Theoretical Framework: Ontology and Epistemology	20
	1.8 Conceptual Framework	22

1.9	Definitions	29
1.9.1	Epistemology	29
1.9.2	Scientific Epistemology	29
1.9.3	Epistemic Practices	29
1.9.3.1	Epistemic Episodes	31
1.9.3.2	Epistemic Operations	31
1.9.3.3	Epistemic Moves	31
1.9.4	Science Discourse	31
1.9.4.1	Epistemic Agents	32
1.9.4.2	Activities Oriented by Discourse	32
1.9.4.3	Discourse Moves	32
1.9.5	Norm	33
1.10	Summary	33
2	LITERATURE REVIEW	34
2.1	Overview	34
2.2	Issues Associated with Current Physics Education	35
2.2.1	The Direction of Science Education Research in Malaysia	37
2.3	Scientific epistemology studies and the philosophical assumption	41
2.4	Scientific Epistemology	48
2.4.1	Different Ontological and Epistemological Perspectives towards Scientific Epistemology Development	49
2.5	Recognizing Epistemic Practices and Science Discourse Norms	54
2.5.1	Physics as Epistemic Practices	54
2.5.2	The Substance of Epistemic Practices which are Later Identified as Epistemic Episodes	58
2.5.3	Science Discourse as a Site for Epistemic Talk	61
2.6	Summary	65
3	METHODOLOGY	66
3.1	Introduction	66
3.1.1	Philosophical Approach	67
3.2	Methodological Approach	68

3.2.1	Approaches to Critical Discourse Analysis (CDA)	71
3.3	The Analytical Framework of CDA as a Methodology and Method	74
3.4	Research method	75
3.4.1	Non-participant Observation	77
3.4.2	Self-reflexivity	80
3.4.3	Audio and Video Recording	80
3.4.4	Interview	81
3.5	Participants in this Study	82
3.5.1	Teachers	82
3.5.2	Students	86
3.6	Research Framework	87
3.6.1	Phase 1	87
3.6.2	Phase 2: Piloting Data Collection Approach	87
3.6.3	Phase 3	91
3.6.4	Phase 4: Transcription and Data Preparation	91
3.6.5	Phase 5	91
3.7	An Overview of Data Analysis	92
3.7.1	Identifying the Discourses: Context of My Choice of Text	93
3.7.2	Familiarisation with the codes	94
3.8	Ethical Concerns	97
3.9	Addressing Trustworthiness for Research Credibility	98
3.10	Summary	101
4	ANALYSIS OF SCIENCE DISCOURSE	103
4.1	Introduction	103
4.2	Freedom in the Classroom: How Teachers Treat “Knows” in the Classroom	103
4.2.1	Available Epistemic Agents in Physics Classrooms	110
4.2.2	Teacher-student Consensual Relationship	122
4.3	The Routine of Science Discourse Activities	126
4.4	Sculpting Explanations using Discourse Moves	137
4.5	Summary	146

5	ANALYSIS OF EPISTEMIC EPISODES	147
5.1	Introduction	147
5.2	Rationalizing the Purpose of Investigating Epistemic Norms	149
5.3	The Observed Epistemic Episodes in Physics Classrooms	156
5.3.1	Epistemic Episodes from Analysing Students' Discourse	162
5.4	Eliciting Epistemic Episodes as Established Norms from Discourse	164
5.4.1	Acknowledging Wonder (IP)	166
5.4.2	Positioning Unobservable Entities (IPE)	171
5.4.3	The Flux of Non-observable Entities (FE)	175
5.5	Clouding the Representation of Physics Entities	181
5.5.1	Weak Structure of Entities' Representation in Epistemic Episodes	182
5.5.2	Definition Apocalypse	187
5.5.3	Bundle of Weak Lexical Verbs	191
5.6	Summary	196
6	ANALYSIS OF EPISTEMIC PRACTICES AND FRAMEWORK OF SCIENTIFIC EPISTEMOLOGY DEVELOPMENT	198
6.1	Introduction	198
6.2	Recognizing epistemic operations and epistemic moves	199
6.3	The sequence of scientific epistemology development	205
6.3.1	Stage 1: Breaking Down the Utterance Line by Line	205
6.3.2	Stage 2: Identifying the Property of Assertion	207
6.3.3	Stage 3: Identify the Force Carried by the Illocutionary Act	210
6.3.4	Stage 4: Identify the Agency Role Carried by the Epistemic Practices	211
6.4	The Identified Epistemic Operations	217
6.4.1	Inferring (PI)	218
6.4.2	Description (PX)	222

6.4.3	Defining (PF)	225
6.4.4	Justifying (PJ)	228
6.4.5	Correlation (PC)	230
6.4.6	Argument (PA)	234
6.4.7	Generalization (PG)	236
6.4.8	Exemplifying (PE)	238
6.4.9	Modeling (PM)	239
6.5	The Epistemic Moves	241
6.5.1	Evaluating the Quality of Ideas	243
6.5.2	Providing Feedback to Give Added Value	243
6.5.3	The Identified Problems with the Epistemic Moves	251
6.6	Attending to Research Question 3 (RQ3)	255
6.6.1	Accessibility When Publicizing or Privatizing Physics Ideas	256
6.6.2	The Norm of Scientific Epistemic Practices	262
6.6.1.1	Ways of Representing Epistemic Practices	263
6.6.1.2	Ways of Privileging in Physics Classrooms	265
6.6.3	A Suggested Framework for Sophisticated Scientific Epistemology Development	266
6.7	Summary	270
7	DISCUSSION AND CONCLUSION	271
7.1	Introduction	271
7.2	Science Discourse as a Site of Epistemic Practices	272
7.3	Reflections about the Research Process	277
7.4	Contributions of the Research to Theory and Practice	281
7.4.1	Violating the Demand for ‘Proper’ Argumentation through Confirmation Bias	282
7.4.2	Radicalizing the Ontological Commitment to Enrich Epistemological Resources	285
7.4.3	Realizing How Power Shapes the Norms that	

Explain the Development of Scientific Epistemology	287
7.5 Suggestions for Practice in Physics Teaching	290
7.6 Limitations of the Study	293
7.7 Direction for Future Research	295
7.8 Conclusion	296
REFERENCES	297
Appendices A - E	316-327

LIST OF TABLES

TABLE NO.	TITLE	PAGE
3.1	The Interview Protocol	88
3.2	Summary of Research Participants	84
3.3	The Relationship between Units of Meaning in Discourse	96
3.4	Summary of Research Questions, Methods and Analytical procedures	102
4.1	Available Epistemic Agents during Epistemology Development	112
4.2	Learning Environment during Teachers' Talk	127
4.3	Coding for Activities Oriented by Discourse in Teachers' Talk	129
4.4	Coding for discourse moves that facilitating discourse' activities	138
6.1	Epistemic Operations and Descriptions	242
6.2	Epistemic Moves and Sub-nodes	243
6.3	Summary of Research Questions (RQ) and Types of Discourse	256
6.4	Summary of Science Discourse Norms	259
7.1	Application of CDA's Analytical Framework	273

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Theoretical Framework	23
1.2	Conceptual Framework	28
3.1	Research Framework	88
3.2	The Relationship between Units of Meaning in Discourse	96
6.1	Epistemic Operations in Science Discourse	208
6.2	A Framework of Scientific Epistemology Development	268

LIST OF ABBREVIATIONS

CDA	-	Critical Discourse Analysis
CA	-	Conversation Analysis
NOS	-	Nature of Science
MOE	-	Ministry of Education
JPNJ	-	Jabatan Pelajaran Negeri Johor
NEM	-	New Economic Model
S&T	-	National Science and Technology
OECD	-	The Organisation for Economic Cooperation and Development

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Permission letter from MOE	316
B	Permission letter from JPNJ	317
C	Guarantee letter from Faculty of Education, UTM	318
D1	Permission letter to the Ms Zi's school administration	319
D2	Permission letter to the Ms Ai's school administration	320
D3	Permission letter to the Mr Haz's school administration	321
D4	Permission letter to the Ms Chung's school administration	322
E	Table 2.1: Summary of Units of Meaning From Previous Studies	323

CHAPTER 1

INTRODUCTION

1.1 Introduction

Robust development in Malaysia has created huge pressure on every part of society to be scientifically and technologically literate. Teachers and science educators are sitting at the front line of the effort to educate the society about science and technology (S&T) in order to enable Malaysia to develop holistically. The responsibility is challenging but promises revolution and globalisation, as embedded in the nation's mission to become a high income country (MOE, 2012). The Ministry of Education (MOE) has initiated a variety of efforts to account for the development of the physics curriculum. This growth can be seen as part of a wider movement for scientific literacy, with an emphasis on scientific skills and scientific values (MOE, 2013).

Becoming wiser consumers of science and technology is vital, given the explosion of information in the modern world. Societies must have the resources to differentiate between science and pseudoscience by making critical scientific arguments (Jiménez-Aleixandre & Erduran, 2007). This goal will have the benefit of nourishing and sustaining people's interest in science because it will equip students with better logical justification when making claims. As the phrase "scientific literacy" is attracting more attention, students are struggling with evaluating their scientific arguments against value judgements. The conflict between them stems from the lack of emphasis on the nature of science, scientific inquiry and scientific enterprise.

Value judgements involve students' subjectivity while making an observation (Kuhn, Cheney & Weinstock, 2000) or learning about scientific knowledge. This is a gap that hinders the actual goal of science education to communicate science to the society. To address this issue, the science curriculum should not only teach about the contents of science, but also explore how science works.

1.2 Background to the Study

The appearance of the 'how science works' element is commonly regarded as a rising trend in science education research (Akerson & Abd-El-Khalick, 2003) that promotes the idea of physics learning as a way of knowing. Prominent researchers such as Abd-El-Khalick, Osborne, Sandoval, Erduran and many others have expanded the scope and challenged the classical idea of teaching science as a body of knowledge. Epistemology of science is a branch of philosophy that studies the nature of science (Abd-El-Khalick, 2012) and has become a topic of interest among science educators and researchers since the 1950s. Scientific epistemology explains an individual's understanding about 'what science is' and 'how science works' (Sandoval, 2005).

In proposing this complex perspective, many researchers have aimed to trace the understanding of 'how science works' explicitly through science discourse (Jiménez-Aleixandre & Erduran, 2007). A logical description of what students think and why can be traced from their discourse in science classes (Jiménez-Aleixandre & Erduran, 2007). Thus, the focus is more about physics as a way of knowing that teachers and students need to construct and support in physics lessons. Therefore, the rich description entailed in the discourse is actually communicating the elemental description of physics learning and knowledge construction. In order to help Malaysia's society to develop physics proficiency by engaging in scientific argumentation, more evidence is needed to understand the extension and limitation of how new knowledge is generated and validated. Hence, the following discussion will carefully examine the poles in the current state of physics education and then

proceed to examine the application of critical realism views to explore the development of scientific epistemology.

1.2.1 Science and Technology Education Scenario in Malaysia

For policy makers, scientific literacy represents the nation's economic aims to become a high income country through the development of human capital, as mentioned in the New Economic Model (NEM) and the Tenth Malaysia Plan of 2011-2015. This ambition was most clearly communicated in the National Science and Technology (S&T) policy in April 1986 (MOE, 2012), which policy highlighted the urgent need to increase the science professional capacity to empower socio-economic growth, with an estimated need for 493,830 scientists and engineers (MOE, 2012). International trends have had a great impact on science education development in Malaysia (Lee, 1997), and this condition is forcing the Ministry of Education (MOE) to produce 270,000 science students before the year 2020 (MOE, 2012). The government began to increase the ratio of science to art students to 60:40 in 1967 (EPRD, 2000) as its main solution to drive these policies.

Based on the statistics on students' enrolment in different streams or specializations in Malaysian secondary schools, the percentage of students who are enrolled in the science stream has never exceeded 31.22% (Phang et al., 2014). The only year in which the highest percentage of students was enrolled in the science stream was 2005. After nearly a decade, during which the science curriculum has gone through many changes, the 60:40 ratio can no longer be seen as justifiable (MOE, 2012). The ramifications of the 60:40 policy pertain not only to the fact that it has never been achieved from 1981 until 2010 (Phang et al., 2014), with the highest recorded percentage of students enrolled in the science stream being just 31.22% in 2005. Instead, if the ratio can be achieved, the central aim of teaching physics as a way of knowing must be brought to the forefront of discussions because the objective of the 60:40 policy brings no guarantee towards the quality of students.

Another implication of the increasing emphasis on producing more science professionals is that it allows the content-driven curriculum to dominate teaching practice. This point is demonstrated by Salmiza's (2014) finding that the culture of physics activities in elementary schools is monotonous, regardless of the encouraging motivation at the early stage. Thus, physics learning is described as disconnected and fact-laden (MOE, 2012) from the learner's perspective, as mentioned in the 60:40 report, which is an analysis of the 60:40 policy carried out by the Research Communities of the 60:40 Sciences/Technical: Arts Stream. The thrust of the above reviews demonstrates the urgent need to understand the impact of the 60:40 policy on the science culture in Malaysia's schools and what should be done to enable them to move forward. This alienation appears as the gap that Russ et al. (2008) pointed out as a discontinuity or contradiction (Freire, 2005) between teachers and students. Bridging this gap requires a shift in understanding of what went wrong during the construction of meaning-making. Given the importance of epistemology highlighted in science education (Sandoval, 2014), the cognitive process concerning what quality science knowledge entails and why it must be acquired requires a thorough explanation to retain students' rationale for learning science. It is hoped that this approach will fill the gap in understanding of the phenomenon of alienation.

Clearly, the 60:40 policy is implemented with the best interest for the nation's growth, but the declining trend in elementary science classes suggests that there is a limitation in this perspective. This view was supported by the recent concerning news from the Programme for International Students Assessment (PISA) assessment of scientific literacy. Scientific literacy is a well-known concept, and the recent unpleasant news showed that Malaysian performance in science, particularly in physics, has declined sharply since 2003 and is below the international average level (Sander et al., 2013). Although PISA's results showed a significant increase from 420 in 2012 to 443 in 2015, this result is still below international average level. Some researchers have tried to look further into the scientific conception which revolves around students' beliefs about the content itself to explain the alienation phenomenon. According to Mohd Najib and Abd Rauf (2011), scientific conception, defined as part of the epistemic entities, measures the nature of science, methods in science, science sociology, and science and technology towards society (STM). However, this line of research has yet to mature in Malaysia with regard to the nature

of science understanding among local physics teachers and students. Nor Farahwahidah (2013) found that 42.9% of physics teachers hold a low transition state of understanding about scientific epistemological constructs. In the contemporary culture of education, studies of scientific epistemology have been gaining tremendous attention as the basis of curriculum development, such as in the K-12 education policy in the United States (Abd-El-Khalick, 2012). The driving factors to emphasize here are the concern for the production of scientifically literate students (Abd-El-Khalick, 2012) rather than merely evaluating students' grades. Thus, in order for the nation to successfully produce a scientifically literate society, a sophisticated understanding about scientific knowledge is needed to help to sustain the learning process.

As this study attempts to explain the phenomenon of alienation, it appears that more discussion is needed about the theories of learning and the power issues that inform current education. Physics learning in Malaysia has gone through many changes in teaching modes, particularly from the behaviourist to the constructivist perspective of teaching. On this path, science educators proposed to embed the content driven-curriculum with ICT-based education (MOE, 2001) and effective pedagogical tools to support the transition perspective. These instructional tools are regarded as sophisticated (Maria, 2010) because the innovations aim to produce students with great thinking skills. Given that background, science professionals such as scientists or science teachers hold the highest positions in the hierarchy to encourage students to adopt, enact and practice the skills and body of knowledge. Yet, the basic assumption of this transformation is still within the behaviourist perspective, because science education has become a matter of shaping learners' responses through instructional procedures (Palinscar, 2005).

Freire (2014) criticized this norm of education because of the tendency to stimulate teacher-student contradiction by making students memorize mechanically the narrated content. This perspective provides a limited account of logical sequences that would build progressively towards the goal of science literacy, which in turn might impel the students to develop the great mind of a scientist. The sequence of learning is seen as experiencing oppression, as the curriculum is carefully sequenced to ensure that the students acquire certain skills and knowledge at the end of each

lesson (Palinscar, 2005). This educational practice attempts to account for approach of the behaviourist perspective, in which education quality is pertinent to recognizing only students' change in behaviour. Drawing from these arguments, in order to support the transition perspective in teaching physics, this study highlights the alienation phenomenon, offering the solution of teacher-student contradiction towards scientific knowledge. Freire (2014) proposed that reconciling the poles of understanding contradiction between teachers and student will avoid the pitfall of education as a process of inquiry. Understanding is a reflection of thinking (Ritchhart & Perkins, 2008) that needs to be understood to establish a cultural transformation, as demanded by the 60:40 policy.

The manner in which physics teaching is treated in Malaysian setting however varied significantly from developed countries. This is because most of the policy measures are implemented with top-down approach (Gill, 2014) which makes the norms of teaching physics strictly follows the regulated rules as decided by the authority such as the Ministry of Education. The decision made about what kind of physics must be taught to the students are top-down because physics teachers are meant to follow the same established curriculum specification like Integrated Curriculum for Secondary School Physics (MOE, 2005). The curriculum specification is focused on the contents needed to be addressed without the philosophical account of the scientific knowledge. This claim is made based on Lee's (1999) finding that the curriculum emphasises on the objectives and contents, new teaching style and new instructional strategies. Yet, the accusation of physics knowledge only being discussed in reaction to the Language Policy and Language Planning (LPLP: Gill, 2014) as a discourse medium for teaching physics.

The discussion about language policy however is leaning towards understand the decision made with the change of language for instruction in teaching. Knowing is a reality in scientific epistemology study in which also addressed accusation planning like LPLP. The discussion is more concerned with the treatment toward the physics knowledge as students make meaning about physics concepts. This understanding is essential as it appears to be the manhole for students to be part of the scientific culture development. Therefore, in order to address the issue of how students decide not to pursue the science stream, evidence is needed regarding their

understanding about ‘how science works’. In terms of understanding the process and development of scientific understanding, the scientific epistemology field deals with the question of ‘how science works’ from a different perspective.

Additional efforts to examine knowledge progression represent a rising trend towards greater specification in the science curriculum. Therefore, creating a cohesive sequencing of physics content is a key element of the mission towards achieving scientific literacy in Malaysian society. The role of scientific literacy during the scientific process of meaning-making resides in every science classroom, with the recent focus on the role of spoken and written language (Jiménez-Aleixandra & Erduran, 2007). Scientific literacy is illustrated as the cognitive process where in learning science is a process of knowledge construction, as described by constructivists (Jiménez-Aleixandra & Erduran, 2007). The chain of inquiry that relies heavily on the products of the inquiry instead the process of inquiry, as discussed previously does not support Jiménez-Aleixandra and Erduran’s (2007) claim.

Constructivism is not new to the context of Malaysia’s science curriculum: it was introduced in 2001 with the publication of the constructivism module by the MOE (MOE, 2012). This effort illustrates the policymakers’ commitment to achieve quality science education, and demonstrates the shift from a behaviourist framework to one of constructivism. However, the role of constructivism in the current science curriculum has unclear epistemic apprenticeship: thus, Jiménez-Aleixandre and Erduran’s (2007) perspective on the enculturation of the practice of scientific knowledge has gone unnoticed and uncriticized in this context. Hashimah, Zaridah and Raper (2004) noted the lack of understanding about constructivism among science teachers. This discrepancy is traced to teachers’ difficulties in conducting lessons using the constructivist approach due to lack of training, which eventually causes a distortion in their science pedagogical knowledge.

In the creation of a constructivist environment, multimedia is commonly used as a knowledge building tool to manipulate students’ artefacts. This premise is derived from Abbas, Lai and Hairul Nizam (2013), who claimed that constructivist teachers are more likely to use technology compared to those who follow a different

philosophy of learning. This leads to a degree of expectation among science teachers that multimedia should be integrated as a meaningful tool to allow constructivists to deliver physics content. What remains clear in this specification towards multimedia is the greater attention to advocate students' involvement during knowledge construction. It is evident that teachers in Malaysia appreciate social interaction processes during knowledge construction. However, without the opportunity to explore these interactions, the emphasis on constructivism or on multimedia as a tool is shallow. For teachers to amplify students' cognitive activities, the tools used must have a clear chain of inquiry that builds towards a sophisticated understanding of scientific knowledge. The urgency to explore social interaction during physics learning will help with a greater specification for those who work within that perspective.

An initiative to clearly inform the chain of inquiry that improves scientific literacy is needed, particularly given that the status of scientific literacy in this nation is alarmingly poor. The declining trend, the phenomenon of alienation and learning theories informing education, as discussed above, highlight the ongoing need to search for a better explanation to address the gap that exists in the current physics teaching and learning context. With increased interest in empowering culture transformation, the importance of language production in promoting physics learning assumes greater prominence. In the following review, this study will intellectually position the post-modern constructivism view towards physics learning through a social constructivistcritical realism perspective. Palinscar (2005) stated that learning and understanding are inherently social and bound up with language, which is regarded as an integral part of knowledge development. Thus, to understand the gap that exists during knowledge development in physics and to reflect the scientific epistemology that informs this development, science discourse is the key starting point.

1.2.2 Philosophical Considerations in Physics Education

Educational researchers, policy makers and teachers share a set of common values to produce Malaysian citizens who are scientifically literate. However, the intersection between educational researchers, policy makers and teachers' values about scientific literacy features are not clearly bounded and defined. For decades, science educators have focused on skills for learning science (Maria, 2010), content knowledge and the implications of pedagogical content knowledge (Halim, Sharifah Intan Sharina & Subahan, 2014). It is very challenging to find studies that address philosophical discussion to frame educational practice in the Malaysian setting. This is because previous studies have focused on making and evaluating the end products of physics learning instead its practices. Bhaskar (1978: 21) described this reality as 'one side of knowledge'. This has led to limited accounts that reflect on scientific culture and the potential to transform society. Halim, Sharifah Intan Sharina and Subahan (2014) discussed how moderate students insist on conceptual representation of physics, unlike higher achievers. Students with high grades are more inclined to demand teachers' pedagogical knowledge about assessment and teaching strategies. High-grade students showed a lower mean requirement for their teachers to have a great understanding of physics concepts. However, they needed to be provided with examples to clarify their understanding. Students' views about teachers' pedagogical content knowledge reveal that they themselves have the capacity to evaluate the inquiry process presented in the classroom. Thus, it is wise for this study to understand how things work within the physics learning context to empower students' need.

The lack of coordination between current policies and scientific literacy is recognized in that a few studies support the proposition that epistemic practices and science discourse are translated directly to human capital as visions in the national science education philosophy. The physics domain is an exemplar of science that has a major role in the history of the philosophy of science (Erduran, 2014). The puzzle of what is actually occurring in students' minds in relation to physics and science teaching has invited more interest in attitude studies. Aziz and Lin (2011) showed that students with high conceptual understanding unfortunately have negative

attitudes towards science. Kamisah, Zanaton and Lilia (2007) also indicated that most students' attitudes towards science failed to align with their level of education. The attitudes measured previously reveal that although students might excel academically, attitudes towards science are not the ultimate driving factors.

As much as physics educators place great interest in individual attitudes, it would be quite naive to assume that this attitude represents the culturally based social endeavour towards learning science. Rather, these findings provide a glimpse of teachers' and students' dilemmas when the knower is independent of scientific knowledge, which Freire (2014) described as banking education. Banking education is an example of the behaviourist perspective of education, in which the teacher's task is to fill the students with content through narration (Freire, 2005). In a parallel development to shift the focus of the science curriculum towards inquiry and constructivism (MOE, 2001), science education practices must be examined from the critical realist perspective. Following Bhaskar (1979, cited in Lawson, 1998), social transformation is part of the agent embedded in critical realism philosophy. The transformation can only be achieved if the power and mechanism that bring about the change are studied.

During the science discourse, students are expected to engage actively in explanation or argumentation that involves the nature of scientific understanding. This assumption however is not applicable when education is still confined within the traditional setting. The description of traditional classroom is defined as covering a preset curriculum (Matusov, 2009) that is parallel with the norms of top-down policies in Malaysian context. The limitation to transform the traditional classroom despite of the good intention with constructivism can be explained using the culture of power distance. Due to the top-down curriculum management, the phenomenon of power distance in science education is relatively obvious. The power distance appears to be high because teachers' and students' opinions who experienced the phenomenon are often ignored (Gill, 2014). Hence, both teachers and students are groomed to accept when the power is distributed unequally as they are making an effort to make learning physics successful. Hofstede's (2008) analysis of the power distance index showed that Malaysia scored the highest numbers among other ASEAN countries. This evidence indicates that teacher-centred is still prevailing because of the cultural

influences. The manifestation of power distance in classroom implied that the acquisition of physics knowledge is exclusively depending to teachers' sophistication about physics (reference?). With such, hierarichal order and centralization appeared as accepted norms among the physics teachers. Therefore, examining the norms of physics education requires refined understanding in what ways this culture interplay with the norms of science discourse and epistemic practices.

Knowledge about the nature of science reflects upon scientific epistemology as the transforming power during the knowledge construction. This emphasis on science conception is what Mohd Najib and Abd Rauf (2011) are most concerned about, particularly their poor understanding about the nature of science. Their finding showed that only 19.8% science teachers hold an understanding about the elements in science conception. However, researchers in developed countries such as the United States (Sandoval, 2014; Abd-El-Khalick, 2012) have stressed the importance of epistemic practices and science discourse as they ponder tacit understanding of the social construction of knowledge. If, indeed, the national goal in science education is to develop scientifically literate human capital, it seems that science education practitioners would be remiss to exclude science discourse and epistemic practices discussions to inform teachers' practice.

Monk and Osborne (1997) proposed that education is central to scientific epistemology and to shaping the universal value towards scientific knowledge. Western science educators are far ahead in teaching the history of the philosophy of science (HPS: Monk & Osborne, 1997) and the nature of science (NOS: Abd-El-Khalick, 2012), and the origin and shaping of their scientific epistemology have been rigorously discussed. Hence, as the Malaysian context is still confined within the traditional setting, the epistemology is merely there, without a clear idea of how it is being shaped. Therefore, students' achievement norm, in the Malaysian context, is the opposite to what Monk and Osborne (1997) described earlier, because scientific epistemology is in control of education. This lack of research on the role of current science education curricula in shaping the value of scientific epistemology has resulted in little, if any, research on scientific epistemology and science discourse.

Drawing from previous researchers' efforts, Nor Farahwahidah (2013) initiated an investigation of scientific epistemology among physics teachers and their students in the city of Johor Bahru, Malaysia. The study indicates that without making scientific epistemology a central feature in the science curriculum, the existence of scientific epistemology is generally low among teachers and students (Nor Farahwahidah, 2013). Similarly, Mohd Najib and Abd Rauf (2011) explained that only 19.8% of teachers in their study had a reasonable understanding of scientific conception, whereas 80.2% of them showed the opposite. Nor Farahwahidah (2013) proposed four models of teacher-student epistemology for different level of scientific epistemology – naive, low transition, high transition, and sophisticated – which were formulated using multiple regression analysis. This empirical evidence is limited in explaining the social endeavour aspect of scientific epistemology, but these models describe its significant presence. However, the empirical evidence provided is insufficient to justify the poor status of scientific literacy in the current science education system, as emphasized by Nor Farahwahidah (2013). Thus, this study only provides what Monk & Osborne (1997) described as a topology of the scientific landscape, without exploring the underlying account of why this landscape is the way it is.

The cultural transformation has raised modernism issues among teachers, as constructivism is disposed and programmed (Boboc, 2012) into teachers as the way to teach physics. As previously discussed in relation to cultural transformation and power distance, it is crucial to discuss the current philosophical underpinning of science education in Malaysia. The transition into constructivism, although clearly documented, creates an issue of post-modernism because of the oppression created by the constructivist approach itself. Breen (1999) referred to the post-modernist classroom as a reaction toward changes in the political agenda toward education. The transformation from modernism to post-modernism has had an impact on classroom pedagogy which requires an urgent understanding of the manifestation. The critical realism perspective suggests that learning and development are viewed as culturally and contextually specific (Palinscar, 2005). Thus, with this assumption, analysing the norms of science discourse and epistemic practices embedded in scientific epistemology development provides an insightful understanding of what has gone wrong during physics talk. The recommendation is supported by the result from Nor

Farahwahidah (2013) regarding the poor status of teachers' and students' understanding about the scientific epistemology. The exploration is hope to understand the underlying causes and condition to develop better sophistication toward physics knowledge.

1.2.3 Scientific Epistemology Development in Relation to Science Discourse and Epistemic Practices

Communication, according to the Ministry of Education, is a science process skill that requires students to use words or graphic symbols to describe an action, object or event (MOE, 2013). In this sense, communication skill does not capture the scientific epistemology and science discourse norm within the development of knowledge and actions. The simplistic definition from the ministry refers to the mode of communication in science learning that is directed towards visual representation and its self-explanatory nature.

This narrow focus implies that the framework of communication skills in the physics syllabus is inadequate to promote the importance of communication as a practice. Science discourse within the framework of scientific epistemology is an ability to construct a valid scientific argument (Hanauer, 2006) and to distinguish this feature with explanation (Brigandt, 2016; Osborne, 2011). This notion suggests that the basic structure of science discourse to generate an argument is to acknowledge the developmental aspect of scientific epistemology. Thus, scientific epistemology will achieve its rightful place in the science curriculum, beginning by acknowledging that the structure of science discourse can promote scientific epistemology components. Rather than viewing the developmental framework as a process where in scientific epistemology is an argumentative product, this study seeks an understanding of what science discourse can tell us about scientific epistemology.

Science discourse analysis is crucial because it aims to reveal the role of language in shaping and reshaping the social reality. There are many areas of strong consensus among the researchers who relate science discourse and epistemology (Hutchison & Hammer, 2010; Lundqvist, Almqvist & Ostman, 2009; Lidar,

Lindqvist & Ostman, 2006), but there is no clear agreement concerning the preferred ways to investigate this area. Some studies of science discourse that adopt a pragmatic theoretical perspective examine epistemology as a result of their practical experience (Sandoval & Millwood, 2007) in order to assess students' processes of meaning-making. This philosophical stance allows researchers to focus on the language that people use in practice (Lundqvist, Almqvist & Ostman, 2009), which contains different epistemological positions.

Another study by Lidar, Lindqvist and Ostman (2006) developed approaches to analyse how epistemic practice interplays between teachers' epistemology moves and students' practical epistemology by adopting the same theoretical framework as Sandoval and Millwood (2007). Within this study, epistemology is framed as a cause for knowledge to be constructed: what Hutchison and Hammer (2010) described as an epistemological framing. This term refers to how students frame their learning activities which evidenced to become the reason to their practical epistemology practices. Hutchison and Hammer (2009) provided that instructional practices from teachers cause a tension in students' epistemological framing when learning physics. Their findings raise many more questions about what kind of epistemic practice or discourse should be the focus and how it is developed over time through instruction.

The theory of practical epistemology (Sandoval, 2005) proposed that epistemology development can be traced through epistemic practice during discourse. This theory is not interested in the epistemological level, which Tsai (2007) described as sophisticated, moderate and naive, but rather focuses on the role of epistemic practice in guiding scientific inquiry. The development or the progression of epistemic practice within Sandoval's (2005) theory of practical epistemology is in line with Kuhn and Park (2005) study about intellectual value. Kuhn and Park (2005) showed that value of intellectual engagement is obtained from the value of the scientific activity itself to support the epistemology development. Indeed, Sandoval (2005) is very cautious about the findings and the possible use of belief levels to study scientific epistemology, stating that epistemic practice is more sophisticated than the express beliefs about science (Sandoval & Millwood, 2007). However, characterizing the developmental process invites extensive debate on how this interferes with the confusion of theory and laws, theory certainty, creativity,

differentiating between inferences and observation and the practice of scientific methods, known as the nature of science (Abd-El-Khalick, 2012).

Consideration of this way of investigating science discourse enables this study to understand that epistemology development is assigned to the description of epistemic operation (Sandoval, 2007), which is a unitary developmental process. Duschl (2007) used five epistemic operations, namely operational, categorization, prediction, evaluation and appeal, assign posts for epistemology development. However, starting from this assumption, the authenticity of knowledge of scientific enterprise mentioned by Tsai (2007) is poorly explained during the argumentative analysis. Schommer-Aikins (2002) commented that the development process should be regarded as multidimensional. Hence, the development of every dimension has the state of being distorted during the discourse. This disagreement must be acknowledged by this study because many have reported (Duschl, 2007) the difficulty of separating out all developmental aspects during discourse analysis. This is because the nature of the discourse itself represents multiple realities (Erduran, 2014), and thus can hardly be explained from a single development process.

Science discourse offers a great opportunity to understand scientific epistemology development. Some researchers focus on the development and qualities of argumentation (Sandoval & Millwood, 2007; Duschl, 2007), while others look for epistemology development (Hutchison & Hammer, 2010; Lidar et al., 2006), which can be traced from practical epistemology (Lidar et al., 2006). Hutchison and Hammer (2010) proposed to focus on epistemological framing, as this relates to teachers' instructional goal, in which Lidar et al. (2006) described science discourse as context dependent. While there are concerns to understand what initiates students' epistemological development, Lidar et al. (2006) focused more on describing the ongoing process during the sense-making stage. This description represents teachers' epistemological moves and students' practical epistemology (Lidar et al., 2006).

Some researchers who study scientific epistemology are keener to understand the coherency of scientific epistemology between teachers and students (Tsai, 2007). Both Lidar et al. (2006) and Tsai (2007) sought to understand the connection between teachers' and students' epistemology. However, Tsai's (2007) definition of

'coherency' relies on the development of each dimension of scientific epistemology, whereas Lidar et al. (2006) work in the psychological framework, focusing on social operations. Those who come from a linguistic perspective, such as Hanrahan (2005), believe that science discourse consists of cues that can foster or hinder knowledge development. Shifting from this focus on epistemic operation, other researchers in science discourse are interested in the argumentative norm residing in the classroom. It works as a tool for discourse analysis (Duschl, 2007) and intervention (Christadoulou & Osborne, 2012) to improve science discourse. The analysis of argumentation focuses on how to support the claim and this is also related to the scientific epistemology.

In short, every teacher has an epistemological move that depends on their context and epistemology resources, reflected in their discourse, with students performing their responses based on their practical epistemology and epistemological framing. This whole process can be enhanced by paying special attention to the linguistic cues that are often confusing for students, as proposed by Kawalkar and Vijapurkar (2013) when they analysed teachers' questions. The argumentative approach in investigating science discourse provides a micro-level analysis of how the knowledge of science develops as a process in supporting the claim about physics phenomenon. However, Tsai's (2007) work does not seem to fit the conclusion above, as its focus is on the development of the scientific epistemology component rather than the individual. Therefore, to what extent is the research from Christadoulou and Osborne (2012), Hutchison and Hammer (2010), Duschl (2007), Sandoval and Millwood (2007) and Lidar et al. (2006) able to describe the development of scientific epistemology component?

The gap in the literature suggests that the basis in providing anthropomorphic accounts of scientific epistemology and science discourse is focused on the changing dimension of scientific knowledge. Referring to the critical realist perspective, this study agrees that previous studies are circulating to discuss knowledge when scientific practice is part of the social activity, but that they cannot fully explain how scientific epistemology possesses the properties of scientific practices in itself. Therefore, the development of scientific epistemology is a component of social interaction that can be scrutinized. From a critical realist perspective, this study seeks

to identify the impact of power on understanding the development of scientific epistemology through science discourse. The interpretations will in turn help to identify the epistemological assumption in shaping ways of knowing.

1.3 Problem Statement

This study focuses on detailed accounts from critical realism and philosophy of science perspectives to illustrate how these theoretical fields can provide an input to improve not only science education practices, but also the practice of scientific epistemology dimensions. With respect to philosophical accounts, this study claims that failure to recognize how physics is not explicitly taught will always result in under representation of the science discourse norm. Through this lens, interpretation of science discourse is a vital key to begin with to streamline the production and refine the product (Monk & Osborne, 1997), which is the student. Hence, this study will go further to explore the accepted norm of scientific epistemic practices, as well as the science discourse norm, to fill the gap discussed earlier.

In doing so, this study attempts to explore what lessons can be learned from the social context mediated during physics learning, which relies heavily on the epistemological claim about scientific knowledge (Siegel, 2014) and its modes of communication (McNeill & Pimentel, 2009). It is hoped that addressing the value of scientific knowledge will provide greater understanding and thus make physics more visible to teachers and students. The value of scientific knowledge as a way of knowing resides closely in the study of scientific epistemology and science discourse. The present study believes that this will provide a route for the study of physics education with a deeper understanding about why people feel alienated from physics.

1.4 Rationale of the Study

Lederman et al. (2002) outlined seven accounts of scientific epistemology that explain the nature of scientific knowledge that been used by many developed countries. Canada, Western Australia, Taiwan, the National Research Council (NRC) in the United States (1996), Turkey, Venezuela (Abd-El-Khalick, 2012) and the National Curriculum for England and Wales (QCA) in 2006 (Erduran, 2013) have already designed their curriculums centred on this scientific knowledge foundation. Their central ambition is to detail what science learning entails and avoid the ambiguity that often causes dissatisfaction for students attempting to understand the nature of scientific knowledge.

Lederman et al. (2002) touched on the tentativeness of scientific knowledge, observations and inferences, subjectivity and objectivity in science, creativity and rationality in science, social and cultural embeddedness in science, scientific theories and laws and scientific methods as the dimensions for the nature of scientific knowledge. Social and cultural embeddedness refers to science as a human endeavour (Abd-El-Khalick, 2012): thus, the decision as to what physics education should entail is affected by different cultural elements (Lederman et al., 2002). The emphases in this tenet support the argument by Archer (2000) that stratification is cultural and depends on social power and structure. Knowledge generation, which is heavily influenced by values, power structure, politics, socio-economic factors and philosophy (Lederman et al., 2002), provides significant differences during communicating physics in the Malaysian context of science education.

Given the considerable change in the science curriculum, physics learning in Malaysian elementary schools requires additional salience about scientific epistemological value. The shift of focus in science education research from the end product to the process of knowledge construction is crucial to raise the importance of scientific epistemology in science learning. The interpretation placed by teachers and students during the discourse offers great insight towards the epistemic practices that serve as a cognitive tool in learning. This effort itself is fundamentally epistemological because it seeks to develop an understanding of how teachers and students value scientific knowledge.

The idea in initiating a thorough study of the development of scientific epistemology is to provide evidence-based research for policy makers. This evidence shall be used as a basis for their development of new pedagogic tools or interventions, as the initiatives will close the gap that exists in that context. The framework of scientific epistemology developed in this study presented based on the analysis of science discourse and epistemic practices norms. The framework emphasized the variables that are fundamental for scientific epistemology development. These variables are conveying a broad set of expectation in which by the end of the lessons, students have an appreciation about the nature of physics knowledge. The framework is designed specifically to guide the scientific epistemology development particularly in traditional setting of education. Through critical realism, the framework also identified the possible challenge inherent in aligning the way traditional teaching with the condition needed for sophistication towards physics knowledge. It is hoped that this research will stimulate an informed discussion and possibly suggest policy measures and feasible changes in physics teaching at the secondary level. In turn, the discussion of this study will help to develop better personal epistemology when physics teachers have a clear view on how to address scientific epistemology explicitly without introducing it as something new to the students.

1.5 Research objectives

The main aim of this research is to analyse teacher-student scientific discourse during physics lessons that promotes scientific epistemology. The objectives are:

1. To explore the norm of science discourse demonstrated during physics lessons.
2. To explore the norm of epistemic practices demonstrated during physics lessons in relation to the norm of science discourse.
3. To develop a framework that showed the generative mechanism needed to develop sophistication toward scientific epistemology development during physics lessons.

1.6 Research questions

Research questions for the purpose of this study are as follows:

1. How are the norms of science discourse demonstrated during physics lessons?
2. How are the norms of epistemic practices demonstrated during physics lessons in relation to the norm of science discourse?
3. What is the framework of generative mechanisms needed to develop sophistication toward scientific epistemology development during physics lessons?

1.7 Theoretical framework: Ontology and Epistemology

The background to this study notes that there are many different approaches to scientific epistemology, underpinned by varying ontological assumptions about what scientific epistemology development actually is. For some researchers, scientific epistemology is a reality that needs to be measured according to their positivist assumptions. Research on epistemological beliefs outside of science has made a major contribution to discussions about students' coordination of subjectivity and objectivity development (Burr & Hofer, 2002). These studies usually refer to epistemology as 'personal epistemology' (Hofer, 2001) and present the developmental process via a unidimensional (Perry, 1968) or multidimensional (Schommer-Aikins, 2000) interpretation. The unidimensional model was initiated by Perry in 1970 to explain the intellectual development of Harvard students. This study explained the developmental process in stages to seek an explanation of the transition from the dualist to the relativist thinking stage. In considering some of the limitations in a unidimensional model to explain the dynamic nature of cognitive development, Schommer-Aikins (2004) proposed a multidimensional model of development. The idea behind this model is to explain development as a frequency distribution, with every dimension growing independently.

From this model, some researchers of personal epistemology, such as Hofer (2001), agreed with the multidimensional perspective in explaining the

developmental process. In the field of science education, scientific epistemological studies often suggest that action should be taken to address sophistication to reduce naive understanding about the properties of scientific knowledge. The epistemology development in this line of research often explains the epistemological stance or epistemological commitment (Akerson & Abd-El Khalick, 2003) held by an individual, such as sophisticated, moderate or naive (Tsai, 2007). This examination of levels shows a similar methodological trend to the work of psychologists.

Such positivist assumptions are often found when researchers assess and cluster development according to their stances towards the nature of science (NOS). There is evidence that positivist approaches are dominant in the NOS literature because of their statistically demonstrable results. However, there has been different progress in this line of studies, which helps to explain cognitive value with respect to scientific knowledge field. However, the attention devoted to explaining sophisticated or naive understanding indicates a positivist undertone, as argued by Erduran (2014). This criticism reflects the experience of Schommer-Aikins's multidimensional model, in which the explanations are directed to explain factors mediating the development process, but neither explains the causal structure itself. In contrast to this, there has also been a move by pragmatists to locate scientific epistemology as epistemic practices (Sandoval, 2005). This has led studies to understand scientific epistemology in real time practice to develop an understanding about scientific knowledge. Vygotsky's (1978) social constructivism is very influential to these researchers, who believe that scientific knowledge is socially constructed. This has led to a massive body of literature about the identification of the construction of epistemic operation and scientific argumentation.

Before considering a potential theoretical framework, I need to articulate my own ontological and epistemological positions on what is considered as reality. This clarification is essential to understand the nature of reality (ontology) and assumptions about how reality is acquired (epistemology). I started my research background from a positivist tradition by formulating a statistical model to represent the relationships between the scientific epistemology stances of teachers and their students (Nor Farahwahidah, 2013). During that time, I assumed that I could obtain the closest approximation of reality by using the positivist paradigm (Antwi &

Hamza, 2015) to represent the probabilistic causal laws (Neuman, 2003) about scientific epistemology between teachers and students. The results stated that sophisticated teachers influence more elements of scientific epistemology in students compared to those with a naive stance. The conjunction form of ‘whenever X, then Y’ (Sousa, 2010), as previously described within the positivist paradigm, is very limited in its ability to explain what happened between X and Y to produce Y. Following this, I experienced a shift during my PhD research training, which relies on understanding the meaning (Lincoln and Guba, 2000) of ‘influencing’. The constructivist perspective was developed prior to this movement to understand meaning. To overcome the reifying gaze of positivism, it was necessary for me to relocate meaning within the broader social context.

A review of previous studies provided some insight into the ontological position surrounding scientific epistemology development research. Recently, there has been a move to recognize the constructivist position that scientific epistemology is socially constructed. As Vygotsky (1978) said, knowing what we know is embedded in humans’ language and their interactions. A very simple distinction between constructivists and socio-constructivists is that the constructivist approach rests on the assumption that knowledge is built by individuals as they attempt to make sense of their experience, whereas for the socio-constructivist approach, knowledge is constructed in communities of practice through social interaction (Vrasidas, 2000). Constructivism and socio-constructivism are associated because, as explained by Cobb (1994), the construction of knowledge occurs as an individual action (constructivism), as well as a social interaction (social-constructivism).

This idea shares a similar position with this study about the reality that knowledge constructions are contextualized. But, at the same time, I have to disagree with the idealist perspective that reality is solely built and interpreted continuously in people’s interactions with each other. In searching for construction of ‘knowledge’, socio-constructivism does not discuss the ‘being’ state of knowledge. Studies of epistemic practices like argumentation feature inscription that enables the practice of argumentation to be made. However, this explanation is limited when exploring the development of scientific epistemology, as the evaluation of science discourse focuses on the structure of argumentation. Russ et al. (2008) explored

epistemological commitment by attending to students' reasoning thinking. This study further supports the need to examine science discourse but microscopically taps deeper into the chaining process between the substances that reveal the structure. This is because, in the Malaysian setting of science education, scientific epistemology does not receive the necessary attention. Therefore, the simple assumption that the scientific epistemology is constructed between teachers and students has led me to identify the fallacy of my constructivist claim. What can be acknowledged is that scientific epistemology is present in physics teaching, although teachers are not constructing it with the students. Figure 1.1 summarises the theoretical framework adopted for this study.

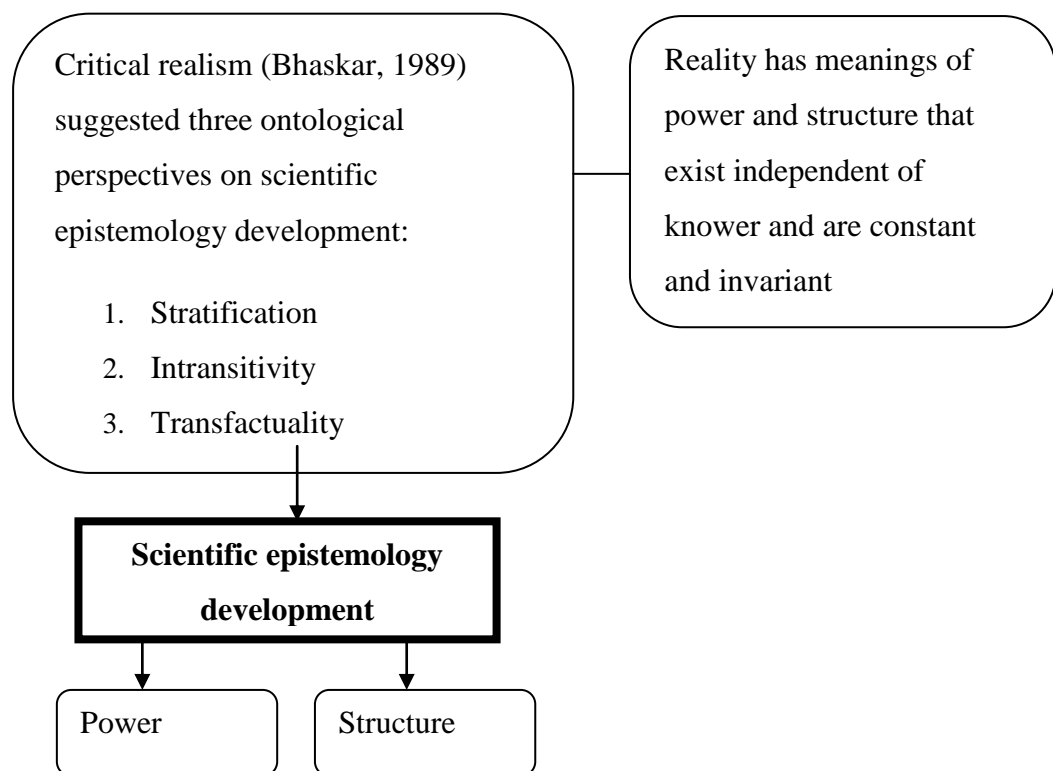


Figure 1.1: Theoretical Framework

I begin to situate myself as a critical realist, and this approach underlines the theoretical assumptions used throughout this thesis. The philosopher Bhaskar was the originator of critical realism in the 1970s (Bhaskar, 1998). Critical realism holds three basic ontological premises about social reality, known as stratification, intransitivity and transfactuality (Archer, 1998). Bhaskar (1978: 56) described

stratification as an ‘ontological map’ between the real, the actual and the empirical. These ontological elements are known as the domain of reality (what constitutes reality). The empirical approach claims that reality is observable and can be experienced. In contrast, Bhaskar’s definition of the real represents reality that exists independently from the knower’s experience. My previous study was empirical and was successful in generating knowledge about scientific epistemological stances among physics teachers and students. The observable social interaction in the empirical domain made me initially confident with what I thought exists. However, while I might be able to observe, the mechanism that allows this result is not observable. Archer (2000) extended stratification to encompass identification between the parts of society, such as teachers and students, with both having independent properties and power. The real refers to the power and structures which allow the scientific epistemology to behave in particular ways. The actual refers to the situation when the power is activated, such as when teachers employ epistemic practices.

Stratification is crucial to distinguish ontology and epistemology to avoid what Bhaskar (1978: 36) described as reducing ‘what is to what we can know about it (epistemic fallacy)’. Critical realism enables this study to recognize the complexity of understanding social reality about scientific epistemology. As a realist, I recognized these three layers of reality to provide this study with an ontological depth that is not presented in other approaches. The ontological status carried by elements in science discourse and scientific epistemology development is therefore regarded as the substance of social dimensions. Archer (2000) calls for another form of stratification to distinguish the parts of society and people within the reality of social structure. This claim is relevant in recognizing that discourse is a social structure and that the individual operates within that structure. The relationship between the individual and the social structure is what differentiates between transitivity and intransitivity.

Intransitivity is the reflection of the real that explains the existence of reality independently of identification or verification (Archer, 1998), or what Danermark et al. (2002) identified as objective reality. Thereby, scientific epistemology is real whether or not it is known by teachers, the classroom community or society on a

bigger scale. When discussing intransitivity, the focus is directed to an understanding about the causal mechanism posited in the development of scientific epistemology which the agent is experiencing in the real domain. Therefore, critical realism calls for a reflexive account in this study to identify, evaluate and prioritise the concerns during interpretation. In keeping with Archer's (2000) claim, examining the role of reflexivity requires me as the researcher to think about the causal world and to acknowledge the significant presence of myself during analysis. This implies a close relationship between reflexivity and action taken while comprehending the power and structure.

The reflexivity account allows this study to appreciate my own perspectives that connect the interpretation of findings with the reality of scientific epistemology development. Therefore, as proposed by critical realism, it is important to acknowledge my presence as a researcher and the way in which the scientific epistemology is approached. This study maintains that understanding is always an interpretation through preconceptions or pre-understandings (Usher, 1996). I have been influenced by Sandoval's (2012) argument that scientific epistemology is only meaningful when it is situated in practice. This view is underpinned by the situative perspective (Sandoval, 2012), which suggests framing the analyses of participation, artefacts produced during that time and individual reflection. Other than that, a suggestion about companion meaning by Lundqvist, Almqvist and Ostman (2009) has also led my philosophical consciousness to accept the critical realism perspective about the reality of the real.

I have also been influenced by Freire's (2005) description of banking education in his book 'The Pedagogy of the Oppressed'. As Freire (2005) noted, oppression occurs through teachers' pedagogy, which causes a contradiction with students towards physics knowledge. The readings have undoubtedly influenced my own understanding about scientific epistemology and supplemented my first experience of thinking critically about empirical truth, which I previously accepted unquestioningly. This philosophical view allows this study to be clear about the position and the influence I carried as the observer of reality. A critical realist approach to scientific epistemology development seeks to identify the impact of power (science discourse and epistemic practices) and its role in shaping ways of

knowing. The suggestion made by critical realism about reflexivity has led me to recognize my influence as a researcher during interpretation. Archer (2000) added that the reflexivity account is what makes the researcher human.

The existence of scientific epistemology development is not directly observable but critical realism believes that it holds certain power and mechanisms. This brings us to the last premise of transfactuality, which refers to the constancy and invariance of social mechanisms (Harrison Woods, 2012). According to Harrison Woods (2012), critical realists present constancy as an indicator that permits the study of mechanisms and certainty that such mechanisms will continue to exist (Archer, 1998). In relation to the development of scientific epistemology, transfactuality means that such development has the capacities to behave in certain ways but at the same time experiences vulnerability to certain kinds of change. Thus, the constancy means that the mechanism is not fixed but durable. Critical realism equates unobservable structure in parallel as a mechanism that holds the power that precedes human agency. For this study, the definition from Russ et al. (2008) that mechanistic reasoning explains the underlying structure and activities that account for the observed phenomenon is also shared by the critical realist approach.

Hence, the present study views 'knowledge' as a social entity rather than an individual property (Sandoval & Cam, 2011). From this perspective, the developmental process is not concerned about universal developmental processes, as in Perry (1970) or Schommer-Aikins (2004); rather, the purpose is directed to seeking adequate explanations about artefacts exhibited during the learning process. According to Sandoval and Millwood (2007), students' construction and evaluation of knowledge can be traced from their discursive practice, and can be regarded as a central artefact of physics learning. Such discursive practices posit numerous accounts about science discourse and epistemic practices during meaning making, which the present study views as scientific epistemology development.

This reframing implies that studies of epistemology in the field of physics lessons have different foundations of belief compared to studies of personal epistemology (Hofer, 2001) and epistemological belief (Schommer-Aikins, 2004). It is certain now that analyses of the physics learning norm will represent multiple

perspectives that are inherent in human endeavours. The experience of exploring my own ontological and epistemological accounts has established a critical realist approach for this study. Critical realism does not prescribe a methodological approach to generate knowledge to understand the real domain. For this study, I chose critical discourse analysis (CDA: Fairclough, 1989) to accompany my philosophical assumption (details are provided in Chapter 3). CDA allows this study to relate the events in the structure at both a micro and a macro level.

1.8 Conceptual Framework

Due to the nature of its aim and its research questions (to explore how scientific epistemology develops in a particular context), this study is conducted under the paradigm of critical realism. To test the implication of this perspective, this study attempts to pursue the connection between the norm of scientific epistemic practices and the norm of science discourse. A naturalistic approach is adopted for the present study to investigate teachers' science discourse during physics lessons in a natural classroom setting. Science discourse negotiated during meaning-making process is taken as the artefact for further investigation of scientific epistemology development.

Although the conceptual framework does not provide an explicit description of the phenomenon, it is possible that the cognitive analysis will provide greater support for science discourse in sustaining productive meaning-making process. According to Mayes (2010), science discourse is commonly recognized as explanation or argumentation. These two have different capacities of exploration that need to be empowered with productive epistemic practices. Osborne and Patterson (2011) added that the value of argument during interaction has different intentions from the value of explanation. Therefore, this implies that the norm of science discourse shall not demand an understanding about correcting this norm, but rather accommodating the process towards sophistication. The conceptual framework in Figure 2.1 is developed using insights from critical realism and has a primary objective to support systematic analysis for research on physics learning.

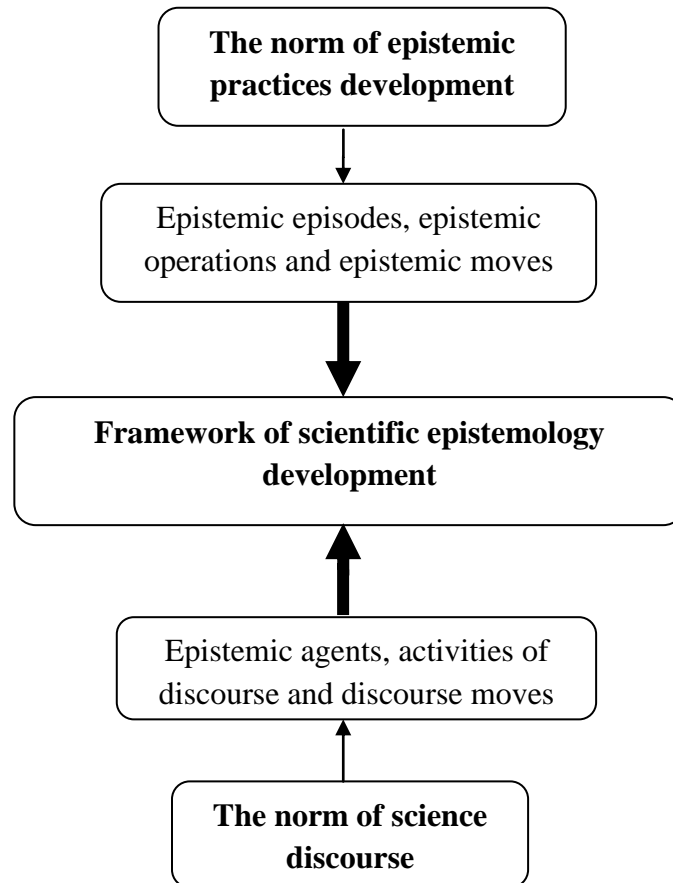


Figure 1.2: Conceptual Framework

Figure 1.2 shows the exploration of scientific epistemology development by making excellent use of the existing situated perspective (Sandoval, 2014) to account for the context of investigation. These perspectives can be seen to be superior to the study of scientific epistemology, as it is concerned with the practice of knowledge that occurs during learning. Instead of identifying contributing factors to scientific epistemology development, the analysis of discourse hopes to shed some light on the true nature of development. The tension when applying these perspectives involves identifying the appropriate units of meaning for analysis. As the situated perspective favours argumentation as its analysis tool, the present study agrees more with the epistemological resource perspective, which concentrates on the substance or entities while practicing argumentation. The substance that resides in science discourse is the central focus of this study, which happens as a result of teachers' epistemological moves and students' practical epistemology.

Russ et al. (2008) implied that students' responses are mechanistic reasoning processes, while Lidar, Lindqvist and Ostman (2006) segmented these interactions into encounters, gaps and relations. Within each segment, Russ et al. (2008) detailed the process as describing the target phenomena (encounter), identifying the setup condition, identities, activities and properties of the entities (gap), and identifying the organization of entities and backward and forward chaining (relation). Hence, the principle objective of the present study is to identify the specific transition of development that is developed into sophisticated, moderate or naive understanding. This attempt to characterize the transition development might depict a reasoning mechanism (Russ et al., 2008) that entails the value of a substance during the inquiry process. Lidar, Lindqvist and Ostman's (2006) analysis proposed five epistemological moves made by teachers, namely confirming, re-constructing, instructional, generative and re-orienting moves. These moves are made to complement students' practical epistemology during the meaning-making process. Studying both allowed the present study to have an overview of the complete picture of interaction mobilized during physics lessons.

In addressing such aims, the argument is presented in two parts: (1) This study needs to examine epistemic practices and its function within physics learning; and (2) It is crucial to establish an understanding about the function of science discourse in physics learning and how these values are being positioned during the process.

1.9 Definitions

This section provides definitions of terminologies that are used during this thesis. The definitions are derived from literature and theories. There is major debate in the study of epistemology regarding the developmental process, thus inviting great concern about what this process entails and how meaning is exhibited in the process.

1.9.1 Epistemology

Epistemology is a branch of philosophy that discusses the nature of knowledge and knowing, usually known as personal epistemology (Hofer, 2001). Schommer-Aikins (2004) added studies of learning to this definition, which leads to extensive research on epistemological belief. Studies about epistemology are commonly divided into studies of epistemic cognition and epistemic belief (Sandoval, 2014). The argument as to whether to examine epistemic cognition or epistemic belief usually relies on their different philosophical views.

1.9.2 Scientific Epistemology

Studies of epistemology in the field of science education use a terminology that pertains to scientific epistemology (Sandoval, 2014) or the nature of science (Lederman et al., 2002) instead of personal epistemology and epistemological belief. This line of research describes scientific epistemology as an appreciation of scientific knowledge. Therefore, questions about ‘what science is’ and ‘how science is developed’ have been addressed in a different manner from those within the psychology framework. Lederman et al. (2002) outlined seven general specifications of scientific knowledge, namely subjectivity and objectivity in science, creativity and rationality in science, scientific method, observation and inferences, tentativeness of scientific knowledge, theories and laws and social and cultural embeddedness. Most studies of the nature of science focus on the epistemological stance toward these seven features of scientific knowledge.

1.9.3 Epistemic Practices

Those who worked under the umbrella of pragmatism, such as Sandoval (2012), refer to scientific epistemology as practical epistemology. This shift mirrors their efforts to examine the practice of scientific knowledge, usually among students. Others who are concerned with teachers’ epistemological practice examine their epistemological moves (Lidar, Lindqvist & Ostman, 2005), which reflect their

pedagogical approach when teaching. Different terminologies can be seen, as each of them has different interests and desires towards explaining the phenomenon of science learning. Most of the arguments within the practice of scientific epistemology work under the socio-constructivist perspective towards learning (Sandoval, 2014). Thus, there has been substantial attention towards the epistemological resources used during the learning process (Hammer & Elby, 2002). Throughout the thesis, this study uses scientific epistemology to refer to epistemic episodes, epistemic operations and epistemic moves.

1.9.3.1 Epistemic Episodes

Epistemic episodes consist of frames that are characterized by discursive activities (Pontecorvo & Girardet, 1993). The goal of discussion for each episode is framed according to the representation of physics entities.

1.9.3.2 Epistemic Operations

An epistemic operation is a discursive action that communicates the practices of construction, justification and evaluation of knowledge claims (Kelly, 2011).

1.9.3.3 Epistemic Moves

Epistemic move is a notion borrowed from Lidar, Lundqvist and Ostman (2005). According to them, an epistemological move is an act to expose students to what counts as knowledge in the specific social practice.

1.9.4 Scientific Discourse

To explain the characteristics of argumentative and explanatory discursive practice, it is necessary not only to identify the process, but also to explain their nature constituting science discourse. Discourse thereby is an artefact that is inherent

to specific epistemology commitment and is socially constructed. The analysis is hoped to present the characteristics and norms of science discourse that support, sustain or diminish the development of scientific epistemology.

1.9.4.1 Epistemic Agents

Since the development of scientific epistemology occurs at the social level, the discourse that communicates this development is orchestrated by actors. The actors that take part in these interactions are teachers and students. Their group or individual roles are identified as epistemic agents.

1.9.4.2 Activities Oriented by Discourse

Activities oriented by discourse are the utterance behaviours in teachers' talk. Most studies, such as the work of Chang (2009), associate the behaviour as the activity to which the utterance leads students.

1.9.4.3 Discourse Moves

The discourse move is a move that is used to sculpt the social context for the development of scientific epistemology. The social context is identified as the social condition created from teachers' discourse activity.

1.9.5 Norms

The concept of the norm is taken from Lundqvist, Almqvist and Ostman (2009), who define norms as the rules for how to talk and act in a practice. They also point out that studies of norms seek to find 'the regularities of actions that are seen as correct by the participants in the studied practice' (Lundqvist, Almqvist & Ostman, 2009: 862). To be established as a norm for the phenomenon under investigation, the norm should be able to explain the fundamental value inherent in science discourse

and how such a norm becomes a dilemma among teachers to employ scientific practices. This study scrutinized the accepted norm for science discourse and scientific epistemology development.

1.10 Summary

This chapter provides the general setting for this study based on the gap explained in the background of the study and a statement of the problem. This study attempts to explain teacher-student knowledge construction by identifying scientific epistemology development through norms of science discourse and epistemic practices. In proposing more provisional explanations of the development process, it becomes imperative to study epistemology development from the discourse and practices participating in the process. Hence, teacher-student scientific epistemology development provides ample opportunities to explain the accepted norms of science discourse and epistemic practices.

This study has chosen to employ critical realism as a theoretical framework to frame the social phenomenon under investigation. The framework requires an exploration of the power and structure that inhibit the norms of science discourse and epistemic practices. The state of scientific epistemology development is further crystallized for its stratification, intransitivity and transfactuality. Chapter 2 discusses dilemmas and issues surrounding Malaysia's science education, scientific epistemology and the field of science discourse.

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