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GUIDELINES FOR LOGIC EDUCATION

THE ASL COMMITEE ON LOGIC AND EDUCATION

Introduction. Yesterday's education does not meet the needs of tomorrow's world. In particular, the increasingly technical demands placed on people by the information revolution makes it all the more important that people understand basic logical principles of reasoning.

The Association for Symbolic Logic (ASL) is a worldwide organization that has been devoted to the study of logic since 1936. After careful study, the ASL has adopted the following guidelines and recommendations for logic instruction, with the aim to insure that all—scientists, humanists, the general population and professional logicians—can acquire from logic the tools they need.

This document draws out in broad strokes the material in the field of logic that should be incorporated into the educational system at various levels–for young children, adolescents, and college students. It does not go into the question of what should be available at the graduate level of various disciplines; that issue is too special to the traditions of particular institutions and research interest of their respective faculty members.

Primary and secondary education. Everyone needs to be able to tell, at some intuitive level, the difference between a valid argument and an invalid one. One needs to be able to give simple valid arguments, and to spot logical fallacies in others. Just how much one needs to know depends, of course, on

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As a result of continuing informal discussions, the *Association for Symbolic Logic* established an *ad hoc* Committee on Logic and Education in 1991, charged with drafting a set of specific recommendations on logic education. The committee circulated a draft proposal in 1992 and a final set of recommendations in 1993. These recommendations were discussed at a special meeting of members at the 1993 ASL Annual Meeting. They were adopted by the Council, along with the mandate that the recommendations be widely distributed in an attempt to have a positive impact on logic education throughout the world.

The members of the Committee on Logic and Education who prepared this document were Jon Barwise, Chair, James Baumgartner, Martin Davis, Claudia Henrion, David Marker, Wilfried Sieg, Albert Visser, and Peter Woodruff.

Comments and questions about this report may be addressed to the Association for Symbolic Logic, Department of Mathematics, University of Illinois, 1409 West Green St. Urbana, IL 61801, email: `asl@symcom.math.uiuc.edu`.

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many factors. A mathematician, for example, presumably needs these skills honed to a finer edge than someone in a manual vocation.

Recommendation: *Promote and facilitate logical (i.e., analytical) reasoning at an early age.*

The notion of a correct proof and the method of debunking fallacious proofs by means of counterexamples should be introduced as early as possible. It is not necessary, or even advisable, to introduce specific courses in logic. Rather, the recognition of valid and invalid arguments should be an integral part of education in the sciences (mathematical, physical, biological, and social), and the humanities quite generally. After all, part of what it means to be literate involves the ability to distinguish valid reasoning from invalid reasoning.

Strategy: Ages 5–9: Integrate logical matters on "good" and "bad" arguments into other material in a completely informal way with effective, "inquisitive" teaching techniques.

Strategy: Ages 10–13: Emphasize heuristic strategies for problem solving in the spirit of Polya's *How to Solve It*. Take the first steps towards recognizing the form of statements, formulating corresponding rules, and using interpretations. Give some word problems that have a distinctively logical component to their solution.

Strategy: Ages 14–17: Teach the explicit use of logical notions and techniques to give proofs, counterexamples, etc. Mathematics courses are a natural place for the inclusion of such material.

Beginning post-secondary education. Recommendation: *All post-secondary institutions should offer at least one introductory course which teaches the basic notions of logic. All students should be encouraged to take such a course. These courses should include the following:*

- *The informal notion of "logically correct argument".*
- *Informal strategies for producing logically correct arguments and counterexamples to fallacious arguments.*
- *The propositional calculus as an example of a formal language, formal proofs, and the formalization of natural language arguments.*
- *A discussion of the relationship of proof, truth, and counterexamples, including a discussion of the Soundness Theorem.*
- *The predicate calculus extension of propositional logic.*
- *At least an informal discussion of the Completeness Theorem, if time permits.*

Comments: Courses satisfying the above criteria are successfully taught in several kinds of settings, by different kinds of faculty, and addressed to the needs of different kinds of students. Philosophy departments often present this sort of course for a general audience. Mathematics and computer science departments often present a more technical version.

Here are some tips to help make these courses successful.

(1) Most important, make sure the instructor is interested in and well grounded in logic.
(2) Spend some time on amusing logic problems and puzzles of the sort Raymond Smullyan has made famous. Consider discussing some topics from this history of logic.
(3) Spend some time on real-life examples of sound and unsound reasoning. (In the U.S. at least, this could include the kind of logic problems commonly found on GRE and LSAT exams.)
(4) If formal rules are taught, present them as a mathematical model of informal reasoning methods.
(5) Treat some applications that have been made of ideas in logic, say in computer science, in detail.
(6) Consider using some of the available courseware in logic. Logic provides just the sort of material for which computer aided instruction can be used to good effect. And there are several good programs for teaching logic available.

Advanced post-secondary education. Like other areas of intellectual inquiry, logic now has certain "core" material, material which everyone who claims any proficiency in the subject simply must know, as well as a great deal of additional material. This "core" should form the basis of a logic course available at all institutions that go beyond the first two years of post-secondary education.

Recommendation: *Institutions of higher learning should, in addition, offer a course or (sequence of courses) which cover the following logic-related topics.*

- *Elementary facts about sets (up through basic facts about binary relations, the diagonal method, the proof that uncountable sets exist, and the basic properties of countable sets).*
- *Basic facts about inductive definitions and proofs by induction, of the kind that permeate logic.*
- *Propositional and Predicate Calculus (The formalization of informal argument, the axiomatic method in mathematics and science).*
- *Semantics (truth and validity, definability, the Soundness Theorem, the notion of consistency, the Gödel Completeness Theorem).*
- *An introduction to model theory (at least the Compactness Theorem for countable languages with an application or two).*
- *The Gödel Incompleteness Theorems, their philosophical and foundational consequences.*

The course's format, the instructor's field, and the interests of the students and instructor will all influence the tone, the presentation, the emphasis, and the choice of additional topics. The basic concerns and results of logic listed here, however, are relevant and applicable to many areas of science and scholarship, and should be considered within the core of logic.

Whether this core material should be covered in one course or a sequence of two or more courses would depend on many parameters: the backgrounds and abilities of students, the length of the course, and the depth one wanted to go into the various topics, for example. These are matters which will have to be settled at the local level.

Beyond this core material, there is additional material which should be made available to all students.

Recommendation: *Institutions of higher learning should also offer courses which include the following material within their scope.*

- *An introduction to proof theory (Natural Deduction, the Gentzen Hauptsatz, Herbrand's Theorem, for example).*
- *Some additional model theory (e.g., the Löwenheim-Skolem theorems for countable languages, the decidability of the theory of dense linear orderings, the non-expressibility of various mathematical notions in first-order logic, non-standard models of arithmetic).*
- *Some additional set theory (some cardinal and ordinal arithmetic, a discussion of the axiom of choice).*
- *An introduction to computability theory (some machine model of effective computability, Church's Thesis; absolutely unsolvable problems; the undecidability of validity).*
- *An introduction to other kinds of logic. Just which would depend on the interests of the faculty in question. Some examples include intuitionistic logic, higher-order logic, modal logic, temporal logic, infinitary logic, and substructural logics.*
- *An introduction to uses of logic in computer science (e.g., unification and the resolution method and their connections to* PROLOG*, and the* λ*-calculus and its connections to* LISP *in particular and computation in general).*

Unlike the previous recommendation, the order in this list carries no significance. Nor does this recommendation suggest that all these topics would fit in the courses recommended earlier or any other single course, or that new logic courses should be established to cover them. There are many ways these topics could be covered in a combination of courses in various departments. Still, any student who is preparing for further study or work in mathematics, computer science, philosophy, cognitive science, or linguistics should be exposed to most of them.