Developing Foundations for Knowledge Management Systems

Dorit Nevo, Yair Wand (supervisor)
University of British Columbia
Vancouver, Canada
dorit.nevo@commerce.ubc.ca

Abstract

Knowledge Management (KM) is an important issue in organizations. However there are several barriers to successful KM. In particular, knowledge hoarding, difficulties in identifying organizational knowledge, not understanding KM requirements, and technical difficulties of knowledge representation. In this work we focus on a connection between the managerial and technical aspects of knowledge management. We study the nature of organizational knowledge in order to derive knowledge management requirements to support the design of computerized Knowledge Management Systems.
The work consists of three parts: 1) Defining organizational knowledge that needs to be managed. 2) Using the definition of organizational knowledge and its attributes to identify knowledge management requirements. This involves identifying the various facets of knowledge as well as the perceived meta-knowledge requirements of users. 3) Deriving guidelines for the efficient design of knowledge management systems.

1. Introduction

In recent years, practitioners as well as researchers have come to recognize the importance of organizational knowledge as an asset (Davenport and Prusak (2000), Drucker (1998), Sveiby (1997), Alavi (2000)). Knowledge that resides in the organization represents experiences, education and other valuable lessons to the management and operation of the organization. Such knowledge is crucial to success in an environment of increased competition and globalization (Alavi, 2000)[1].

To enhance organizations' abilities to handle knowledge, various approaches for *Knowledge Management* (KM) have evolved. Some of these are managerial in nature while others are more technology focused and are termed "Knowledge Management Systems" (KMS). Regardless of the KM practices or technologies used, the aim of KM is the same:

> "Knowledge management involves efficiently connecting those who know with those who need to know, and converting personal knowledge into organizational knowledge" (the Yankee group, cited in Cairncross, 2000)

Although the importance of KM has been identified, some major barriers exist. Cultural barriers include the lack of motivation to share knowledge; lack of preexisting relationships between individuals (trust for example); asymmetry of knowledge ownership and use; lack of absorptive capacity (money, time, management resources, etc.); and more (O'Dell and Grayson, 1998, O'Leary, 1998, Davenport and Prusak, 2000). In the KPMG report on KM (KPMG, 1998)

[1] In a 1998 report on Knowledge Management (KPMG, 1998) 43% of the respondents said that when they did not manage their knowledge a relation with a key client or supplier was damaged. 10% of the respondents said that their organization lost significant income.

the major barrier identified both by companies that are planning KM projects and by companies that are already involved in projects was the lack of time to share knowledge (49% and 55% respectively). 22% of the organizations that plan to implement KM identified current organizational culture as unsupportive of KM initiatives. Only 16% of the respondents in companies that already launched KM projects said that individuals were unwilling to share knowledge.

Other barriers to KM relate to the ability to identify and exchange knowledge. Davenport and Prusak (2000) mention the problem of having incomplete information about the knowledge. Macintosh et al (1999) identify the lack of an enterprise-wide vocabulary; the need to identify, model and explicitly represent knowledge; and the need to share and re-use knowledge. Some technological barriers are also mentioned in the KPMG report. These include the lack of skills in KM technique (49%), lack of appropriate technology (26%), and the difficulty to locate knowledge (19%).

Information technology can be used to alleviate such barriers through the use of "Knowledge Management Systems" (KMS). Although KMS are not new, there is a gap in research concerning the theoretical foundations of these systems. Alavi (2000) identified the need for research on factors that influence the KM requirements of firms and for the development of effective and efficient methodologies for determining these requirements. In addition, Ruggles (1998) surveyed over 400 companies and discovered that among the biggest difficulties were determining what knowledge should be managed (40% of respondents) and mapping the organizational existing knowledge (28%). Following this, the objective of this research is to develop the requirements for effective KMS. These requirements will address the three problems mentioned above: defining organizational knowledge to be managed; identifying KM requirements of organizations; and mapping organizational knowledge.

Our objective leads to the following research questions:

1. What is organizational knowledge?
2. What do we need to know about organizational knowledge in order to manage it?
   - 2a. What are the relevant facets of knowledge that we require to know in order to be able to manage it?
   - 2b. How can we formalize and operationalize these facets?

Answering question 1 will provide the organization with an understanding of why certain knowledge is considered organizational knowledge and should be managed by the KMS. Question 2 provides an insight into the knowledge management requirements of the organization and the required information about the knowledge that the system should maintain and provide. The final research question ties the previous conclusions to address the general objective of the work:

3. How can we use our answers to the previous questions as a theoretical foundation to derive guidelines and principles for designing KMS?

Our research approach is based on philosophical foundations, information systems analysis methods, organizational knowledge management theory, and some aspects of linguistics and artificial intelligence. In particular, we propose to use ontological foundations to specify the *contents* of the knowledge, and epistemological foundations to define *attributes* of knowledge. We intend to use a combination of theoretical analysis to define organizational knowledge, modeling technique to map this knowledge, and empirical work to understand meta-knowledge requirements of the users.

Section 2 provides a review of relevant literature. Section 3 will describe the work we have done so far, which mainly includes a model for knowledge ownership in organizations. Section 4 will describe our methodology and future research.

2. Literature Review

2.1. Knowledge

2.1.1. Epistemology

The basic definition of knowledge – in epistemology - is of a "Justified True Belief" (Lehrer, 1990) or more formally:

> Person S knows proposition p if and only if (i) p is true; (ii) S believes that p; (iii) S is (completely) justified in believing that p[2].

Objection to this definition was brought up by both Karl Popper and Hans Albert (cited in Moldoveanu, 1999). Popper argues against the truth condition of the definition on account of the unreliability of empirical knowledge compared to that of knowledge acquired by deductive means. Albert argues that justification leads the user to an infinite regress due to the need to justify each statement by another, which also requires justification. In addition, Gettier (1963) presented an example where a person may have a justified true belief yet we are reluctant to say that they own knowledge. Another situation in which a "justified true belief" might not imply knowledge is the notion of the "social aspect of knowledge" presented by Harman (1968). Harman demonstrated that there is a "social aspect" of knowledge that requires us to know all that is commonly known. Therefore, in such cases again even a justified true belief might not be considered knowledge.

2.1.2. Knowledge in organizations

Although extensive attention has been given to the management of knowledge in organizations, the concept itself has been somewhat neglected in organizational and IS literature. Several definitions do exist – and are presented in Table 2.1 – but it seems that mostly the meaning of knowledge has been taken for granted.

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[2] For example, when I say: "It is raining outside" three conditions must hold in order for me to know this: it must be raining; I must believe (accept) that it is raining; and I need to have a proper justification for believing this. Such justification is – for example – looking out the window and seeing the rain.

Authors	Definition
Davenport and Prusak (2000)	"Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms."
Alavi (2000)	"Knowledge is a justified personal belief that increases an entity's potential for effective action"
Sveiby (1997)	"A capacity to act"
O'Dell and Grayson (1998)	"Information in action" "What people in an organization know about their customers, products, processes, mistakes, and successes, whether that knowledge is tacit or explicit."
Drucker (1998)	"Knowledge is information that changes something or somebody -- either by becoming grounds for actions, or by making an individual (or an institution) capable of different or more effective action"

Table 2.1 Definitions of knowledge

2.1.3. Classifications of knowledge

Nonaka (1994) – building on a previous work by Polanyi – distinguished between tacit and explicit knowledge where knowledge is defined as a "justified true belief". Explicit knowledge can be expressed using language or other formal representation and communicated easily. Tacit knowledge is highly personal and hard to formalize. It is rooted in action, commitment, and involvement in a specific context. Tacit knowledge can be technical – representing skills and crafts – or cognitive, referring to our beliefs, ideas and mental models.

Bunge (1974) distinguishes between several dimensions of knowledge: it can be first hand (acquired by experience) or second hand (communicated). It can be private (about oneself or about others) or public (ordinary (everyone knows), specialized (shared by a certain community)). Finally, knowledge can be of the following types: formal (about constructs), factual (about facts), empirical (about experiences), moral (about right conduct), or epistemological (about knowledge).

2.2. Knowledge Management Tools

2.2.1. Knowledge Management

Similar to knowledge, Knowledge Management has several definitions in organizational literature. However, definitions usually fall into one of two types: defining KM by its goals or by its main activities. In the latter, many of the definitions refer to activities of knowledge generation, knowledge codification, and knowledge transfer. A common definition of the first type (the goal of KM) refers to the ability of bringing "…The right knowledge to the right people at the right time and in the right format." (Milton et al, 1999)

2.2.2. Knowledge Management Tools

> "Knowledge management tools are technologies, broadly defined, which enhance and enable knowledge generation, codification, and transfer. As with any tools they are designed to ease the burden of work and to allow resources to be applied efficiently to the tasks for which they are most suited." (Ruggles, 1997)

Related knowledge projects

There are several projects conducted to facilitate KM in organizations through the use of ontology[3]. We will review some of them briefly here:

The Cyc Project – the Cyc knowledge base is part of the 'knowledge server' project, aimed at creating a foundation for knowledge-intensive products and services. The knowledge *server* is based on the Cyc ontology. The knowledge *base* is a large representation of fundamental human knowledge such as facts or rules of thumb. (Cyc)

CommonKADS – CommonKADS is a "methodology to support structured knowledge engineering" by providing methods to analyze knowledge-intensive tasks and processes and develop knowledge systems. It is intended to support organizations in developing, distributing and using knowledge resources (KADS).

The Knowledge Sharing Effort – A consortium that aims to develop conventions to facilitate sharing and reuse of knowledge bases and knowledge based systems. The project includes the use of ontologies, agents, and formal knowledge representation languages, to create a reusable knowledge base (ARPA).

The enterprise ontology – The enterprise ontology was developed as part of the enterprise project, an initiative of the UK government to promote the use of knowledge based systems in organizations. The ontology provides the basic means of exchanging information between the different tools that were developed in the project (for example a procedure builder, an agent toolkit and a task manager) and between different agents (AIAI).

2.3. Ontology

Ontology can be defined as a specification of "the objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them." (Genesereth & Nilsson, 1987; cited in Gruber, 1993).

Why use ontologies?

Recall that some of the barriers to KM involved the lack of a shared language and the lack of knowledge about knowledge. We propose that ontology may provide a possible solution to the latter through its use in our knowledge ownership model described in section 3. As for the lack of a shared language, ontology is - by definition - a shared language that may be used between people and/or computer systems for sharing knowledge. Once everybody commits to a specific ontology, they agree to use only concepts included in it thus facilitating knowledge sharing.

We attempted to construct ontology for a small Internet company using Uschold's (1996) methodology. The main difficulty we encountered was the ongoing change in the company's operating environment. Our conclusions from this experiment are described in the next section.

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[3] Ontology is defined as: "The objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them." (See section 2.3)

3. The Knowledge Ownership Model

This model is intended to provide the basis for KM in organizations as it allows users to keep track of both tacit and explicit knowledge as well as to identify the meta-knowledge characteristics of each piece of knowledge. The model is based on the organizational ontology to assure its completeness.

3.1. Creating organizational ontology

We have found Uschold's (1996) methodology useful for constructing organizational ontology. However, our experience led us to suggest some additional guidelines for building *dynamic* ontologies – ontologies whose contents might be quite volatile:

1. Modularity: to adapt to structural changes the ontology should be modular.
2. Minimal inter-dependence: definitions should be as independent of each other as possible. This carries a "price" of repetition in definitions, and hence requires cost-benefit considerations.
3. "Outsource": when possible, use definitions from 'solid' domain ontologies.
4. Level of ontological commitment should reflect the organizational unit.
5. Versioning: Define a time frame for "freezing" the ontology. Later changes and additions will enter the ontology via a maintenance process.

3.2. The Model

3.2.1. Defining knowledge and facets of knowledge

We use the following working definition of organizational knowledge:

> "Organizational knowledge is the ability of an agent[4] to change or to predict the change of things – in accordance with organizational goals – either by actions (tacit knowledge) or by predicates (explicit knowledge)"

In addition, we define the following three facets of knowledge:

1. Subject: knowledge deals with one or more concepts or instances of concepts. These concepts are a part of the organizational ontology.
2. Ownership: knowledge has one or more owners
3. Meta-knowledge: characteristics about the knowledge.

We propose to describe each 'piece' of knowledge as a cell in a conceptual cube – termed 'the knowledge cube' – of subject-owner-meta knowledge, as presented in Figure 1. (Note that this is not an 'actual' cube in the sense that each cell has a precise measurement on the three dimensions but rather an abstraction meant to visualize the facets of knowledge.)

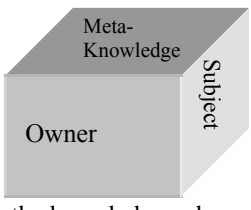

Figure 1: the knowledge cube

[4] An agent is a person, a document, or a process, either internal or external to the organization.

Now we may infer statements such as "owner 'O' has knowledge on subject 'S'" or "Owner 'O's knowledge on subject 'S' is justified through experience". We refer to these statements as *Knowledge Specification Statements (KSS)* - predicates that are derived from the facets of knowledge. Therefore, although the knowledge itself may be tacit or hard to communicate and record, we can easily keep track of the knowledge in the organization through the collection of KSS. This tracking is required for purposes of managing the knowledge (to distinguish from actually representing the knowledge itself which is not a part of this work).

3.2.2. Explaining the cube: what does each dimension include

a. Subject

The subject of the knowledge may be any concept or instance from the organizational ontology. We define:

Concept – Any abstract notion or idea by virtue of which we apply general terms to things. (Examples: client; project manager)

Instance – physical/concrete realization of a concept that possesses all the properties of that concept. (Example: a specific client)

A *relation* between concepts and/or instances is represented by any n-place predicate that is true and relevant in the universe of discourse. (Examples: is a(..); works in(..)). Two specific relations are: *Instantiation* and *Specialization.*

We use the following formal notations:

Rel(x,y,..,z) = x, y, and z are related by an n-place predicate

C = {x | x is a concept} = organizational ontology

I = {x | x is an instance} is the set of all instances of the ontology

Instantiation: Ins(x,y) = x is an instance of y; $x \in I$, $y \in C$;

I_c – the set of instances of a specific concept – is defined as follows:

$$\forall x(Ins(x,c) \blacklozenge (x \lfloor I_c))$$

$$I = \bigcup_c I_c; \quad I \quad C = \phi$$

S = {x | x is a subject of knowledge}; $S = C \cup I$

Specialization[5]: Sp(x,y) = x is a specialization of y; $x \in C$ and $y \in C$

b. Owner

An *owner* of knowledge is any person, document, group, or process that is able to provide statements on subjects of knowledge (by statements we mean either actual knowledge or Knowledge Specification Statements). We define:

Group – a department, committee, or any other groups in the organization[6].

Role – a set of concepts representing a function that is performed by an agent in the organization.

Individual – an instance of a role

Document – a physical representation of knowledge

Process – a sequence of tasks performed by agents to attain a certain goal.

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[5] 'c2' is a sub-concept (specialization) of 'c1' if the set of properties of 'c1' is a subset of the set of properties of 'c2'

[6] Instances of one role are a specific case of a group. Groups may consist of instances of several roles (departments in the organization for example).

An owner may be formally required to own certain knowledge (for example as part as a job definition) in which case we will say that they own *required knowledge* of the subject. They may also know something based on personal interest or experience (that is not formally required by any of their job definitions) thus owning *non-required knowledge.*

We denote:
G = {x | x is a group in the organization} is the set of groups; G ⊂ C
R = {x | x is a role} is the set of roles; R ⊂ C
A = {x | x is an individual} is the set of individuals; A ⊂ I

A_r – the set of all the individuals with a specific role is defined as follows:

$$\forall x(Ins(x,r) \blacklozenge (x \lfloor A_r))$$

$$\bigcup_r A_r \mid A$$

D = {x | x is a document} is the set of documents; D ⊂ C
P = {x | x is an organizational process} is the set of processes; P ⊂ C
O = {x | x is an owner of knowledge}[7]; O = R∪A∪D∪P∪G
The group of individuals is included in the set of owners (even though it is merely and instantiation of roles) due to our distinction between required and non-required knowledge. Since individuals may own knowledge that is not owned by their roles they should be separately treated as owners.

We further define the *knowledge relation:*
Knows about – a relation representing knowledge of an owner about a subject.
K(x,y) = x has knowledge about y; x∈ O, y∈ S
This relation is illustrated in Figure 2:

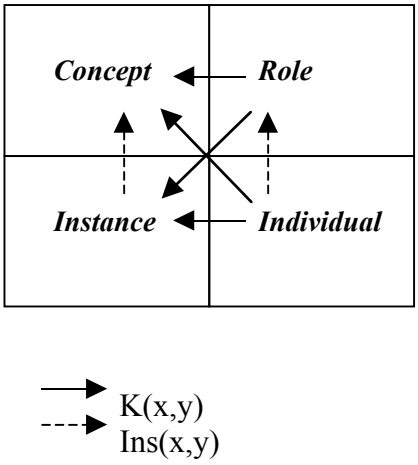

Figure 2: The knowledge relation

There are four types of relations in figure 2:
1. A role knows about a concept (a manager has knowledge related to the concept "client")
2. A role knows about a realization of a concept (a manager has knowledge about a specific client)
3. An individual knows about a concept (a specific production manager ("John") has knowledge about the concept "client")
4. An individual knows about a realization of a concept (John has knowledge about a specific client)

Knowledge that is attributed to a role is (but not necessarily) attributed to all the relevant individuals. Individuals might have additional knowledge that is not "owned" by the role. (In other words, the individual inherits the knowledge of the role and can add to it). Similarly, instances of a concept inherit only the knowledge to the properties of the concept but might have additional unique attributes.

[7] The semantics of ownership may be different for different owners. For example, a document includes representation of knowledge; a process embeds knowledge; an activity manifests knowledge; and an individual owns knowledge.

Finally, a *location* relation is defined for the owners:
Location – a specification where knowledge can be found (either a physical location; a disk; a department; or others)
Located at – represents the location of an owner of knowledge. (Example: The marketing department would be the location of knowledge owned by the marketing manager; a specific computer file location would be the location of knowledge presented in a computer document)
We denote: L(o) is the location of owner 'o'

c. Meta-knowledge

The identification of meta-knowledge (knowledge about knowledge) may be either theoretical or empirical. At this stage we have – theoretically – identified the following meta-knowledge requirements:
Justification – how is the knowledge justified? According to the foundation theory of justification (Lehrer, 1990) sensory knowledge may be considered a basic belief that requires no justification. Therefore, based to Bunge (1974) we draw the following methods of justification:

1. Personal (or team) experience. (First hand knowledge)
2. Witnessing experiences of others. (Second hand knowledge)
3. Experiences communicated to us by another entity[8]. (Second hand knowledge)

Credibility – what is the credibility of the source of knowledge.
Timeliness – is there an "expiry date" on the knowledge?
The study of the meta-knowledge facet is still under research.

After reviewing the three facets of knowledge let us turn to examine some practical ways in which it can be applied.

3.2.3. Applying the model: general queries

Using the model we are able to answer the following queries:

- **What subjects do owner 'o' knows about?**
  The *Knowledge Set* of owner 'o' (KS_o) is the set of all concepts and instances that 'o' has knowledge about. KS_o is defined as:
  $\forall x.x \lfloor S.(K(o,x) \blacklozenge (x \lfloor KS_o))$
  (Or in a different notation: $KS_o = \{x \mid (x \in S) \text{ AND } K(o,x)\}$)
- **Who knows about subject 's'?**
  The *Knowledge Ownership* set of subject 's' (KO_s) is the set of all owners of knowledge regarding 's'. KO_s is defined as:
  $\forall x.x \lfloor O.(K(x,s) \blacklozenge (x \lfloor KO_s))$
- **Where is knowledge about subject 's' located?**
  The *Knowledge Location* set of subject 's' (KL_s) is the set of the locations of owners of knowledge about 's'. KL_s is defined as:
  $\forall x.x \lfloor O.(K(x,s) \blacklozenge (L(x) \lfloor KL_s))$

[8] Either someone telling us certain predicates or reading them in a document

4. Future Work

Our intended work focuses on two major areas: defining organizational knowledge and meta-knowledge requirements, and putting our theoretical findings to work.

4.1. Defining organizational knowledge

We begin our discussion of organizational knowledge from the epistemological view of knowledge as a 'justified true belief'. We then borrow from organizational memory literature (Walsh and Ungson, 1991) the following retaining facilities for organizational knowledge:

1. Individuals – individuals retain information in their memory stores or in their belief structures, values, or assumptions.
2. Culture – Cultural information is stored in language, symbols, and stories.
3. Transformation – transformations embed information such as the logic behind them.
4. Structures – structure and roles represent the organization's perception of the environment and social expectations.
5. Ecology – the physical settings of the workplace represents status hierarchy and behavior perceptions.
6. External archives – former employees, competitors, analysts, media, and government agencies and offices.

However, a problem exists with the knowledge retained by individuals in organization who may retain organizational as well as private knowledge (e.g. knowledge about their family, friends, personal experiences, etc.). In order to define organizational knowledge we need to derive criteria for distinguishing between organizational and private knowledge. We term these criteria '*organizational justification'*. While epistemological justification requires proof of knowledge, organizational justification requires proof of relevance to the organization. The intended line of work is to use organizational theory about the drivers of organizations and organizational action theories (Argyris and Schon 1978) to derive some justification rules for organizational knowledge.

4.2. Identifying meta-knowledge requirements

Apart from organizational justification, another type of justification to be considered when mapping organizational knowledge is *personal justification.* Personal Justification refers to the meta-knowledge requirements of users. It includes factors such as the origin of the knowledge (the method of acquisition); the credibility of the knower; and the timeliness of past knowledge to mention just a few. More generally, personal justification is the evaluation of the characteristics of the knowledge and the knowledge source by the user.

To better assess personal justification we intend to follow three stages:

1. A theoretical analysis of literature. We will investigate literature that involves evaluating sources of information. For example, in library science the following five criteria are used to evaluated printed information: Accuracy of information; Authority (author's qualifications and experience); Objectivity

(minimum bias in presentation); Currency; Coverage (Tate and Alexander, 1996). Additional literature may exist in communications, journalism, and intelligence where attributes of the information source are crucial; literature about trust; and literature on competence and expertise.

2. An exploratory study to understand users' personal justification. We intend to design a case that will be presented to participants in the study. They will then be presented with questions about the case and several possible sources of knowledge. Participants will be allowed to use only a few of the knowledge sources and will be asked to describe what information about the source of knowledge they require in order to select the ones to turn to.
3. Once we have comprised a list of source evaluation criteria (both from potential users and the literature) we will use a ranking process to identify the most important characteristics. These will be included in the KMS.

The intended result is to attain a 'requirements list' that will portray the information about the knowledge to be included in the KMS.

4.3. Designing guidelines for KMS

Recall that the definition we use for knowledge management is: "…efficiently connecting those who know with those who need to know, and converting personal knowledge into organizational knowledge" (the Yankee group, cited in Cairncross, 2000). Our design guidelines for KMS focus on the first part of this definition, namely providing access to knowledge in the organization. In previous stages we determined what knowledge is to be included in the system, what additional information about the knowledge is required, and how to locate and keep track of the knowledge in the organization. This stage involves the integration of our previous conclusions to create design criteria for KMS.

An additional question that we might want to investigate is whether knowledge should be embedded in existing information systems or represented in a separate KMS.

5. Summary

We described an approach for creating foundation for using KMS in organizations. This approach focuses on capturing knowledge *about* the knowledge in order to design KMS. The approach differs from most current work on KMS that focuses on capturing, representing, or distributing the knowledge itself. The main expected contributions are:

Contribution to research

The main expected contribution is developing guidelines to support the design of KMS. We offer a three steps approach: define organizational knowledge; understand the KM requirements of users; and keep track of organizational knowledge. Additional expected contributions are the creation of a theoretically sound – yet usable – definition of knowledge; the use of ontology as a knowledge management tool; and the investigation into the nature of 'personal justification'.

Contribution to practice

Many companies are involved in creating KM practices. As Ruggles (1998) pointed out, companies face several difficulties in identifying knowledge and

knowledge management requirements. We hope that our work can be used to help organizations identify their KM requirements and make better use of their knowledge. In future work, we intend to collaborate with one or two such organizations to test our ideas.

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