

Summary of the Doctoral Dissertation

The Epistemology of Learning and Interaction: A Goal-Directed Adaptive Agent is an Epistemic Agent

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This dissertation, entitled “The Epistemology of Learning and Interaction: A Goal-Directed Adaptive Agent is an Epistemic Agent”, aims at providing new contributions to longstanding arguments in epistemology, such as what internal representations are, the realism/anti-realism debate, causal theories of action, social aspects of epistemology, and naturalization of epistemology, through rethinking those arguments in new ways and referring to empirical results from cognitive science. In particular, the dissertation relates the concept of an *epistemic agent* in epistemology to the concept of a *goal-directed adaptive agent* in cognitive science, and argues for the thesis that a *goal-directed adaptive agent is an epistemic agent*.

Towards achieving these aims, the dissertation restricts its attention to two principal human activities: learning and interaction. This makes easier and simpler the assembly of various new theoretical and conceptual constructs for discussions and arguments. Under this restriction, the dissertation redefines basic epistemic concepts, such as knowledge and belief, from the perspective of cognitive science. Also, it reconsiders representative concepts such as truth, internal representation, causality, and action, from a new standpoint to be proposed and properly positioned in conventional epistemology.

As this new standpoint, the dissertation proposes what it calls *process-oriented constructivism*. This standpoint focuses on processes of an agent for actively constructing, controlling, and regulating internal representations, using information originated in both internal and external sources. Also, it introduces several epistemic norms, and reconsiders various preceding arguments in epistemology, such as the realism/anti-realism debate as a typical example, analyzes structures of various kinds of internal representations, argues for the existence of entities represented by those internal representations, and positions itself in epistemology as a new standpoint based on realism. Further, through these complex discussions, the standpoint relates empirical results in cognitive research on goal-directed adaptive agents to the normative concept of an epistemic agent in epistemology, and contends that a goal-directed adaptive agent is an epistemic agent.

The dissertation consists of the following parts: the Introduction, Chapters 1-3, and the Concluding Remarks and Contributions to Epistemology. First the Introduction provides the aims, motivations, and sketches of Chapters 1-3, as well as a preview of its contributions to epistemology.

Then Chapters 1-3 follow, which constitute the body of the dissertation. Among those three chapters, Chapter 3 plays the principal role for achieving the aims of the dissertation by presenting the main epistemological arguments. Chapters 1 and 2, on the other hand, summarize representative research in cognitive science, especially works on learning and interaction, respectively. The contents of those chapters are extensively used in discussions to be conducted in Chapter 3. The summaries compiled in Chapters 1-2 refer to a wide spectrum of literature in psychology, neuroscience, evolutionary studies, anthropology, linguistics, computer science, and other fields related to cognitive science. The central parts of those summaries are taken from the works of the author of this dissertation and his colleagues.

At the beginning of Chapter 1 titled Theory and Models of Learning, a survey of cognitive studies on learning is given in Sections 1.1-1.3. This includes an overview of learning research in cognitive, developmental, and social psychology, as well as cognitive neuroscience, evolutionary research, and other related fields.

Then, Sections 1.4-1.5 provide an extensive summary of the *theory of learning by doing* and its implications, which compile the longstanding contribution of the author with his colleagues to this topic. Notably, the theory is a *procedural theory* rather than a substantive theory, providing a breaking point for the epistemological arguments of this dissertation. Also, the theory, elucidating processes of a problem-solving agent for discovering and acquiring new problem-solving strategies by itself, empirically explains that the order of strategies learned in those processes is fixed and independent of problem domains and agents. This descriptive result provides empirical bases to epistemic arguments in Chapter 3 on internal processes of an agent in which a belief is turned into knowledge.

These summaries are also used for discussions in the subsequent Sections 1.6-1.8, where more recent results from cognitive science on learning are discussed. In particular, discussions are provided for relations between these recently presented studies and the research on the theory of learning by doing and its implications summarized in Sections 1.4-1.5.

Chapter 1, as such, describes the results of works on the ‘theory of learning by doing’ led by the author for years, their implications, and influences on recent learning research in cognitive science, while providing a general and extensive overview of

cognitive studies on learning in relevant fields.

Chapter 2, titled Theory and Models of Interaction, is devoted to providing comprehensive summaries of cognitive research on interaction. First, Sections 2.1-2.4 summarize cognitive studies on interaction, starting with an overview of relevant studies in social psychology, social cognitive neuroscience, evolutionary studies, and other related fields, and then referring to the research on human-robot interaction by the author and his colleagues. Section 2.4 points out that it is essential to understand an interaction of agents as their ‘sharing of information.’

Next, Sections 2.5-2.6 provide summaries of *the theory of interaction by information sharing* and its implications, taken from the author’s own work. These sections also include summaries of studies on human-robot interaction conducted by the author and his colleagues. Those studies are sources of inductively producing the theory. The theory is a procedural theory, and includes procedures for compositing internal representations with very complex structures like a representation of another agent’s internal representation and a representation of one’s own representation (the infinite-regress argument can be skirted by introducing a constraint on the capacity of an agent’s internal mechanisms). The theory also includes procedures for detecting similarities. Further, it restricts the inferential capability of an agent only to the first-person inference, including no capability for the second- or third-person inference. These two points on similarity and inference are discussed in Chapter 3 from the epistemological perspective. In this way, the theory provides an empirical basis of the epistemological arguments in Chapter 3. Further, in Section 2.5, many important concepts are given their definitions: agent, context, environment, view (an internal representation of an internal representation), the distinction of internal and external, and others. Section 2.6 proceeds to discuss key concepts like knowledge, belief, intention, action, desire, and goal, and also provides, from the cognitive perspective, the four conditions of knowledge: utilizability, robustness, adaptability, and admittability. One of the characteristics of those conditions is that no explicit concern is given to the concept of truth, which is strongly related to the concept of knowledge in epistemology.

Sections 2.7-2.8 compile the recent advances of cognitive science on interaction, particularly including those from psychology, neuroscience, evolutionary studies, computer science, and related fields. These sections also include explanations of various results from the research on human-robot interaction, each based on the theory of interaction by information sharing and its implications given in Sections 2.5-2.6. Section 2.9 extensively discusses the recent trends of cognitive neuroscience, and

presents a model of information processing mechanisms of brain activities that the author calls the functionally networked neural platforms.

Chapter 2, on the whole, provides an extensive review of cognitive research on interaction, describes the author's theory of interaction by information sharing and its implications, and discusses relationships between the theory and diverse conventional studies on interaction by referring to the works on human-robot interaction led by the author for years. Also this chapter presents a variety of basic concepts related to epistemology, and conditions of knowledge from the standpoint of cognitive science as well. These provide bases from empirical sciences for epistemological arguments on social interaction.

Chapter 3 is titled Representations from Process-Oriented Constructivist's Standpoint, and presents discussions and arguments on a broad spectrum of topics in epistemology to properly position process-oriented constructivism in conventional epistemology and to present new contributions.

First, in Section 3.1 (titled Representations and Process-Oriented Constructivism), discussions are given for what representations are and what process-oriented constructivism is, and also a list is provided for enumerating salient results given in Chapters 1-2 which play significant roles in subsequent arguments. Also, Section 3.1 introduces and discusses six norms (the motivatedness norm, constructability norm, processability norm, inferrability norm, knowledge norm, and world norm), which play pivotal roles in drawing a clear boundary between normative epistemology and descriptive cognitive science.

Section 3.2 (Representations as Triadic Relations), then, discusses the structure of internal representations. In particular, it introduces the triadic relation of a representer, representation, and represented entity to the structure of a representation, and argues for its usefulness by referring especially to the relevant works of Dretske, Giere, and Millikan.

In Section 3.3 (Frameworks and Factors for Representational Contents and Structures), further frameworks, called *form* and *format*, are introduced, and the structure of an internal representation, which is a key concept in the dissertation, is delineated in detail. Section 3.4 (More Factors for Representational Structures: Knowledge Structuralizability, Cognitive Strategies, and the Structured World) discusses various factors essential for the internal construction of representations, including constraints on the structuralization of knowledge as internal representations, cognitive strategies of a representer in deciding forms and formats, relationships between the structure of a world and structures of internal representations. Section

3.5 (Classifications of Formats for Representations) states that there exist many kinds of formats, and further that the representer must find it important to choose an appropriate format when it constructs an internal representation.

In Section 3.6 (Goal-Directed Strategy-Driven Representing: Examples from Our Cognitive Studies), following the discussions on representational structures and various new concepts such as representer, three studies of the author and his colleagues, taken from the domains of problem solving, associative memory, and statistical methods in neuroscience, are used as examples to argue that the methodologies to be adopted by scientists drastically change depending to their strategies for selecting forms of representations to attain their scientific goals. This argument provides, following the discussions on representations and their structures in Sections 3.1-3.5, a concrete example for suggesting relationships of scientific methodologies of scientists and representations constructed by those scientists; this topic apparently is less discussed in philosophy of science.

Following the discussions on internal representations and their structures in Sections 3.1-3.6, Sections 3.7-3.14 provide a wide variety of arguments on the relationship between process-oriented constructivism and conventional arguments in epistemology. Those arguments proceed through comparing with various claims given in epistemology, particularly in philosophy of science, and also referring to empirical studies summarized in Chapters 1-2.

The arguments begin with Section 3.7 (Placing Process-Oriented Constructivism in Epistemology: An Introduction), in which surveys are given for the characteristics of process-oriented constructivism, especially by associating them with those in conventional epistemology.

Following this introduction, in Section 3.8 (Sculpting an Epistemic Agent: Why Must an Active Agent be Epistemic?), the definition and conditions of knowledge given in Section 2.6 are related to the concept and conditions of truth. It also discusses the topic of what truth and knowledge mean to a robot in a human-robot interaction. With these discussions, the characteristics of process-oriented constructivism are compared with various theories of truth or knowledge in epistemology such as: the correspondence theory of truth, coherence theory of truth, justification theory of knowledge, reliability theory of knowledge, and causal theory of knowledge. Following these discussions, Section 3.8 provides the argument that *a belief that qualifies the knowledge conditions given in Section 2.6 satisfies truth conditions with the standard definition in epistemology*, while bridging the concepts of truth and knowledge in epistemology to those in cognitive science by the conditions of knowledge presented in Section 2.6. This

provides a base in arguing for the thesis that a goal-directed adaptive agent is an epistemic agent; giving an affirmative answer to this thesis is one of the aims of this dissertation. Section 3.7 also touches on the concept of emotion, and suggests that process-oriented constructivism is able to naturally integrate this concept to the structure of internal representations given in Sections 3.1-3.6.

Section 3.9 (What Do Representations Mean to Goal-Directed Adaptive Agents? Existence of Represented Entities) is devoted to discussions on connecting a wide range of arguments in epistemology to relevant aspects of cognitive research. First, it claims that the theory of learning by doing and the theory of interaction by information sharing, which are summarized in Chapters 1-2 respectively, are both scientific theories, if they are evaluated by standard conditions of scientific theories argued in philosophy of science. On the other hand, it is also recounted in the section that both of them are procedural theories, apparently not sufficiently discussed in philosophy of science.

In Section 3.9, this claim is followed by discussions given for the existence of entities represented by internal representations with various kinds of structures. First, a problem-solving strategy, discussed in Chapter 1, can be regarded as an algorithm, with the reservation that the algorithm is an internal representation constructed by a problem-solving agent. The algorithm is executed by the agent, not by a computer, and thus an output trace and the algorithm must be causally related through the agent's actions. Also, it is pointed out that processes of an agent for learning new strategies can be regarded as processes of the agent to transform a belief to knowledge (in the sense of the knowledge condition in Section 2.6). Then the section provides an argument for the existence of output traces of problem-solving strategies acquired by an expert agent in a learning process. The argument is carried out by applying convergent realism and the inference to the best explanation argument, and defining 'best' in the best explanation as the best for the space complexity of the agent's internal processes.

Further, in Section 3.9, constructive empiricism, a leading school for epistemic anti-realism, is called to task with a comparison to process-oriented constructivism. Also, the discussion refers to criticisms of convergent realism, especially the pessimistic induction argument. In Section 3.9, the dissertation contends that pessimistic induction must be discarded from the present discussion, because it is based on the causal relation between an algorithm executed through actions of an agent and its output traces, and also it relies on the knowledge conditions. Further, for the domain- and agent-independent fixed learning order of problem-solving strategies described in Chapter 1, it is pointed out that this learning order is a structure embedded in an output

trace of a domain- and agent-independent algorithm for learning new strategies. Also, the section argues for the existence of this structure by applying the inference to an appropriate explanation. There, the ‘best’ in the best explanation is replaced by ‘appropriate’ in the sense of being qualified by the conditions of knowledge given in Section 2.6.

The second example of internal representations that Section 3.9 takes is an internal model for problem solving (an internal model is an internal representation of a problem, constructed by an agent through inferring its external environment for solving the problem), using the domain of elementary physics, the same domain used in the empirical studies summarized in Section 1.5. The section points out that such models have many commonalities with models and theories argued in philosophy of science. Then, referring to the experimental result given in Section 1.5 that the same agent learns to construct internal models which can be used more effectively or efficiently in solving problems, the section claims that an internal model constructed by an expert agent can be regarded as a scientific theory in philosophy of science. Accepting this claim, the argument contends the existence of an entity represented by an internal model constructed by an expert, applying convergent algorithm and the inference to the best explanation.

Section 3.9 also provides extensive discussions for comparing process-oriented constructivism with other realism and anti-realism schools in epistemology: entity realism, epistemic structural realism, ontic structural realism, semi-realism, and others for realism arguments; and epistemic structuralism, pessimistic induction, pragmatic empiricism, radical constructivism, social constructivism, and others for anti-realism arguments. From those discussions, the dissertation claims against representative anti-realism arguments, and also points out weaknesses of many representative realism arguments. On the other hand, it partly recognizes the merits of epistemic structural realism because of its two characteristics. One is that this school does not restrict entities represented by theories to those in natural sciences. The other is that it keeps relations of entities with their theories. Moreover, the argument points out that process-oriented constructivism, which attends to processes for constructing internal representations, is able to integrate at least a part of anti-realism arguments into the realism argument, and makes possible discussions that go beyond the dichotomy caused by the realist/anti-realist debate.

As the third example of internal representations, ‘a view on a view’ (a view that represents a view constructed by another agent or the self) is taken in Section 3.9. A view on a view has a complex structure, and also a represented entity is supposedly

unobservable or non-physical. Discussions on this kind of complex representations might necessitate normative arguments, which actually are provided in Sections 3.1-3.6. Here, it is pointed out that a view on a view constructed by an expert agent (an expert in constructing views on views in a specific domain) can be regarded as a theory of supposedly unobservable entities, and also a view on a view of an expert satisfies the knowledge conditions given in Section 2.6. Following this argument, it is claimed that a view represented by a view exists, by applying convergent realism and the inference to an appropriate explanation. Further, the argument is followed by critics of anti-realism arguments such as constructive empiricism for this kind of representations.

The fourth example of internal representations taken in Section 3.9 is a shared view. Suppose that each agent participating in an interaction constructs as an internal representation a set of views on internal representations of all the participating agents, where all of those representations of participating agents are inferred by the agent as being similar. If all the participating agents construct internal representations of this kind, and if they *are* all similar, then such a set of views on representations of all the agents inferred by each agent is called a shared view.

To focus on social aspects of epistemology, the discussions on shared views are restricted to social interactions. A social interaction is an interaction in which a goal state of each participating agent includes sociality. The argument here contends the existence of shared views in a social interaction, by applying the theory of interaction given in Chapter 2, various studies on evolutionary processes (particularly those on the Social Brain Hypothesis and social signals), and the convergent realism argument, in a combined fashion. Also, as noted above, the argument claims for process-oriented constructivism that it is able to explain processes of each agent in a social interaction by inferring that all the participating agents have similar shared views. This supports arguments in Section 3.13 for social aspects of epistemology.

Overall, Section 3.9 affirms the existence of entities represented by various different kinds of internal representations in a variety of ways. This claim provides the basis for the realism stance of process-oriented constructivism.

Following the arguments in preceding sections, Section 3.10 (Structures and Contents of Complex Internal Representation), discuss some important points for relations of internal representations, their structures, and processes for constructing them. First, the KK thesis (or the KK principle) is discussed in relation to the question of whether to identify an internal representation with an internal representation of an internal representation, raised in defining internal representations in Section 2.5. The

argument here claims that the KK thesis must hold if the definition of internal representations keeps consistency. Also, in this section, discussions are provided for how processes for understanding diagrams (as external representations) and diagramming are related to processes for constructing internal representations, and how inferences on similarities between representations are related to those processes. Furthermore, the section provides criticisms of what are labeled as ‘constructivism’ and the like: for example, epistemic structuralism, radical constructivism, social constructivism, and others. It also takes a critical look at functionalism and computationalism, which once covered a large portion of philosophy of cognitive science.

Section 3.11 (Knowledge-How and Belief-How: From Our Standpoint) turns its attention to procedural aspects of knowledge and belief. Being aware that the theories of learning and interaction in Chapters 1-2 are both procedural theories, and that learning processes of a novice to become an agent can be related to processes of an agent for transforming a belief to knowledge, the section argues this topic from the perspective different from conventional epistemology. In particular, the argument here distinguishes explicit-belief-how, which is an internal representation that represents an entity with a symbolic form and format, from implicit-belief-how, which represents an entity whose form and format are not symbolic. Then, it proceeds to argue, based on the intellectualism argument by Stanley and Williams as well as others, that similar contentions to ones provided for the existence of entities represented by problem-solving strategies, internal models, and others can be applied to explicit-belief-how. Further, it points out that process-oriented constructivism is available also for discussions on implicit-belief-how since the standpoint does not state any specific form or format. On the other hand, it is difficult for intellectualism arguments to cope with such discussions for implicit-belief-how.

Section 3.12 (Causal, Attributional, Teleological, and Rational Relations of Goal States and Actions in Internal Representations) provides new perspectives for causes, reasons, actions, and their relations, argued for years in epistemology. As summarized in Chapter 1, the same agent can interpret relations on elements in the same set of internal states and actions in different ways as the causal relation, attributional relation, teleological relation, and rational relation. Further, also the theory of learning in Chapter 1 empirically suggests, in the process of learning strategies to become an expert in problem solving in a specific domain, the same learner is generally able to transform interpretations for relations on elements in a set of states and actions from the causal to attributional, further to teleological, and yet further to rational relation.

It is argued here that an action as a cause and as a reason can be the same action of the same agent. The argument provides new perspective to the longstanding debate in causal theories of action many years ago on whether an intention is a cause, or a reason, of an action, for example, by Davidson and Anscombe.

In Section 3.12, further discussions are given for causal, teleological, and rational relations constructed as internal representations by agents participating in a social interaction, where actions of multiple agents could be exerted at the same time, or such actions may be exerted collaboratively.

Then, Section 3.13 (Social Aspects of Epistemology and Our Process-Oriented Constructivism) is dedicated to discussions on social aspects of epistemology. There, referring to the theory of interaction and experiments on human-robot interaction, both summarized in Chapter 2, epistemic analyses are given for the concept of social action from the process-oriented constructivist's standpoint, particularly from the perspective of the knowledge conditions given in Section 2.6. Also, the section discusses relationships between social reliabilism and process-oriented constructivism, as well as possible reconciliation of relativism and process-oriented constructivism. These discussions point to the merit of process-oriented constructivism that could play the role of bridging externalism and internalism arguments.

In this section, the dissertation further contends that no collective concept is necessary for explaining social interaction. This is because an agent participating in a social interaction makes only the first-person inference, but still it is possible for all the agents to share similar information without the second- or third-person inferential capabilities as argued in Section 3.9. This argument is given by referring to arguments in epistemology that do not introduce collective concepts (such as Bratman's Shared Agency) and those that recruit such concepts (like Gilbert's joint commitment). It is argued further that process-oriented constructivism, which emphasizes the adaptability of agents, runs very differently from Bratman's argument that stresses plans and planning roles.

In Section 3.14, naturalization of epistemology, the issue once raised by Quine and others, is discussed by referring to relevant literature in both epistemology and cognitive science. In particular, the psychological turn and the pragmatic turn are reconsidered, and also some representative experimental methods in cognitive science are reexamined. Those methods include the think-aloud protocol method, computer simulations, analyses of brain activities by massive-data analytics and neuroscience, and the synthetic method by using human-robot interaction. These methods are described in Chapters 1-2, but in this section it is argued that they can be regarded as

scientific methods for advancing specific aspects of cognitive science.

Also, to examine how epistemology can be naturalized, the section employs as an example exercise the triangular explanation that Davidson once presented for advocating externalism. This exercise suggests that epistemology can be, or was already, naturalized to a considerable extent. However, the argument also claims that, although a large part of epistemology will be naturalized, the normative part of it will remain, and not be eliminated. The dissertation opposes the complete naturalization of epistemology, and eliminative materialism, and advocates the modest naturalized epistemology. Especially the argument for this modest naturalized epistemology is characterized as contending the possible symbiosis of normative epistemology and descriptive cognitive science, under the standpoint of process-oriented constructivism affiliated with the epistemic norms and knowledge conditions given in Section 3.1 and Section 2.5, respectively.

Section 3.15, the final section of Chapter 3, provides a summary of the chapter. Also, it affirmatively states, by integrating the arguments given in the chapter, that (1) a goal-directed adaptive agent is an epistemic agent; (2) the capability of constructing, controlling, and regulating internal representations through utilizing information originated in both external and internal sources is an important prerequisite for both a goal-directed adaptive agent and an epistemic agent; (3) a world independent from an agent must exist and entities with diverse structures must exist in this world, since processes for constructing internal representations from information originated in external sources must be similar for multiple agents; and thus (4) process-oriented constructivism can be positioned as an epistemological realism that focuses on an agent's processes for constructing internal representations.

Hence, Chapter 3, along with the aims of this dissertation, reconsiders empirical studies of learning and interaction from the perspective of epistemology, proposes process-oriented constructivism, relates it to conventional arguments in epistemology, claims that a goal-directed adaptive agent is an epistemic agent, creates a new relationship between epistemology and cognitive science, and accordingly, through these arguments, provides new contributions to epistemology.

Following Chapter 3, the dissertation places the Concluding Remarks and Contributions to Epistemology. This last part summarizes Chapters 1-3, and provides the contributions produced from the arguments in Chapter 3 as the list of ten items that follow:

Contribution I: Affirmed the thesis that a goal-directed adaptive agent is an epistemic agent, through the deliberate introduction of theoretical and conceptual constructs and

extensive arguments on those constructs. Also, provided normative explanations to empirical results in cognitive research on learning and interaction by introducing four conditions of knowledge and six epistemic norms. Further, established the process-oriented constructivist's standpoint based on realism arguments, through comparisons with a broad range of arguments in epistemology.

Contribution II: Argued that processes of a novice in a specific domain to learn new strategies, internal models, or views on views for becoming an expert can be regarded as processes of an agent for transforming its belief to knowledge. Also, contended by applying realism arguments the existence of the domain- and agent-independent fixed learning order of problem-solving strategies.

Contribution III: Defined new frameworks for stating the structures of complex internal representations, including forms and formats, as well as the structure with the triadic relation of the representer, representation, and represented entity. Further, using those frameworks, properly positioned processes for constructing those representations in arguments in epistemology.

Contribution IV: Argued for the existence of entities represented by various kinds of internal representations like problem-solving strategies, internal models, views on views, and shared views by applying convergent realism and other arguments. Also, critically argued against anti-realism such as constructive empiricism, and also functionalism and computationalism which served as main players for some time in philosophy of cognitive science. Further, presented a new realism argument by bridging conventional realism arguments with anti-realism. All these arguments were conducted by comparing process-oriented constructivism with arguments proposed by representative schools of epistemic thought.

Contribution V: Argued that processes for learning new strategies to become an expert can be related to processes for an agent to transform a belief-how to knowledge-how. Further, proposed to distinguish explicit-belief-how and implicit-belief-how by differences of forms and formats for those representations (symbolic for the former, whereas distributed for the latter), and claimed that realism arguments similar to those applied to other parts in Chapter 3 can be implemented to explicit-belief-how, but not to implicit-belief-how. Suggested, however, that process-oriented constructivism could be applied to both.

Contribution VI: Shed new light on causal theories of action by attending to the transformation of an agent's interpretation of relations between internal states and actions from causal to attributional, further to teleological, and to rational relations, while the agent learns to become an expert.

Contribution VII: Argued that epistemic arguments on social interaction of multiple goal-directed adaptive agents can be conducted without introducing any collective concept. Also, note that the argument is very different from other arguments that do not use such concepts (such as Bratman's shared agency).

Contribution VIII: Discussing naturalization of epistemology, whose arguments started by Quine and others, from the perspectives of both epistemology and cognitive science, argued for the modest naturalized epistemology. Contends that more portions of normative epistemology will be naturalized but no complete naturalization will occur; normative epistemology and descriptive cognitive science will stay as neighbors mediated by process-oriented constructivism.

Contribution IX: Argued that process-oriented constructivism is superior to various 'constructivisms' in many points related to epistemology such as the contributions listed here.

Contribution X: Declared the new statement that substantially connects epistemology, which deals with 'what is truth?' and hypothesizes the existence of truth, and cognitive science, which does not explicitly assume the existence of truth but works on how goal-directed adaptive agents try to prepare and exert actions to discover and attain their goals through adapting to new environments. The affirmatively answered thesis that a goal-directed adaptive agent is an epistemic agent (Contribution I) is indeed this statement, which contends that any such agent, like a human problem solver such as a student, a business person, or any other, pursues knowledge and truth in the sense of epistemology. The statement, and the arguments given in Chapter 3 as well, provide new meanings originated in process-oriented constructivism to the epistemic concepts of knowledge, belief, truth, and others, at least in the realms of learning and interaction that constitute the two principal activities of human beings.

Overall, this dissertation presents a new realism stance called process-oriented constructivism and offers new contributions to epistemology, through extensive arguments on learning and interaction from the epistemological perspective, referring to a broad spectrum of literature in epistemology and cognitive science including the author's own works.