Answering by Means of Questions in View of Inferential Erotetic Logic

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Abstract
Inferential Erotetic Logic (IEL) gives an account of inferences in which questions play the role of conclusions, and proposes criteria of validity for these inferences. We show that some tools elaborated within IEL are useful for the formal modelling of: (a) replying with questions that are not clarification requests, and (b) question answering based on additional information actively sought for.

1 The dyadic perspective and answering by means of questions

Logical theories of questions supply formalisms for questions as well as characteristics of the question-answer relation.[1] As long as question asking and question answering are concerned, they usually adopt a simple dyadic perspective. It is assumed that there are two parties, a questioner and an answerer. The former asks a question, whereas the role of the latter is to provide an answer to the question. Even eliciting information from Nature is modelled in this way.[2] The answer to be provided must not be a question, or, to be more precise, answers having the form of questions are permitted only if a clarification is needed.

The dyadic perspective, however, does not account for some phenomena which occur in real-life questioning. Generally speaking, these include: (a) replying with questions that are not clarification requests, and (b) question answering based on additional information actively sought for.

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[1] For overviews see e.g. [12], [11], [9]. See also [32], Chapter 2.

[2] *Cf.* [13].

1.1 Replying with questions

When a question is replied with a question, the reply is most often a clarification request.[3] Yet there are cases in which a reply having the form of a question provides, though in an indirect manner, information of the required kind. For instance, let us consider:

Ann: *Is Andrew a genius?*
Bob: *Do penguins fly?*

or

Ann: *Is it true that you always answer with questions?*
Bob: *Really?*

The above examples can be accounted for in terms of "exploitation" of Grice's Conversational Maxims[4] (although the second example presumably requires more than that). Sometimes, however, an analysis of replying with questions carried on in a purely Gricean perspective is insufficient or even inadequate. The story presented below is instructive in this respect.

Example 1. Two parties, **A** and **B**, interact by exchanging questions and information in the following way.

A: *Where did Andrew leave for: Paris, London, or Moscow?*
B: *When did Andrew depart: in the morning, or in the evening?*
A: *In the morning.*
B: *Did Andrew take his famous umbrella?*
A: *No, he didn't.*
B: *[So] Andrew left for Paris.*

B's first move becomes pretty understandable if he knows that:

(1) *If Andrew left for Paris, London or Moscow, then he departed in the morning or in the evening.*
(2) *If Andrew departed in the morning, then he left for Paris or London.*
(3) *If Andrew departed in the evening, then he left for Moscow.*

Similarly, **B**'s second interrogative move is justified if he, in addition, knows that:

(4) *Andrew left for London if he took his famous umbrella; otherwise he did not leave for London.*

Of course, **B**'s premises need not be known to **A**. So the dialogue might have continued as follows:

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[3] *Added in 2013*. For a taxonomy of question-replies (QR) see [21]. A corpus study reveals that clarification requests constitute about 80 % of QR, while about 10 % of QR falls into the category of 'dependent questions'. QR, in turn, constitute slightly more than 20 % of all responses to queries found in the spoken part of the British National Corpus.

[4] *Cf.* [10] .

A: *How do you know?*
B: *Well, Andrew departed in the morning, and if he had done so, he left for Paris or London. But he did not take his famous umbrella, as he used to when traveling to London. So Andrew left for Paris.*

Note that the question-replies are asked by **B** and answered by **A**. The answer to the principal question is, finally, provided by **B**. In other words, **B**, an answerer, temporarily becomes a questioner in order to accomplish his main task, and **A**, a questioner, temporarily becomes an answerer.

1.2 Question answering based on ddditional information actively sought for

In view of the dyadic perspective a questioner requests information that she lacks (and needs for some reason(s)), whereas an answerer is supposed/obliged to provide information that fully satisfies the request. It often happens, however, that a questioner does not receive a satisfactory answer, but in order to arrive at such an answer has to assemble additional information, and this requires asking "good" auxiliary questions. The stories below illustrate this.

Example 2. As in Example 1, there are two parties, **A** and **B**. This time, however, they interact in a quite different way, *viz.*:

A: *Where did Andrew leave for: Paris, London, or Moscow?*
B: *Well, if these are the options, then he departed in the morning or in the evening. And if in the morning, he left for Paris or London; otherwise he left for Moscow. And, moreover, he takes his famous umbrella only when travelling to London.*
A: *When did Andrew depart: in the morning, or in the evening?*
B: *In the morning.*
A: *Did Andrew take his famous umbrella?*
B: *No, he didn't.*
A: *[So] Andrew left for Paris.*

Now questions are asked only by **A**. Observe that **B** does not reply **A**'s principal question with a satisfactory answer. Instead, he provides information which is relevant with respect to the question. Then **A** presses further by asking auxiliary questions and **B** answers them. It is **A** who concludes with the answer to the principal question: the answer is based on **B**'s consecutive answers.

Example 3. Now three parties, **A**, **B**, and **C**, are involved. The story goes as follows.

A: *Where did Andrew leave for: Paris, London, or Moscow?*
B: *Well, if these are the options, then he departed in the morning or in the evening. And if in the morning, he left for Paris or London; otherwise he left for Moscow.*
C: *Andrew takes his famous umbrella only when traveling to London.*
A: *When did Andrew depart: in the morning, or in the evening?*

C: *In the morning.*
A: *Did Andrew take his famous umbrella?*
B: *No, he didn't.*
A: *[So] Andrew left for Paris.*

Agents **B** and **C** do not violate the Maxim of Quantity, since none of them is able to provide a satisfactory answer to **A**'s principal question. Agent **B** supplies information that gives rise to **A**'s first auxiliary question, but the question is then answered by **C**. Similarly, **A**'s second auxiliary question arises from information initially provided by **C**, but is answered by **B**. Agent **A**, then, derives the answer to the principal question. The relevant items of information have been actively sought for by means of asking "good" auxiliary questions. Neither **B** nor **C** knew the answer. However, the answer constitutes an item of distributed knowledge of the group. It is **A** who elicits it — by means of asking auxiliary questions.

1.3 Alternative courses of events

Before we continue, let us observe that each of the above stories could have developed differently if different answers to the emerging questions had been received. The affirmative answer to the umbrella question would give "London" as the outcome. The answer "In the evening", in turn, would give "Moscow" and, what is more important, would cancel the umbrella question. In each case, however, an answer to the principal question will be found. Figure 1 displays possible courses of events.

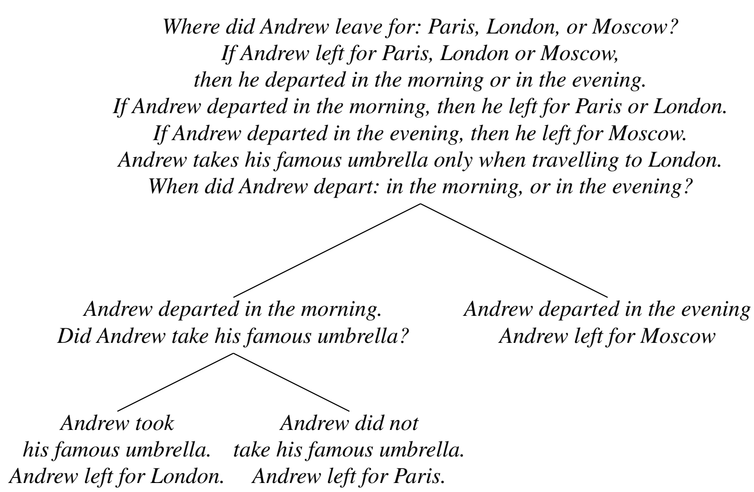

Fig. 1 *Possible courses of events*

2 Transitions from questions to questions: a semantic analysis

Transitions from questions to questions play an important role in any of the stories presented above. Are these transitions subjected to any logic? As we will see, the answer is “yes”. In order to show why, let us, first, analyse the relation between the questions:

(5) *Where did Andrew leave for: Paris, London or Moscow?*
(6) *When did Andrew depart: in the morning, or in the evening?*

in semantic terms.

Question (5) offers three “possibilities”: Paris, London, and Moscow. The use of “leaves for” suggests that these possibilities are mutually exclusive. An erotetic logician would say that question (5) has three *direct answers*[5], namely “Andrew left for Paris”, “Andrew left for London”, and “Andrew left for Moscow”; the short answers “Paris”, “London” and “Moscow” have, respectively, the same meanings (in the current context) as the direct answers. The disjunction of all the direct answers is not a logical truth: it can happen that none of them is true. Andrew might have left for Rome, or stayed at home, and so forth. In terms of erotetic logic: question (5) is *risky*, that is, need not be sound (by a sound question we mean a question which has at least one *true* direct answer). Similarly, question (6) is risky: the direct answers are “Andrew departed in the morning” and “Andrew departed in the evening”, and, again, it can happen that neither of them is true.

Now let us bring into the picture the relevant “premises”, i.e.:

(1) *If Andrew left for Paris, London or Moscow, then he departed in the morning or in the evening.*
(2) *If Andrew departed in the morning, then he left for Paris or London.*
(3) *If Andrew departed in the evening, then he left for Moscow.*
(7) *Andrew takes his famous umbrella only when travelling to London.*

(“only when” is construed here as a biconditional). For brevity, let us designate the set made up of all the above sentences by X^*. Again, the set X^* need not consist of truths. Even if it does, it is still possible that neither question (5) nor question (6) is sound. But suppose that X^* consists of truths *and*, moreover, that question (5) is sound. Now question (6) must be sound: given the assumptions, either it is the case that Andrew departed in the morning, or it is the case that he departed in the evening.[6] In other words, the phenomenon of transmission of soundness and truth into soundness shows up.

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[5] The logic of questions is also called *erotetic logic* (from Greek *erotema* that means “question”). Roughly, a *direct answer* is a possible just-sufficient answer, i.e. a possible answer which provides neither less nor more information than it is requested by the question.

[6] Clearly, it suffices to suppose that question (5) is sound and premise (1) is true. But a stronger assumption, according to which all the premises are true, does not make any harm. We aim at a semantic relation between a question, a set of declarative sentences/formulas, and a question.

Let us generalize. Suppose that Q_1 is a question that arises out of a question Q together with a set of declarative sentences/formulas X. The relevant phenomenon is described by the following statement:

(I) (TRANSMISSION OF SOUNDNESS/TRUTH INTO SOUNDNESS): *If Q is sound and X consists of truths, then Q_1 must be sound.*

Yet, this is not all. The question:

(6) *When did Andrew depart: in the morning, or in the evening?*

has two direct answers, namely:

(8) *Andrew departed in the morning.*
(9) *Andrew departed in the evening.*

Each of the answers is *cognitively useful*, on the basis of the (set of) premises, for finding an answer to question (5). Moreover, this holds due to some underlying semantic dependencies between the answers to question (6), the set X^*, and question (5). For suppose that answer (8) to question (6) is true and that X^* consists of truths. It follows that Andrew left for Paris or London. In other words, given the assumptions, a true direct answer to question (5) belongs to the following *proper subset* of the set of all the direct answers:

(10) $\{$*Andrew left for Paris, Andrew left for London*$\}$.

Now suppose that answer (9) to question (6) is true, and that all the elements of X^* are true. It follows that Andrew left for Moscow. In terms of sets: a true direct answer to question (5) belongs to the following proper subset of the set of all the direct answers:

(11) $\{$*Andrew left for Moscow*$\}$

which happens to be a unit set.

One can generalize this by:

(II) (OPEN-MINDED COGNITIVE USEFULNESS): *For each direct answer B to Q_1 there exists a non-empty proper subset Y of the set of direct answers to Q such that the following condition holds*:

(#) *if B is true and X consists of truths, then at least one direct answer (to Q) in Y must be true.*

So far we have analysed the semantic relation(s) between questions (5) and (6). But what about the questions:

(5) *Where did Andrew leave for: Paris, London or Moscow?*
(12) *Did Andrew take his famous umbrella?*

Recall that, in the above examples, question (12) occurred after receiving answer (8) to question (6). So the relevant set of "premises" is X^* enriched with sentence (8); let us designate this new set by X^{**}. Condition (I) is satisfied for trivial reasons. Condition (II) is fulfilled as well. For if the following is true:

(13) *Andrew took his famous umbrella.*

then, by (7) (and thus also by X^{**}), Andrew left for London. On the other hand, X^{**} yields:

(14) *If Andrew did not take his famous umbrella, then he left for Paris.*

which, together with the negative answer to question (12), i.e.:

(15) *Andrew did not take his famous umbrella.*

gives:

(16) *Andrew left for Paris.*

A remark is in order. Condition (II) is not satisfied by questions (5) and (12) with respect to the initial set of "premises" X^*. Answer (15) to question (12) only gives:

(17) *Andrew did not leave for London.*

The truth of all the sentences in X^* does not warrant, however, that the disjunction of all the direct answers to question (5) must be true, and thus, even if X^* consists of truths and (17) is true, it need not be the case that the following proper subset of the set of direct answers to question (5):

(18) {*Andrew left for Paris, Andrew left for Moscow*}

contains a true answer. This explains why it is wise to ask question (6) first: doing otherwise may produce a "dead end". We will come back to this issue later on. What is important for now is the following observation: consecutive questions are implied, in the sense of *Inferential Erotetic Logic*, by prior question(s) on the basis of the relevant items of information. This remark may sound mysterious. So let us turn to Inferential Erotetic Logic.

3 A short note on Inferential Erotetic Logic

By and large, Inferential Erotetic Logic (IEL for short) is a logic that analyses inferences in which questions perform the role of conclusions, and proposes criteria of validity for these inferences. IEL was developed in the 1990's as an alternative to the received view in the logic of questions, which situated the answerhood problem in the center of attention, and to the Interrogative Model of Inquiry, elaborated by Jaakko Hintikka.

In this Section we briefly present only these elements of IEL which are needed for our purposes. A more detailed presentation of IEL can be found in [34]; see also [32], [33].

IEL starts with a trivial observation that before a question is asked or posed, a questioner must arrive at it. In many cases arriving at questions resembles coming to conclusions: there are premises involved and some inferential thought processes take place. If we admit that a conclusion need not be "conclusive", we can say that sometimes questions play the role of conclusions. But questions can also perform the role of premises: it often happens that an agent arrives at a question when looking for an answer to another question. Thus the concept of an *erotetic inference* is introduced. As a first approximation an erotetic inference may be defined as a thought process in which one arrives at a question on the basis of some previously accepted declarative sentence or sentences and/or a previously posed question. There are erotetic inferences of (at least) two kinds: the key difference between them lies in the type of premises involved. In the case of *erotetic inferences of the first kind* the set of premises consists of declarative sentence(s) only, and an agent passes from it to a question. For example:

Andrew always comes in time, but now he is late.

What has happened to him?

The premises of an *erotetic inference of the second kind* consist of a question and possibly some declarative sentence(s); erotetic inferences in which no declarative premise occurs can be regarded as a special case of erotetic inferences of the second kind. The stories presented in Section 1 involved erotetic inferences of the second kind with non-empty sets of declarative premises. Here is an example of an appropriate erotetic inference which does not rely on any declarative premise:

Is Andrew silly and ugly?

Is Andrew ugly?

An inference, even erotetic, is always someone's inference. In its general setting, however, IEL abstracts from this: erotetic inferences are construed syntactically. Erotetic inferences of the first kind are viewed as ordered pairs $\langle X, Q \rangle$, where X is a finite and non-empty set of declarative sentences and Q is a question. Similarly, an erotetic inference of the second kind is identified with an ordered triple $\langle Q, X, Q_1 \rangle$, where Q, Q_1 are questions and X is a finite (possibly empty) set of declarative sentences. When formal languages enriched with questions are dealt with, X is a set of declarative well-formed formulas. Erotetic inferences construed syntactically are also called *erotetic arguments*.

IEL proposes some conditions of validity of erotetic inferences.

As long as we are concerned with inferences which have only declaratives as premises and conclusions, validity amounts to the transmission of truth: if the premises are all true, the conclusion must be true as well. However, it is doubtful whether it makes any sense to assign truth or falsity to questions and thus one cannot apply the above concept of validity to erotetic inferences. But in the case of questions the concept of soundness seems to play an equally important role as the concept of truth in the realm of declaratives. Recall that a question Q is *sound* if and only if at least one direct answer to Q is true, and unsound otherwise. This concept is extensively used in the analysis of validity proposed by IEL. Yet, some other concepts are needed as well.

There are erotetic inferences of (at least) two kinds, and the conditions of validity are distinct for each kind. In this paper we are interested only in erotetic inferences of the second kind. Let $\langle Q, X, Q_1 \rangle$ be such an inference. The message is: the relevant conditions of validity imposed by IEL are exactly the conditions (I) and (II) specified in Section 2. Let us recall them.

(I) (TRANSMISSION OF SOUNDNESS/TRUTH INTO SOUNDNESS): *If Q is sound and X consists of truths, then Q_1 must be sound.*

(II) (OPEN-MINDED COGNITIVE USEFULNESS): *For each direct answer B to Q_1 there exists a non-empty proper subset Y of the set of direct answers to Q such that the following condition holds*:

(#) *if B is true and X consists of truths, then at least one direct answer (to Q) in Y must be true.*

There is no space for a thorough discussion on these conditions, but it can be found elsewhere.[7] Let us only say the following. (I) is a natural generalization of the standard condition of validity. It is only a necessary condition of validity, however. If (I) had been sufficient, then, for instance, the following would have been valid inferences:

Is Andrew a logician?
Some philosophers are logicians, and some are not.

Is Andrew a philosopher?

Is Coco a human?
Humans are mammals.

Is Coco a mammal?

The problem here is that the questions which are conclusions have (direct) answers that are cognitively useless: these answers, if accepted, would not contribute to finding answers to initial questions.[8] On the other hand, an intuitive account of validity suggests that direct answers to the question which is the conclusion should be potentially useful, on the basis of the declarative premises, for finding an answer to the

[7] *Cf.* [32], Chapters 1 and 8; see also [33], [34].

[8] In the first case none of the answers is potentially useful. As for the second case, the negative answer is useful, whereas the affirmative answer is useless. Needless to say, in any of the above cases condition (I) is satisfied for a trivial reason, due to the structure of the "question-conclusion" only.

initial question. To secure this, IEL imposes (II) as the second necessary condition of validity. Let us stress that condition (II) is very demanding: it requires *each* direct answer to the question which is the conclusion to be (potentially) cognitively useful. One may argue that this is too much. However, as we will see, the universality of the claim of condition (II) makes the conceptual apparatus of IEL well suited for the analysis of the phenomena we are interested in here (and, needless to say, not only for this).

Conditions (I) and (II) are expressed somewhat loosely. Of course, IEL offers more than just formulating them. The semantic relation of *(erotetic) implication of a question by a question on the basis of a set of declarative formulas* is defined. The exact definition pertains to (a class of) formal languages enriched with questions and supplemented with an appropriate semantics. The details of the construction are presented in the Appendix. Let us stress, however, that erotetic implication is defined in such a way that when a question Q implies a question Q_1 on the basis of a set of declarative formulas X, the conditions (I) and (II) are satisfied. Then an erotetic inference, $\langle Q, X, Q_1 \rangle$, is said to be *valid* iff Q implies Q_1 on the basis of X; implies in the sense of IEL.

We will write **Im**(Q, X, Q_1) for "Q implies Q_1 on the basis of X".

IEL characterizes the properties of the relation **Im**. Again, there is no space for presenting them.[9] Let us only mention here, first, that **Im** is monotone with respect to sets of declaratives involved: if **Im**(Q, X, Q_1) and X is included in Y, then **Im**(Q, Y, Q_1). Second, **Im** is not "transitive" in the sense that if **Im**(Q, X, Q_1) and **Im**(Q_1, X, Q_2) hold, then **Im**(Q, X, Q_2) need not hold (although it holds in some cases). This is a consequence of the fact that **Im** has the property required by the condition (II). On the other hand, as we will see, this lack of "transitivity" makes chains of erotetic inferences non-trivial.

Im is defined in semantic terms. But a transition to the syntactic level is easy. IEL provides *question-implying rules*. These rules are grounded in (meta)theorems which say what questions are (erotetically) implied by what questions on the basis of what sets of declarative formulas.

Although the concept of erotetic implication serves as a tool for defining validity of the corresponding erotetic inferences, the area of applicability of the concept is wider. When **Im**(Q, X, Q_1) holds, then both transmission of soundness/truth into soundness takes place and the effect of open-minded cognitive usefulness shows up. These are, undoubtedly, desired properties in case Q_1 is an auxiliary question with regard to Q.[10] As we have seen in Section 2, the transitions from questions to questions that occur in the stories described in Section 1 display these properties; it is not difficult to show that the relevant items are linked by the relation **Im**. So the message is: there is more logic in the phenomena we are interested in here than one can expect at first sight. However, the logic involved is not specific to them, since erotetic inferences, including valid ones, occur in almost every process of inquiry.

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[9] See [31], [32], [33], [34].

[10] In the case of dialogues, as Ginzburg [8] observes, when query responses are erotetically implied, relevance (in a dialogue) is retained. Of course, relevance of query responses can be retained in other ways as well.

So in order to get a better account of the phenomena something more is needed. Our claim is: *erotetic search scenarios* may be of help.

4 E-scenarios

In order to show what erotetic search scenarios[11] (e-scenarios for short) are and how they can be used in our enterprise, let us tell, again, a simple story first.

Suppose that one is looking for the (right) answer to the question of the form: *Which one of the following: p, q, r, holds?* Suppose further that it is known that p holds if s holds, and that either q or r holds if $\neg s$ holds. In this situation one arrives at the question: *Does s hold?*

What can happen next? It depends on the epistemic situation. If the request for information will be satisfied by s, the answer p to the initial question is found. If, however, the request will be satisfied by $\neg s$, the initial question transforms into the question: *Which one of the following: q, r, holds?*

Now suppose that it is also known that q holds if, and only if u holds. In this case one arrives at the question: *Does u hold?* If this request for information will be satisfied by u, one gets the answer q to the initial question. If the outcome will be $\neg u$, one gets r, since if u does not hold, q does not hold either, and, as $q \vee r$ holds, r must hold.

In each case an answer to the initial question is found.

We have told the story in epistemic terms. Let us now look, however, at the underlying structure displayed in Figure 2. It is syntactic[12] and is of course completely *domain-unspecific*.

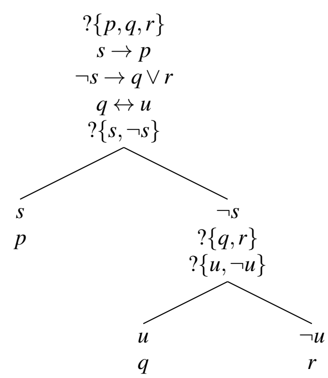

Fig. 2 *An example of an e-scenario*

[11] The concept of erotetic search scenario was introduced in [35]. See also [34].

[12] For simplicity, we operate on the propositional level. Letters p,q,r,t, ... are propositional variables. $?\{A_1,...,A_n\}$ is a question whose direct answers are exactly the explicitly listed formulas $A_1,...,A_n$.

The exact definition of e-scenarios can be found elsewhere.[13] Here we only highlight some of their basic properties.

An e-scenario is always *for* a given ("principal", "initial", "main") question and *relative to* a set of declarative sentences/formulas ("premises"). E-scenarios have a tree-like structure with a principal question as the root and possible (direct) answers to this question as leaves. Auxiliary questions enter e-scenarios on the condition of being erotetically implied (in the sense of IEL). Either an auxiliary question has another question as the immediate successor (*cf.* question $?\{q,r\}$ above) or an auxiliary question has all the direct answers to it as its immediate successors (*cf.* $?\{s,\neg s\}$ and $?\{u,\neg u\}$). In the latter case the immediate successors represent the possible ways in which the relevant request for information can be satisfied, and the structure of an e-scenario shows what further information requests (if any) are to be satisfied in order to arrive at an answer to the principal question. If an auxiliary question is a "branching point" of an e-scenario, it is a *query* of the e-scenario. However, an e-scenario can involve auxiliary questions which are not queries, but serve as ("erotetic") premises only. Finally, any declarative sentence/formula that occurs at a path of an e-scenario is either an initial premise, or a direct answer to a query, or a logical consequence of some initial premise(s) and/or answer(s) to queries that occur earlier at the path.

The e-scenarios approach transcends the common scheme of "production of a sequence of questions and affirmations." The fact that information requests can be satisfied in one way or another is taken seriously. An e-scenario shows what is desirable next in case the previous information request has been satisfied in such–and–such way, and does this with regard to any possible way of satisfying the request. In other words, (a diagram of) an e-scenario provides conditional instructions which tell what auxiliary questions should be asked and when they should be asked. Or, to put it differently, it shows "where to go" if such–and–such a direct answer to a query appears to be acceptable and does so with respect to any direct answer to each query.

Still, e-scenarios are abstract entities, defined accordingly in terms of IEL.

E-scenarios differ with respect to degree of complexity. Figures 3 and 4 present examples of relatively simple, yet quite useful e-scenarios.

Let us comment on Figure 3. Either of q and r constitutes a sufficient condition for p, and their disjunction constitutes the necessary condition for p. So it is rational to ask first if one of them holds. If the tested sufficient condition holds, there is no need for a further question, and the initial issue is solved affirmatively. If it does not hold, it is rational to ask whether the other holds. If it does, the initial issue is solved affirmatively. Otherwise the issue is, finally, solved negatively. Note that neither $?\{p,\neg p,q\}$ nor $?\{p,\neg p,r\}$ is a query. However, they are necessary in the IEL-grounded transitions which lead to queries.[14]

[13] See [35]. [34], [36]. In the Appendix we present an equivalent definition in terms of (labelled) trees.

[14] In IEL based on Classical Logic we do not have $\mathbf{Im}(?\ \{A, \neg A\}, B \to A, ?\ \{B, \neg B\})$. However, we have both $\mathbf{Im}(?\ \{A, \neg A\}, B \to A, ?\ \{A, \neg A, B\})$ and $\mathbf{Im}(?\ \{A, \neg A, B\}, ?\ \{B, \neg B\})$. So, although

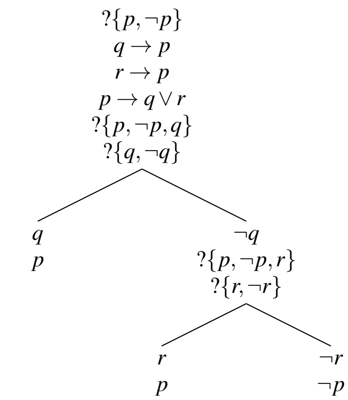

Fig. 3 *An example of an e-scenario*

As for Figure 4, this time both q and r are necessary conditions for p, and their conjunction constitutes a sufficient condition for p.[15]

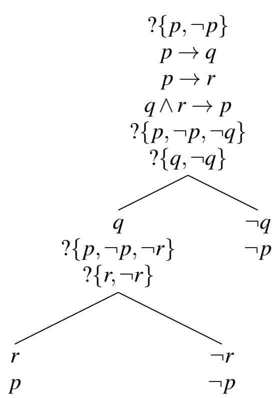

Fig. 4 *An example of an e-scenario*

There exist e-scenarios which do not involve any initial declarative premises (i.e. e-scenarios relative to the empty set). Figures 5 and 6 present simple examples of e-scenarios of this kind.[16]

For further examples of e-scenarios see e.g. [34], [35], [36].

Im is not "transitive", it is possible to reach $?\,\{B, \neg B\}$ from $?\,\{A, \neg A\}$ and $B \to A$, but *in two steps* (recall that **Im** is monotone with respect to sets of declaratives).

[15] Again, there are non-queries involved. As long as Classical Logic constitutes the background, we do not have **Im**($?\,\{A, \neg A\}, A \to B, ?\,\{B, \neg B\}$). But we do have **Im**($?\,\{A, \neg A\}, A \to B, ?\,\{A, \neg A, \neg B\}$) and **Im**($?\,\{A, \neg A, \neg B\}, ?\,\{B, \neg B\}$).

[16] $? \pm |p, q|$ abbreviates the *conjunctive question* $?\,\{p \wedge q, p \wedge \neg q, \neg p \wedge q, \neg p \wedge \neg q\}$.

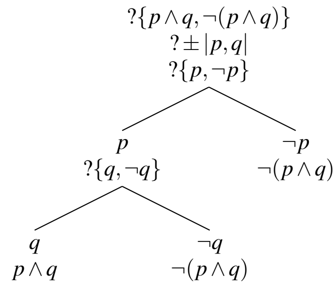

Fig. 5 *An example of an e-scenario*

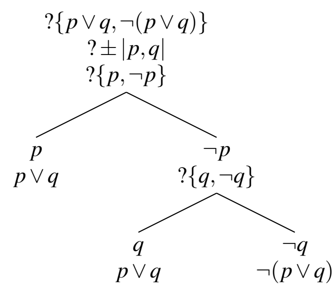

Fig. 6 *An example of an e-scenario*

There are e-scenarios of different kinds. But information-picking e-scenarios seem most useful in an analysis of answering by means of questions. In order to define them we have to introduce some technical concepts first.

Let Φ be an e-scenario for Q relative to X. For simplicity, let us construe Φ as a finite labelled tree (see the Appendix). The labels are either questions or declarative well-formed formulas (d-wffs for short). If γ is a node of Φ, we write ϕ_γ for the path of Φ whose last element/node is γ, and we use $\mathbf{dec}(\phi_\gamma)$ for the set of d-wffs which are labels of the nodes of ϕ_γ.[17] So when γ is a leaf, ϕ_γ is a branch (i.e. a maximal path from the root) and $\mathbf{dec}(\phi_\gamma)$ is the set of d-wffs that label the "declarative" nodes of the branch. By the definition of e-scenarios, the leaves of Φ are labelled by direct answers to Q. Let ℓ be the labelling function of Φ; $\ell(\gamma)$ is thus the expression (a d-wff or a question) that is the label of node γ.

By an *initial premise* of an e-scenario for Q relative to X we mean an element of X that labels a node of the e-scenario.

We say that a question Q is *informative relative to* a set of d-wffs Z iff no direct answer to Q is entailed by Z.

An e-scenario Φ for Q relative to X is *information-picking* iff:

(a) Q is informative relative to the set of initial premises of Φ, and

(b) if γ is a node of Φ such that $\ell(\gamma)$ is a query of Φ, then $\ell(\gamma)$ is informative

[17] It can happen that a given question labels more than one node of an e-scenario. However, $\mathbf{dec}(\phi_\gamma)$ is always unique, since γ refers to a node.

relative to $\mathbf{dec}(\phi_\gamma)$, and no immediate successor of γ is labelled by a direct answer to Q, moreover

(c) if γ is a leaf of Φ, then $\ell(\gamma)$ is entailed by $\mathbf{dec}(\phi_\gamma) \setminus \{\ell(\gamma)\}$.

Generally speaking, an information-picking e-scenario has the following features: (i) the principal question cannot be legitimately answered by deriving an answer to it from the relevant initial premises, (ii) all queries of the e-scenario are informative relative to the (sets of) d-wffs that "precede" them: each direct answer to each query brings in new information that is not provided by the (set of) d-wffs which "precede" the query at the relevant path of the e-scenario, (iii) no direct answer to a query is a direct answer to Q, and (iv) it shows that once all the queries that occur at a branch are truthfully answered in the way indicated by their possible (direct) answers occurring at the branch, and the initial premises are all true, the corresponding answer to the principal question (i.e. the direct answer that labels the leaf of the branch) is truthful and thus right.

The e-scenarios displayed in figures 2–6 are information-picking.

Finally, let us point at a certain feature of (all!) e-scenarios which is essential in view of possible applications. One can prove that e-scenarios have the *golden branch property* **GB**:

(GB) *If Φ is an e-scenario for Q relative to X, question Q is sound and the set X consists of truths, then there exists at least one branch of Φ such that each question which is (a label of) a node of the branch is sound, and each d-wff which is (a label of) a node of the branch is true.*

Needless to say, a golden branch "leads" to a true direct answer to the principal question.

5 E-scenarios and answering by means of questions

Let us come back to the examples presented in Section 1. The description of possible courses of events is shown in Figure 1 (see page 4).

Now consider the e-scenario displayed in Figure 7.

It is clearly visible that the e-scenario presented in Figure 7 is exemplified by the content of Figure 1.[18] Observe that the e-scenario is information-picking.

Let us consider Example 1 presented in Section 1. The key departure from the dyadic model was: an answerer, **B**, replies the questioner, **A**, with questions that are not clarification requests. How can this be explained?

One possible way of thinking is the following. **A**'s question is directed to **B** and hence becomes the principal question of **B**. Then **B** acts according to a *ramified plan*. The plan has the form of an e-scenario *for* the principal question *relative to* what **B**, at the moment, knows about the case. This is, pragmatically, a good plan. First, it is potentially executable due to the golden branch property of e-scenarios —

[18] For simplicity, we remain at the propositional level.

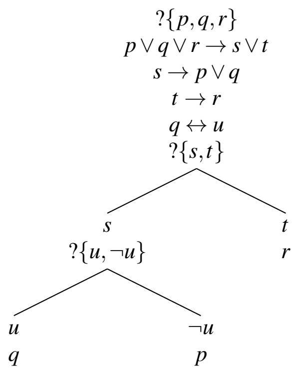

Fig. 7 *An e-scenario that corresponds to Figure 1*

of course assuming that the principal question is sound. Second, the plan copes with any of **A**'s reactions of the expected kind (by this we mean here providing a direct answer to a query). This effect is two-fold: the plan always shows what to do next regardless of which direct answer to a query would be provided by **A**, and the order in which possible queries occur warrants that no direct answer to any query would create a "dead end". Coming back to the example itself. **B** replies with "When did Andrew depart: in the morning, or in the evening?", because this is a query of his ramified plan based on the e-scenario, and replies with this question first because it is the first query of the e-scenario. Then **B** replies with the umbrella question because this is a query of the relevant e-scenario that should be asked if the previous query is answered with "In the morning", and the previous query has been answered this way.

Observe that once the queries are answered, **B** is able to reach his main objective, that is, to provide a satisfactory answer to **A**'s principal question.

Let us now turn to Example 2 of Section 1. It dealt with the phenomenon of question answering based on additional information actively sought for. This time the "interrogative" roles of **A**, the questioner, and **B**, the answerer, were standard and stable. Yet, **B**'s first answer had not been a satisfactory one, and **A** pressed further by asking consecutive auxiliary questions. Intuitively, each of the auxiliary questions seems "good" with respect to what has happened before. Moreover, the answers received, jointly, yield a satisfactory answer to the initial question. It is **A** who assembles them and finally arrives at the answer. How can all this be accounted for?

As before, one of the possible ways of thinking is the following. After receiving an unsatisfactory answer to her principal question, **A** acts according to a ramified plan. This plan, again, is based on an e-scenario for the principal question, but this time the e-scenario is relative to the item(s) of information received in reply to the question (and, possibly, **A**'s knowledge relevant to the case). The plan has all the advantages specified above. By executing it accordingly, **A** seeks for additional information which, if received, enables her to find, at the end, a satisfactory answer to her principal question. The answer is satisfactory because it displays two desired features. First, it is a direct answer, that is, as Belnap puts it, an answer which is "directly and precisely responsive to the question, giving neither more nor less information than what is called for."[19] Second, the answer is true assuming that the consecutive answers provided by **B** are true.

Now let us consider Example 3. It differs from Example 2 in that it illustrates how a satisfactory answer can be elicited from pieces of knowledge which are scattered over a group (from distributed knowledge of a group). A possible model is this. The questioner, **A**, acts according to a ramified plan based on replies received first. Again, the plan has the form of an e-scenario for the principal question, relative to the replies received first and, possibly, items of **A**'s knowledge (relevant to the case). The details are analogous as above.

So far so good. But three problems arise: (1) where do e-scenarios come from? (2) are the explanations relying on ramified plans (based, in turn, on e-scenarios) empirically adequate?, and (3) do they provide a complete account of the phenomenon of answering by means of questions? The last question is the easiest one, and the answer is obviously "No". As for the first question, the simplest answer is: "E-scenarios just exist, as other logical objects do". If one is not pleased with this Platonic answer, a cautious yet true answer is: IEL enables to construct them. Concerning the problem of empirical adequacy, it can be resolved only by empirical means. My guess is that the explanations are sometimes empirically adequate. But even if this is not right, the aspects of question answering analysed in this paper are real and one may be interested in designing AI agents — or "communities" of them — which act as the models sketched above show, especially when faced with a problem solving task.

6 Final remarks

The concept of e-scenario was initially introduced in order to model some aspects of effective problem solving. One of the crucial principles which govern effective problem solving is the following:[20]

(DP) (DECOMPOSITION PRINCIPLE): *Decompose a principal problem (PP) into simpler sub-problems (SPs) in such a way that solutions to SPs can be assembled into an overall solution to PP.*

This principle, viewed from the standpoint of the logic of questions, reduces to:

(EDP) (EROTETIC DECOMPOSITION PRINCIPLE): *Transform a principal question (PQ) into auxiliary questions (AQs) in such a way that: (a) consecutive AQs are dependent upon previous questions and, possibly, answers to previous AQs, and (b) once AQs are resolved, PQ is resolved as well.*

[19] [5], p. 124. For direct answers in Belnap's sense see [6].

[20] I owe this formulation of DP to Mariusz Urbański.

Clearly, e-scenarios enable precisely this. An e-scenario determines a ramified search plan which has all the nice properties we have pointed out above. The more e-scenarios are at hand, the more efficacious an agent who solves problems can be.[21]

As for problem-solving, e-scenarios have been used in computational settings as well (cf. e. g. [7], [19]). The concept of e-scenario, however, was also applied in some areas outside problem solving proper: in proof theory (cf. e.g. [27]), in co-operative answering (cf. [18]), and in the modelling of interrogator's hidden agenda (cf. [28], [20]). As we have seen in this paper, the area of applicability of the concept is even wider.

It is an open question still whether, and if yes, how, the e-scenario approach can be combined with the "issue management" logic of van Benthem and Minică (cf. [29], [30]). A similar question pertains to the multi-agent propositional epistemic logic with questions introduced by Peliš and Majer (cf. [23]), and substantially developed in [22].[22] Recall that Example 3 and its analysis deal with the process of answer mining among agents (but directed by a "main" agent). Moreover, a branch of an information-picking e-scenario can be viewed as showing after what sequence of truthful public announcements a direct answer to a principal question becomes a piece of common knowledge.

⋆ ⋆ ⋆

Formal modelling of problem-solving processes has been one of the subjects of interest of Diderik Batens.[23] This turned his attention to the logic of questions. We have never fully agreed as to what the final solutions should be. Nevertheless, Diderik's criticism and his remarks were always inspiring to me. I dare to dedicate this paper to him. Needless to say, if you blame Diderik for the weak points of this paper in particular, and of IEL in general, you are absolutely wrong. Moreover, there is no adaptive logic that justifies the withdrawal of this conclusion.

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[21] It may be of interest that there also exists a second IEL-based approach to problem solving. This time the underlying idea is: transform a question into consecutive questions until a question which can be answered in only one rational way is arrived at. This is modelled by means of the so-called *erotetic calculi*. Rules of these calculi operate on questions only; a rule transforms a question into a further question. A *Socratic transformation* is a sequence of questions, starting with a question about entailment/derivability/theoremhood. This question is then transformed, step by step, into consecutive questions according to the rules of a calculus. Answers play no role in the process. There are successful and unsuccessful transformations; a successful transformation ends with a question of a required final form (the details depend on the logic under consideration). A successful transformation is a *Socratic proof*. The rules are designed in such a way that once a successful transformation is accomplished, the initial issue is affirmatively resolved and there is no need for performing any further deductive moves. Moreover, each step in a Socratic transformation is an IEL-valid inference from a question to a question. So far erotetic calculi have been developed for Classical Logic (see [37] and [38]), some paraconsistent propositional logics (see [39]), and normal modal propositional logics ([14], [15], [16], [17]). An approach to Intuitionistic Propositional Logic based on a similar idea can be found in [26].

[22] Cf. also [24].

[23] See e.g. [1], [2], [3], [4].

Added in 2013. This paper was written in 2011. The reader can find more information about IEL and e-scenarios in: Andrzej Wiśniewski, *Questions, Inferences, and Scenarios*, College Publications, London 2013.

APPENDIX

1. Erotetic implication.

Let L be an arbitrary but fixed formal language such that the following conditions are satisfied:

(a) the set $\mathbf{D}_L$ of *declarative well-formed formulas* (d-wffs) of L is defined;

(b) the set Ψ_L of *questions* of L is defined, where $\mathbf{D}_L \cap \Psi_L = \emptyset$;

(c) if Q is a question of L, then there exists an at least two-element set $\mathbf{d}Q \subseteq \mathbf{D}_L$ of *direct answers* to Q;

(d) (the declarative part of) L is supplemented with a semantics rich enough to define the concept of *truth* for d-wffs, and the class of *admissible partitions*.

A *partition* of $\mathbf{D}_L$ is an ordered pair $\mathrm{P} = \langle \mathbf{T}_\mathrm{P}, \mathbf{U}_\mathrm{P} \rangle$, where $\mathbf{T}_\mathrm{P} \cap \mathbf{U}_\mathrm{P} = \emptyset$, and $\mathbf{T}_\mathrm{P} \cup \mathbf{U}_\mathrm{P} = \mathbf{D}_L$. Intuitively, $\mathbf{T}_P$ consists of all the d-wffs which are true in P, and $\mathbf{U}_\mathrm{P}$ is made up of all the d-wffs which are untrue in P. For brevity, we will be speaking about truths and untruths of a partition.

By a partition of L we simply mean a partition of $\mathbf{D}_L$.

Note that we have used the term "partition" as pertaining to the set of d-wffs only. What is "partitioned" is neither the "logical space" nor the set of questions. Recall that $\mathbf{D}_L \cap \Psi_L = \emptyset$. Thus when we have a partition $\langle \mathbf{T}_\mathrm{P}, \mathbf{U}_\mathrm{P} \rangle$ of L and a question of L, the question is neither in $\mathbf{T}_\mathrm{P}$ nor in $\mathbf{U}_\mathrm{P}$.

A question Q is *sound* in a partition $\langle \mathbf{T}_\mathrm{P}, \mathbf{U}_\mathrm{P} \rangle$ iff $\mathbf{d}Q \cap \mathbf{T}_\mathrm{P} \neq \emptyset$.

The concept of partition is very wide and admits partitions which are rather odd from the intuitive point of view. For example, there are partitions in which $\mathbf{T}_\mathrm{P}$ is a singleton set, or in which $\mathbf{U}_\mathrm{P}$ is the empty set. In order to avoid oddity on the one hand, and to reflect some basic semantic facts about the language just considered on the other, we should distinguish a class of *admissible partitions*, being a non-empty subclass of the class of all partitions of the language.

Admissible partitions are defined either directly or indirectly. In the former case one imposes some explicit conditions on the class of all partitions. In the latter case one uses a previously given semantics of d-wffs. For example, when $\mathbf{D}_L$ is the set of well-formed formulas of Classical Propositional Calculus (CPC), a partition $\langle \mathbf{T}_\mathrm{P}, \mathbf{U}_\mathrm{P} \rangle$ is called admissible iff for some CPC-valuation v, $\mathbf{T}_\mathrm{P} = \{A \in \mathbf{D}_L : v(A) = \mathbf{1}\}$, and $\mathbf{U}_\mathrm{P} = \{A \in \mathbf{D}_L : v(A) = \mathbf{0}\}$.

In what follows it is assumed that we are dealing with expressions of L and admissible partitions of L. For brevity, the specifications "in L" and "of L" are omitted.

Let X stand for a set of d-wffs and let A be a d-wff. *Entailment*, symbolized by $\models$, is defined by:

Definition 1. $X \models A$ iff there is no admissible partition $\langle \mathbf{T}_\mathrm{P}, \mathbf{U}_\mathrm{P} \rangle$ such that $X \subseteq \mathbf{T}_\mathrm{P}$ and $A \in \mathbf{U}_\mathrm{P}$.

We also need *multiple-conclusion entailment* (mc-entailment for short).[24] This is a relation between sets of d-wffs. Mc-entailment, $||\!\!=$, is defined as follows:

Definition 2. $X \,||\!\!= Y$ iff there is no admissible partition $\langle \mathbf{T}_\mathrm{P}, \mathbf{U}_\mathrm{P} \rangle$ such that $X \subseteq \mathbf{T}_\mathrm{P}$ and $Y \subseteq \mathbf{U}_\mathrm{P}$.

Thus X mc-entails Y if there is no admissible partition in which X consists of truths and Y consists of untruths. In other words, mc-entailment between X and Y holds just in case the truth of all the d-wffs in X warrants the presence of some truth(s) among the elements of Y: whenever all the d-wffs in X are true in an admissible partition P, then at least one d-wff in Y is true in the partition P.

Erotetic implication is defined by:

Definition 3. A question Q implies a question Q_1 on the basis of a set of d-wffs X (in symbols: $\mathbf{Im}(Q, X, Q_1)$) iff

1. for each $A \in \mathbf{d}Q : X \cup \{A\} \,||\!\!= \mathbf{d}Q_1$, and
2. for each $B \in \mathbf{d}Q_1$ there exists a non-empty proper subset Y of $\mathbf{d}Q$ such that $X \cup \{B\} \,||\!\!= Y$.

2. E-scenarios as labelled trees.

E-scenarios have been defined in [35] (*cf.* also [34], [36]) as families of interconnected sequences of questions and d-wffs, the so-called *erotetic derivations*. In this paper, however, we give an equivalent definition in terms of trees. E-scenarios will be defined here as *labelled trees*, where the labels are d-wffs and questions.

Definition 4. A finite labelled tree Φ is an erotetic search scenario for a question Q relative to a set of d-wffs X iff

1. the nodes of Φ are labelled by questions and d-wffs; they are called e-nodes and d-nodes, respectively;
2. Q labels the root of Φ;
3. each leaf of Φ is labelled by a direct answer to Q;
4. $\mathbf{d}Q \cap X = \emptyset$;
5. for each d-node γ_d of Φ: if A is the label of γ_d, then
   - $A \in X$, or
   - $A \in \mathbf{d}Q^*$, where $Q^* \neq Q$ and Q^* labels the immediate predecessor of Φ, or
   - $\{B_1, ..., B_n\} \models A$, where B_i $(1 \leq i \leq n)$ labels a d-node of Φ that precedes the d-node γ_d in Φ;
6. each d-node of Φ has at most one immediate successor;

[24] For this concept see Shoesmith and Smiley [25].

7. there exists at least one e-node of Φ which is different from the root;
8. for each e-node γ_e of Φ different from the root: if Q^* is the label of γ_e, then $\mathbf{d}Q^* \neq \mathbf{d}Q$ and
   - $\mathbf{Im}(Q^{**}, Q^*)$ or $\mathbf{Im}(Q^{**}, \{B_1, ..., B_n\}, Q^*)$, where Q^{**} labels an e-node of Φ that precedes γ_e in Φ and B_i $(1 \leq i \leq n)$ labels a d-node of Φ that precedes γ_e in Φ, and
   - an immediate successor of γ_e is either an e-node or is a d-node labelled by a direct answer to the question that labels γ_e, moreover
     – if an immediate successor of γ_e is an e-node, it is the only immediate successor of γ_e,
     – if an immediate successor of γ_e is not an e-node, then for each direct answer to the question that labels γ_e there exists exactly one immediate successor of γ_e labelled by the answer.

A *query* of an e-scenario Φ can be defined as a question that labels an e-node of Φ which is different from the root and whose immediate successor is not an e-node. Paths of e-scenarios are construed in the standard manner; a branch is a maximal path which originates from the root. By d-wffs *of* a branch we mean the d-wffs which are labels of d-nodes of the branch, and similarly for questions.

The following holds:

(**Golden Path Theorem**) *Let Φ be an e-scenario for Q relative to X. Let* $\mathrm{P} = \langle \mathbf{T}_{\mathrm{P}}, \mathbf{U}_{\mathrm{P}} \rangle$ *be an admissible partition such that $X \subseteq \mathbf{T}_{\mathrm{P}}$ and Q is sound in* P. *Then the e-scenario Φ has at least one branch ϕ such that*:

- *each d-wff of ϕ is in* $\mathbf{T}_{\mathrm{P}}$, *and*
- *each question of ϕ is sound in* P, *and*
- *the leaf of ϕ is (labelled by) a direct answer to Q which is in* $\mathbf{T}_{\mathrm{P}}$.

The core of the proof lies in the following observations. Erotetic implication preserves soundness given that the relevant declarative premises are true. Needless to say, entailment preserves truth. On the other hand, by the clause (8) of Definition 4, a query has all the direct answers "as" immediate successors, and thus also the true answer(s).

Although the theorem speaks about a ("golden") branch, it is called a Golden Path Theorem because in the original setting (see [35]) e-scenarios are not defined as trees and what is called a path of an e-scenario in the "old" setting corresponds to a branch of an e-scenario in the current setting.

References

1. D. Batens. A formal approach to problem solving. In C. Delrieux and J. Legris, editors, *Computer Modeling of Scientific Reasoning*, pages 15–26. Universidad Nacional Del Sur, EDIUNS, Bahia Blanca, Argentina, 2003.
2. D. Batens. A diagrammatic proof search procedure as part of a formal approach to problem solving. In L. Magnani, editor, *Model Based Reasoning in Science and Engineering. Cognitive Science, Epistemology, Logic*, pages 265–284. King's College Publications, London, 2006.
3. D. Batens. Content guidance in formal problem solving processes. In O. Pombo and A. Gerner, editors, *Abduction and the Process of Scientific Discovery*, pages 121–156. Centro de Filosofia das Ciencias da U. de Lisboa, Lisbon, 2007.
4. D. Batens. Adaptive logics as a necessary tool for relative rationality. Including a section on logical pluralism. http://logica.ugent.be/centrum/writings/pubs.php (downloaded March 6, 2011), 2011.
5. N. D. Belnap. Åqvist's corrections-accumulating question sequences. In J. Davis, P. Hockney, and W. Wilson, editors, *Philosophical Logic*, pages 122–134. Reidel, Dordrecht, 1969.
6. N. D. Belnap and Th. P. Steel. *The Logic of Questions and Answers*. Yale University Press, New Haven, 1976.
7. A. Bolotov, P. Łupkowski, and M. Urbański. Search and check: Problem solving by problem reduction. In A. Cader and et. al, editors, *Artificial Intelligence and Soft Computing*, pages 505–510. Academic Publishing House EXIT, Warszawa, 2006.
8. J. Ginzburg. Relevance for dialogue. In P. Łupkowski and M. Purver, editors, *Aspects of Semantics and Pragmatics of Dialogue. SemDial 2010, 14th Workshop on the Semantics and Pragmatics of Dialogue*, pages 121–129, Poznań, 2010. Polish Society for Cognitive Science.
9. J. Ginzburg. Questions: logic and interactions. In J. van Benthem and A. ter Meulen, editors, *Handbook of Logic and Language. Second Edition*, pages 1133–1146. Elsevier, Amsterdam/ Boston/ Heidelberg, 2011.
10. H. P. Grice. Logic and conversation. In D. Davidson and G. Harman, editors, *The Logic of Grammar*, pages 64–75. Dickenson, Encino, CA, 1995.
11. J. Groenendijk and M. Stokhof. Questions. In J. van Benthem and A. ter Meulen, editors, *Handbook of Logic and Language. Second Edition*, pages 1059–1132. Elsevier, Amsterdam/Boston/Heidelberg, 2011.
12. D. Harrah. The logic of questions. In D. Gabbay and F. Guenthner, editors, *Handbook of Philosophical Logic, Second Edition*, volume 8, pages 1–60. Kluwer, Dordrecht/Boston/London, 2002.
13. J. Hintikka. *Inquiry as Inquiry: A Logic of Scientific Discovery*. Kluwer, Dordrecht/ Boston/ London, 1999.
14. D. Leszczyńska. Socratic proofs for some normal modal propositional logics. *Logique et Analyse*, 185–188:259–285, 2004.
15. D. Leszczyńska. *The Method of Socratic Proofs for Normal Modal Propositional Logics*. Wydawnictwo Naukowe UAM, Poznań, 2007.
16. D. Leszczyńska-Jasion. The method of socratic proofs for modal propositional logics: K5, S4.2, S4.3, S4M, S4F, S4R and G. *Studia Logica*, 89:371–405, 2008.
17. D. Leszczyńska-Jasion. A loop-free decision procedure for modal propositional logics K4, S4 and S5. *Journal of Philosophical Logic*, 38:151–177, 2009.
18. P. Łupkowski. Cooperative answering and inferential erotetic logic. In P. Łupkowski and M. Purver, editors, *Aspects of Semantics and Pragmatics of Dialogue. SemDial 2010, 14th Workshop on the Semantics and Pragmatics of Dialogue*, pages 75–82, Poznań, 2010. Polish Society for Cognitive Science.
19. P. Łupkowski. Erotetic search scenarios and problem decomposition. In D. Rutkowska, J. Kacprzyk, and A. Cader, editors, *Some New Ideas and Research Results in Computer Science*, pages 202–214. Academic Publishing House EXIT, Warszawa, 2010.
20. P. Łupkowski. A formal approach to exploring the interrogator's perspective in the Turing Test. *Logic and Logical Philosophy*, 20:139–158, 2011.

21. P. Łupkowski and J. Ginzburg. A corpus-based taxonomy of question responses. In *Proceedings of the 10th International Conference on Computational Semantics (IWCS 2013) – Short Papers*, pages 354–361, Potsdam, Germany, 2013. Association for Computational Linguistics.
22. M. Peliš. *Logic of Questions*. PhD thesis, Charles University in Prague, Faculty of Arts, Department of Logic, 2011.
23. M. Peliš and O. Majer. Logic of questions from the viewpoint of dynamic epistemic logic. In M. Peliš, editor, *The Logica Yearbook 2009*, pages 157–172. College Publications, London, 2010.
24. M. Peliš and O. Majer. Logic of questions and public announcements. In N. Bezhanishvili, S. Löbner, K. Schwabe, and L. Spada, editors, *Logic, Language, and Computation 8th International Tbilisi Symposium on Logic, Language, and Computation*, volume 6618 of *Lecture Notes in Computer Science*, pages 145–157, Berlin/ Heidelberg, 2011. Springer.
25. D. J. Shoesmith and T. J. Smiley. *Multiple-conclusion Logic*. Cambridge University Press, Cambridge, 1978.
26. T. Skura. Intuitionistic socratic procedures. *Journal of Applied Non-Classical Logics*, 15:453–464, 2005.
27. M. Urbański. Synthetic tableaux and erotetic search scenarios: Extension and extraction. *Logique et Analyse*, 173–175:389–427, 2001.
28. M. Urbański and P. Łupkowski. Erotetic search scenarios: Revealing interrogator's hidden agenda. In P. Łupkowski and M. Purver, editors, *Aspects of Semantics and Pragmatics of Dialogue. SemDial 2010, 14th Workshop on the Semantics and Pragmatics of Dialogue*, pages 67–74, Poznań, 2010. Polish Society for Cognitive Science.
29. J. van Benthem and Ş. Minică. Toward a dynamic logic of questions. In X. He, J. Horty, and E. Pacuit, editors, *Proceedings of Second International Workshop on Logic, Rationality and Interaction, LORI II, Chongging, China*, volume 5834 of *Lecture Notes in Computer Science*, pages 27–41. Springer, 2009.
30. J. van Benthem and Ş. Minică. Toward a dynamic logic of questions. *Journal of Philosophical Logic*, 41:633–669, 2012.
31. A. Wiśniewski. Erotetic implications. *Journal of Philosophical Logic*, 23:174–195, 1994.
32. A. Wiśniewski. *The Posing of Questions: Logical Foundations of Erotetic Inferences*. Kluwer, Dordrecht/Boston/London, 1995.
33. A. Wiśniewski. The logic of questions as a theory of erotetic arguments. *Synthese*, 109:1–25, 1996.
34. A. Wiśniewski. Questions and inferences. *Logique et Analyse*, 173–175:5–43, 2001.
35. A. Wiśniewski. Erotetic search scenarios. *Synthese*, 134:389–427, 2003.
36. A. Wiśniewski. Erotetic search scenarios, problem-solving, and deduction. *Logique et Analyse*, 185–188:139–166, 2004.
37. A. Wiśniewski. Socratic proofs. *Journal of Philosophical Logic*, 33:299–326, 2004.
38. A. Wiśniewski and V. Shangin. Socratic proofs for quantifiers. *Journal of Philosophical Logic*, 35:147–178, 2006.
39. A. Wiśniewski, G. Vanackere, and D. Leszczyńska. Socratic proofs and paraconsistency: A case study. *Studia Logica*, 80:431–466, 2005.