

Commercializing a Multiagent-Supported Collaborative System

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ABSTRACT

In this paper, we describe our effort and lessons learned in commercializing an innovative infrastructure to support student participation and collaboration and help the instructor manage large or distance classrooms using multiagent system intelligence. The system, called I-MINDS, has a host of intelligent agents for each classroom: a teacher agent ranks and categorizes real-time questions from the students and collects statistics on student participation, a number of group agents that each maintains a collaborative group and facilitate student discussions, and a student agent for each student that profiles a student and finds compatible students to form the student's "buddy group". Our commercialization plan is three-fold: (1) to strengthen our understanding of potential customers, (2) to understand our competitors and alternative products, and (3) to examine and estimate the market potential for I-MINDS. To accomplish the above, we have conducted experiments to further investigate the impact of I-MINDS in actual use, comprehensive research on existing products and technologies, secure legal protection of our technology, plug-and-play I-MINDS for various demonstrations to companies for joint research and development.

Categories and Subject Descriptors

I.2.11 [Artificial Intelligence]: Distributed Artificial Intelligence – multiagent systems, intelligent agents.

General Terms

Algorithms, Design, Experimentation.

Keywords

Multiagent, Cooperative Learning, Distance Education.

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1. INTRODUCTION

In December 2005, we founded a start-up company called I-MINDS, LLC, with the intention of commercializing a multiagent system called I-MINDS. Subsequently, we received funding from the National Science Foundation's Small Business and Innovative Research (SBIR) program to further improve the system technically and commercially. This paper describes our effort this past year and the lessons learned.

I-MINDS is a computer-supported cooperative learning (CSCL) system. There is need for CSCL systems especially in large or distance classrooms. Students in large or distance classrooms often do not enjoy the same level and quality of student-to-student and student-to-instructor interactions during the class (synchronously) or after the class (asynchronously) as in smaller classrooms. Such interactions are, however, important to foster group-based learning and student affinity in a class. To improve such interactions, educators have turned to technology such as personal response systems, online chat rooms, teleconferencing tools, and computer-supported cooperative learning (CSCL) environments. However, these systems do not adapt to diverse student and instructor needs and behaviors. These systems are passive participants in the process and students and instructors often resort to other modes of interactions (e-mail, phone, or face-to-face meetings) in order to address individual problems. Further, the advent of Internet and multimedia technology has meant potentially drastic changes in the teaching and learning process from the traditional classroom setting to a more geographically distributed, virtual but still interactive one. Hence, there are both motivation and opportunity to develop intelligent CSCL systems.

The long-term goal of our technical and commercial effort is to ultimately build systems to support intelligent virtual classrooms where students enjoy peer interactions as well as on-site, small classroom students, and where students enjoy student-instructor instructions as well as on-site, small classroom students. A secondary goal is to extend the virtual classrooms concept to other group-based applications such as decision support, focus group studies, and corporate training, and other cooperative work where agents might play a role [14], since the technologies and features of a CSCL system could be of significant use in these applications. For example, agents that support collaboration between two students can be used to mediate the discussions between two focus group participants.

Our commercialization effort for started with three main objectives to study the commercial feasibility of the I-MINDS technology.

Objective 1. To strengthen our understanding of potential customers. To assure that the technical design of the I-MINDS system meets education needs of teachers and students and successfully reach customers in the later-phase commercialization, we have researched to gain an in-depth understanding of potential customers from the following perspectives: (a) needs of teachers and students in real-time virtual classroom environment, (b) the current market offerings and how I-MINDS can fill the gap to fulfill unsatisfied customer needs, and (c) the decision-making processes of purchasing and implementing technology improvement in post-secondary schools in both academia and industry.

Objective 2. To understand competitors and alternative products. An effective evaluation of our competitors and alternative solutions will help us understand the online educational market. With this evaluation, we will be able to identify important issues during the commercialization phase, such as the I-MINDS business model, pricing strategy, competitive advantages and potential entry barriers.

Objective 3. To examine and estimate the market potential for I-MINDS. Further, we have investigated the current situation for overall education and training industry and our specific targeted market. Based on our analysis of the information collected about customer, market and competitors, we will be able to identify the key success factors in the industry which will help commercialize I-MINDS more effectively.

In the following, we first describe I-MINDS and its capabilities in Section 2. Section 3 discusses specific steps that we have taken towards achieving our three aforementioned objectives and more. Section 4 presents the lessons learned. Finally, we conclude.

2. I-MINDS

Our innovation is an infrastructure called the Intelligent Multi-agent Infrastructure for Distributed Systems in Education (or I-MINDS). I-MINDS consists of different intelligent agents working together to actively support student-student and student-instructor interactions. Specifically, there are agents that rank and categorize questions, and profile students to help the instructor manage a classroom in real-time; agents that find compatible agents to form “buddy groups” for students; and agents that form and maintain structured cooperative learning groups.

We have pilot tested I-MINDS and further deployed the software in the laboratory of an introductory computer science course at the Computer Science and Engineering Department of the University of Nebraska. Tests based on student assessments and control-treatment groups showed that I-MINDS, though still needing better graphical user interfaces and further development, could support and improve student performance and instruction in several pedagogical aspects.

2.1 Architecture

I-MINDS is built using a loosely-coupled layered architecture [7], which makes I-MINDS flexible and usable in heterogeneous environments.

The bottom layer (i.e., the network layer) in I-MINDS provides the basic communication functionalities by using sockets. Since sockets are available in a variety of platforms across the network, this layer allows I-MINDS to communicate in heterogeneous situations.

The second layer provides system-level protocols and encapsulations with necessary abstraction to provide convenient communication and deployment functions to the upper layers. This level includes a Relational Database Management System (RDBMS)-type database (MySQL) and an audio/video server (Macromedia Flash[®] Communication Server). The database is used by the agents for fast storage and retrieval of information and the audio/video server helps establish audible and visual communication between the teacher and the students.

Finally the topmost two layers of I-MINDS contain the intelligent agents i.e., teacher agents, student agents, and group agents. Each intelligent agent has two sets of modules: content dependent and content independent. The content independent set provides the definitions and processes for general education-related services, while the content-dependent module handles specific course-related information and knowledge base, providing the required data and the heuristics used to gather, analyze, disseminate and process the generated data.

2.2 AGENTS and TOPOLOGY

Figure 1 shows an example of the topological infrastructure of I-MINDS [8]. The manager manages the ongoing classroom sessions. It manages system level information such as the list of ongoing classes, list of courses and teachers, the login names and passwords for the students for each of the classrooms, etc. I-MINDS is capable of holding multiple concurrent classroom sessions. In each I-MINDS classroom session, the teacher, students and student groups are assigned the teacher agent, student agents and group agents, respectively. These agents support the person/group that they serve.

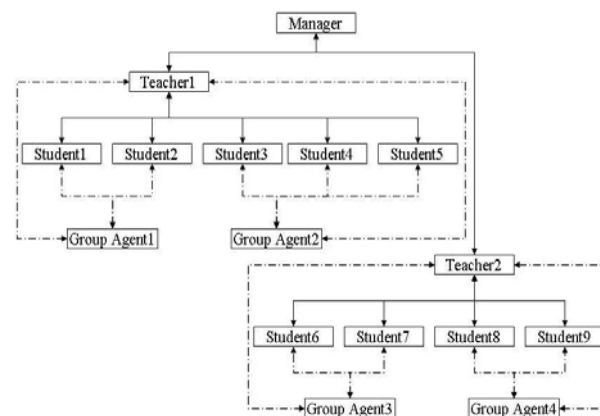


Figure 1: I-MINDS Agents and Topology

Intelligent agents are autonomous and can operate robustly in rapidly changing, unpredictable, or open environments. With these intelligent agents serving and catering to students' unique needs and behaviors, students will be able to participate in a computer-supported cooperative learning (CSCL) environment actively rather than listening to the lectures passively as in a traditional large or distance classroom. Currently, I-MINDS has three

types of intelligent agents: (1) teacher agents, (2) student agents, and (3) group agents.

2.2.1 Teacher Agent

A teacher agent, interacting with a teacher, is responsible for disseminating information streams to student agents, maintaining profiles for all students, assessing the progress and participation of different students, ranking and filtering of the questions asked by the students, and managing the progress of a classroom session. A teacher agent mainly interacts with an instructor. It also sends instructions to the group and student agents.

Question ranking is a key feature that allows the teacher agent to manage large or distance classrooms for the instructor. When questions are asked, the teacher agent scores each question based on a set of keywords and heuristics. Keywords are subject-topic specific and weighted. Heuristics are course-specific. For example, a question asked by a student with a high-score profile will be given a high score; a question asked by a student who has never asked a question before will also be given a high score to encourage the student to ask more questions in the future; and a “why?” question is scored higher than a “what?” question. After scoring, the questions are ranked and displayed to the instructor. The instructor may choose to answer or discard a question. This is how the instructor’s actions trigger the reinforcement learning mechanism of the module. When the instructor chooses a lowly-ranked question over a highly-ranked question to answer, the teacher agent takes this as an indication that it has ranked the question incorrectly. It thus traces back to the heuristics and keywords that have contributed to the high score of the question and lower their weights; likewise, it increases the weights of the heuristics and keywords that have scored the question low in the first place. Thus, by answering and discarding ranked questions, the instructor implicitly teaches the teacher agent how to better score and rank the questions. Details of this module can be found in [9].

Question grouping is another feature that allows the teacher agent to address multiple similar questions together and profile students who ask similar questions. Future applications of this feature include automatically generated and answered Frequently Asked Questions (FAQs). Question grouping is based on question classification and keyword matching. To achieve question classification, we adopt the *utterance classification* approach in the AutoTutor [3]. We use the ApplePie parser [11] and the utterance classifier program of AutoTutor [10] to classify a question into one of twelve classes such as Contribution, Discovery, and so on. This classification feature also allows the group agent to monitor the roles of group members in group discussions. Two questions are also considered similar if they share a high percentage of keywords. Details of this module can be found in [6].

A student is profiled by I-MINDS’ agents in several ways. First, student-instructor interactions are profiled mainly based on the quality of questions that a student asks. Based on the grouping of these questions, students can also be profiled relative to others in terms of compatibility.

2.2.2 Student Agent

In an I-MINDS supported classroom, a student agent serves a unique student, and, similar to a teacher agent, it also has a GUI front-end. A student agent primarily interacts with a student. It

also exchanges information with the teacher agent and the group agents.

The student agent first allows for student login and course registration through communicating with the manager and the teacher agent, respectively. The student agent then acts as a medium: displaying the instructional materials received from the teacher agent to the student and relaying information from the student to the teacher agent.

When a student asks a question or performs some kind of collaborative activities (e.g., initiates a forum discussion or participates in sketching out ideas), his or her profile is changed and subsequently updated with the teacher agent and other student agents. The change might trigger other student agents to recruit the student to join their buddy groups. Thus, a buddy group is dynamic. Further, if a student is not responsive to a buddy group that he or she is a member of, he or she can be dropped from the group. Hence, more responsive students will be approached more frequently than the others. The student agent also adjusts its heuristic rules according to the current classroom environment. For example, in a course in which students are very active in collaborative learning in every classroom session, a buddy who has not been active for the entire session may be dropped. Thus, the student agent keeps a profile of its student’s buddies in terms of their responsiveness in collaborative activities (forums and digital whiteboard). These include the number of messages sent, type of messages, frequency of messages being sent, time spent on “idea sketching”, the number of times a student is dropped from a buddy group, and so on.

2.2.3 Group Agent

In I-MINDS, a group agent is activated when there are structured cooperative learning activities. Structured cooperative learning involves specified activities that explicitly require students to cooperate. Since a group agent works behind the scene, it does not have a GUI front-end.

To support structured cooperative learning, the content-independent module set is capable of forming groups (or coalitions) of students based on their profiles, evaluating student perception of teamwork and other members through online surveys, tracking student participation, and improving its heuristics in monitoring and forming better groups.

To support the Jigsaw learning model [1, 2, 4], we have designed an auction-based learning-enabled coalition formation algorithm called VALCAM that combines automatically tracked collaboration activities with subjective peer-based evaluations of a student’s performance in structured cooperative learning.

In VALCAM, the teacher agent acts as a coordinator or the coalition formation process and makes global decisions, such as, what should the least number of members in a coalition be, how long should the coalitions last, how the performance of each coalition should be evaluated, etc. The group agents then manage the coalitions. Each group agent monitors the performance and activities of the members of its assigned group. After the coalition has completed their tasks, the group agent also evaluates the performance of each student agent as a group member.

VALCAM algorithm is based on reinforcement learning of the student agents. In the beginning of every session the teacher agent chooses a few students and then initiates the group formation.

During the group formation process, each student agent bids—an iterative Vickrey auction—to join its favorite group based on virtual currency earned from previous Jigsaw activities. Once the groups are formed, the student agents work with their group members to complete tasks assigned by the instructor. Finally, when the assigned task is completed, the student agents are rewarded with virtual currency based on their individual performance and their performance as a group member through surveys of their peers' evaluation of the student. Students who performed well will receive more virtual currency, allowing them to more successfully bid for their favorite groups in future sessions. Details of this algorithm can be found in [5].

3. COMMERCIALIZATION EFFORT

During the past year, we have taken several steps towards commercializing the I-MINDS system and its technology, in accordance to our three feasibility objectives. Specifically, we have conducted the following.

First, we have worked with our university to protect the intellectual property of our technology. This has involved identifying what we want to market as our product since we want to protect the product as well.

Second, we have continued to improve the I-MINDS technology and product. Based on our deployment of I-MINDS in actual classrooms, we have identified features that would improve I-MINDS' user-friendliness and also identified agent-based technologies to better utilize agent intelligence to support a virtual classroom.

Third, we have continued to deploy I-MINDS and collect more data to evaluate I-MINDS' impact on student learning.

Fourth, we have continued to solicit additional funding and sponsorships. We succeeded in obtaining funding from Microsoft to port I-MINDS to the Conference XP Platform.

Fifth, we have worked with a consultant company to research the potential markets for I-MINDS. Under their guidance, we have conducted two comprehensive studies into the e-learning market and the focus group market.

Sixth, we have contacted several companies and demonstrated I-MINDS. For each demonstration, we have customized I-MINDS to fit the individual company's application needs.

3.1 Intellectual Property

Protecting the intellectual property of our technology is of paramount importance. Identifying what to protect is also critical. Since the company executives are all associated with the University of Nebraska, and since the I-MINDS was developed using university resources and on university properties, our agreement with the university is as follows. The university has the rights to the technology. However, the university gives us the exclusive rights to commercialize the I-MINDS technology developed thus far. Further I-MINDS technologies developed using non-university funds and off the university properties, as a result, will belong to our company.

3.1.1 What Is Our Product?

Identifying the specific innovation to protect and the type of protection is critical. After numerous discussions with the University's technology transfer office and legal experts, there are several choices: (1) the entire I-MINDS as a software product, (2) the

I-MINDS technology as an enabling technology, and (3) the I-MINDS technology as a data collection service. The first choice basically sells I-MINDS as a standalone, packaged software product. Choosing this option implies that our business plan would be to create different versions of end-to-end, full-feature I-MINDS to suit different needs such that I-MINDS can be used with plugging it into other existing software modules that our customers might already have. This choice is less desirable as it would impose a heavy product development cost on our startup company, which we cannot afford.

The second choice is to provide technical expertise to companies that would like to incorporate I-MINDS technologies into their existing software modules. Here, the unique I-MINDS technologies are the three groups of agents, equipped with machine learning capabilities, and the multiagent system technology. Choosing this option implies that our business plan would be to embed intelligent agent and multiagent technologies into our customer's existing software and to enable computer-supported collaborative environments. This choice is more attractive to us as it would allow our company to grow in steps that are more manageable.

The third choice is to help our customers build agents to support virtual collaborative environments to collect, analyze, and report data for them. Choosing this option implies that our business plan would be to promote the autonomous capability of these agents in observing their environments, making decisions, actuating those decisions, and tracking every action and outcome, and how one could gain insights from looking at how users interact in a collaborative environment. This choice is less attractive than the second choice as it would probably detract our company from what we initially set out to do. That is, our long-term goal is to research and develop intelligent computer-supported collaborative systems. However, we recognize that this third choice might be a feasible as an intermediary one to make our first baby step into the commercial world.

3.1.2 What Kind of Protection?

There are several types of protection. We are concerned with formal patent protections and various software license agreements. Filing a formal patent protection has its pros and cons. In terms of advantages, it protects the product or technology (as described in the first two choices as described in Section 3.1.1) strongly. It also gives us the satisfaction of being recognized as inventors. However, the patent application process is expensive and lengthy. While the process is taking place, it would also be not convenient for us to publish related research papers on the technology. On the other hand, software license agreements are more flexible and can be structured at a per customer basis. Other contractual agreements can also come into play. As a result, as we develop more and more features and technologies, we do not have to keep filing for patent protections.

Presently, we have duly filed for a provisional patent with the United States' Patent and Trademark Office. Meanwhile, when we demonstrate our products to other companies, we require both parts to sign a non-disclosure agreement.

3.2 Technical Improvement

Building a research prototype and developing a marketable product is different. For the latter, the product needs to be reliable, user-friendly, well-designed and well-suited for the customers. A reliable product does not crash and, if it does crash, should be

easily re-started without loss of data or incurring additional costs on the users, for example. Towards this end, we have continued to simplify how our product can be downloaded, installed, and executed, and to improve the look-and-feel of the graphical user interface. Some examples of improvement are as follows. Currently, our I-MINDS tool supports the Jigsaw cooperative learning model and also provides visual analysis of classroom data.

3.3 Deployment and Evaluation

Actual deployments and evaluations are important to our commercialization effort as we can (1) study how I-MINDS impact the users—in our particular situation, how students learn, and (2) study how to improve I-MINDS’ look-and-feel to be a more polished product ready for the commercial market. Encouraging results have allowed us to pitch I-MINDS more convincingly to companies as we try to seek commercial partnerships in the past year.

3.3.1 Pilot Study

To determine the potential impact of I-MINDS on student learning, a pilot study [12] was conducted in May 2003 where the tool was used by subjects in a controlled experiment to assess what impact it had on student learning of Global Information Systems (GIS) content.

In the pilot study, the *control* group was conducted like a traditional classroom, with the instructor and the students in the same room. The *treatment* group was conducted as a distance classroom where the instructor and the students were in separate rooms and their only communication channel was through I-MINDS. Results from the two testing sessions were encouraging. Here we outline the results as reported previously in [12].

Although there was a slight difference in the means of the experiment and control groups for Test 2, this difference was not statistically significant ($p > .05$), and *the amount that the treatment group improved from the pretest to the posttest was nearly twice that of the control group*.

Comments from the university professor who used I-MINDS in teaching both of the content lessons were also encouraging. He indicated that the teaching tool was very easy to learn and use. He also said that the tool could enhance distance learning, especially by making it possible for building an archive of information that could be accessed “on-demand” by students. The instructor also noted that questions asked of him via I-MINDS tended to have higher quality, reflecting a deeper understanding, and demand a richer response than those questions posed during the control sessions.

3.3.2 Deployment in Actual Classrooms

In Spring 2005, we deployed I-MINDS in the laboratory of an introductory computer science course at the University of Nebraska. The course is CS1, the first core course for computer science and computer engineering majors in the Computer Science and Engineering Department. The course had three 1-hour weekly lectures and one 2-hour weekly laboratory sessions. In each lab session, students were given specific lab activities to experiment with Java and practice hands-on to solve CS problems. In Spring 2005, there were three different lab sections, each with about 20 students.

Our study utilized two sections. In the control section, students worked in Jigsaw cooperative learning groups without using I-

MINDS. Students were allowed to move around in the room to join their Jigsaw groups to carry out face-to-face discussions. In the treatment section, students worked in Jigsaw cooperative learning groups using I-MINDS. Students were told to stay at their computers and were only allowed to communicate via I-MINDS. With this setup, we essentially simulated a distance classroom environment.

For each lab, the students were given a lab handout with a list of activities—thus, a lab is a task and its activities are the subtasks. We conducted the study for three weeks, covering topics in debugging and testing, Unified Modeling Language (UML), and recursion.

Table 1 shows the post-test scores of the three sessions for the “Control” (i.e., Jigsaw without I-MINDS) and “Treatment” (i.e., Jigsaw with I-MINDS) sections. The results indicate that students using I-MINDS for the Jigsaw activities were able to obtain comparable and even better post-test scores. We had initially hypothesized that the students in the control section would perform better than the students in the treatment section simply because the students in the former would have a chance to discuss face-to-face and were able to use paper and pencil to draw and share the same computer screen during the stages 2 and 3 of the Jigsaw process. On the other hand, I-MINDS, still lacking user-friendly GUI, had been expected to hinder such free, natural interactions among students, leading to ineffective collaborations. Thus, the result had not been expected. Students in the Treatment section performed better than the students in the Control section in the later two sessions. Further, students in the Treatment section also achieved better standard deviation—meaning that these students’ post-test scores were more tightly clustered than those of the Control section. Upon closer analysis, we suspect that the act of typing and communicating through the forum and digital whiteboard of I-MINDS forced the students to articulate explicitly their thoughts and focused their attention to the tasks at hand. This in turn improved student understanding of the subject matter.

Table 1: Student performance for the Control (Jigsaw only) and Treatment (Jigsaw w. I-MINDS) sections

Peer Rating Questionnaire Results				
Week	Control Section		Treatment Section	
	Mean	Std. Dev	Mean	Std. Dev
1	42.02	2.68	35.60	5.97
2	39.06	7.05	33.30	8.65
3	39.90	4.80	38.59	6.34

The results were very encouraging: without face-to-face interactions, students carried out their I-MINDS-supported Jigsaw tasks and performed relatively well in individual post-tests.

Details of the results can be found in [13].

3.4 Other Sponsorships

We have also submitted proposals for additional funding and have received a grant from Microsoft Research to port I-MINDS technology into the Microsoft Conference XP Platform. This partner-

ship allows us to develop an I-MINDS product enabled by a far more reliable infrastructure in the Conference XP Platform than we could ever build on our own in the short term.

3.5 Market Research and Consultants

The National Science Foundation's Small Business and Innovative Research (SBIR) Program has retained Foresight Science and Technology, a high-tech consulting firm specializing in "moving technology out of people's minds and into practical applications," to help SBIR grantees devise a business plan (or commercialization plan). Working with Foresight, we have conducted two comprehensive market studies: (1) e-learning, and (2) focus groups. Here we report briefly on the market research studies.

3.5.1 E-Learning

Here, our *market drivers* (economic, social, or political) are (1) the consolidation of the e-learning market, (2) increased reliance on technology, particular the Internet, (3) increased number of online universities, and (4) decrease in funding in traditional post-secondary education. In terms of the *market size*, according to a report by Eduventures, the market for fully online distance learning will grow 38 percent over 2004, reaching revenues of more than \$5 billion. According to a report from Frost & Sullivan, by 2010 the total market size for e-learning is estimated to be \$12.18 billion. The education segment of that market is anticipated to be 28.5%, giving us a market for educational e-Learning that is roughly \$3.5 billion. The corporate segment is anticipated to be 67%, giving us a market of approximately \$8 billion. The government segment is anticipated to be 4.5%, giving us a market of approximately \$500,000. In terms of *competitors*, there are numerous commercial, popular products such as eClassroom, Blackboard, Desier2Learn Suite, Centra, and so on, that support e-learning. Some also support cooperative learning, but none uses agent or multiagent intelligence. In terms of *potential patent infringements*, we searched the US Patent Office (USPTO) for both issued patents and patent applications with a set of relevant terms. We have identified several similar patents but are able to distinguish our technologies clearly from these patents. We have also looked into recent and *ongoing research and development* and identified a host of projects on e-learning software. For example, the University of Illinois at Urbana-Champaign presented a framework for mutual online concept learning for multiple agents in 2002, the University of South Carolina at Columbia has an NSF-funded project to develop multiagent technology for e-commerce and other applications which could have implications for the educational and training markets, and so on. In terms of *customers*, we look into both competitors and users. Competitors could be potential customers for joint research and development. Potential users are universities that provide online education. In terms of *promotion*, participating in conferences, workshops, and trade shows is one way. Further, having a good website (homepage) for our company, posting the results of our studies, and contacting educational organizations such as the Association for Educational Communications and Technology and the United States Distance Learning Association are also worthwhile promotion approaches.

3.5.2 Focus Groups

Here, our *market drivers* are (1) consumer behavior becoming much more difficult to understand using traditional focus group survey methods, (2) lack of training on how to conduct such sur-

veys and to analyze such survey data, and (3) online focus groups save time and money. In terms of the market size, it was roughly \$300 million in 2001. According to Gantry Group Newsletter (issue no. 3, October 2001), "the movement to online research is considered to be the largest paradigm shift in market research since the high penetration of telephones in the late '50s. Market-ing research is currently a \$6 - 7 billion dollar industry in the U.S., with online research making up just under \$300 million. Larry Gold, editor of Inside Research, has predicted that this figure will double in each of the next several years." In terms of *competitors*, there are several products such as WebSurveyor, QualBoard, and SnapSurveys suite of survey software. In terms of *potential patent infringements*, we once again searched the US Patent Office (USPTO) for both issued patents and patent applications with a set of relevant terms. We have identified several similar patents but are able to distinguish our technologies clearly from these patents. We have also looked into recent and *ongoing research and development* and have not found specific projects that are related to supporting online focus groups. One relevant project is the Group Support Systems at the University of Western Australia. In terms of *customers*, once again, both competitors and users are our potential customers. In terms of *promotion*, associations of interest are the Council of American Survey Research Organizations, the Market Research Society, the American Marketing Association, etc.

3.6 Customized Demonstrations

In the past year, we have also demonstrated our product to three potential customers—three companies who could partner with us for joint research and development of the I-MINDS technology. For each demonstration, we first investigated about what the company wanted and what their application needs were, then we added customized features to I-MINDS, and finally tailored our demonstrations to the company's domain application. One example of such customizations is the use of vocabulary pertinent to each company on our software and in our presentation. Other customizations have included building special visual displays, adding new functionalities to I-MINDS, and setting up specific test scenarios for the demonstration. These have been time-consuming activities.

4. LESSONS LEARNED

In this section, we report on the lessons learned in our year-long commercialization effort of I-MINDS. In Section 3, we have outlined and described activities such as identifying our product and intellectual property protection, improving the technology, deploying and collecting results on the technology, soliciting additional funding, studying the markets, and presenting the technology with customized demonstrations.

Overall, the process has been educational and time-consuming. We have learned about the legal issues, market studies, promotion, and how to build a startup company from the ground up. Here we specifically talk about our experience in five aspects: (1) how to distinguish our technology or product and the notion of agents, (2) being innovative or "cutting edge" does not always translate into marketability, (3) how deciding on the intellectual property protection strategy help shape our focus, (4) the costs and benefits of customized demonstrations, and (5) the market research studies.

4.1 The Notion of “Agents”

Based on our market research studies, we identify the intelligent agents and the multiagent infrastructure as the distinguishing technology that I-MINDS has in the commercial world for online collaborative applications and systems. However, the use of agents is still not commercially mainstream in our e-learning and focus group domains. The awareness of agents or the appreciation of what agents and a multiagent system can do is still not widely apparent. Thus, in our contacts with potential companies, we have had to explain the notion of intelligent agents: what they can do individually, and what they can do as a team, and what they can learn to do overtime to adapt to their environments. We have also learned that the notion of intelligent agents is not practical without a context—specifically a context that the potential customers are familiar with, preferably a context that is tailored to their applications or domains. We have also learned that promoting intelligent agents is not always the right thing to do as how “these modules” can offer the potential customers what they need but do not have is more important.

Also, explaining the notion of intelligent agents and multiagent systems in layman’s term is very important. We have learned that situating agents in a big picture, within the context of the potential customers’ needs and applications, is key in cases where they appreciate the advantages of agent technology.

4.2 Curse of Cutting Edge

Due to the economic downturn, at least in the U.S., for the past few years, companies might not be willing to invest as much in the “research” portion of their research and development (R&D). Some companies look for applications that are almost ready to be plugged into their mainstay of software products; some companies look for applications that can be used off-the-shelf. We have had difficulty in locating companies that are willing to invest in joint R&D effort. Partly this is due to the nature of our technology and product. Being a software product, companies do think that if one can build such as product, then they can also build it. Thus, there is no point in joint R&D.

More importantly, if the technology is “cutting edge”, then companies might not be willing to invest in joint R&D and wait for a few years for the technology to transfer into matured applications.

In a sense, we tend to believe that we are visionistic and see the potential impact of our technology and product in changing how people collaborate online. And we have not succeeded in convincing our potential customers of that vision.

4.3 Intellectual Property

Securing an intellectual property protection is of paramount importance in terms of protecting the revenue of the company. However, we have also learned that the process of identifying the product or technology that we want to protect and types of protection suitable could help shape what we really want to market. Thus, this discussion should take place early and reach a decision as soon as possible.

Based on our experience, initially, we had a vague idea of marketing I-MINDS as a standalone, packaged system. However, as we clarified on what we wanted to protect through our discussions with our technology transfer office and legal experts, we have come to realize that it is also the use of agents and the multiagent

system framework that could be marketed as well as the expertise and experience that we have accumulated during the R&D of I-MINDS. These could be translated into enabling technologies or services, which might not be easy to patent but could be contracted or protected through other agreements.

4.4 Customized Demonstrations

Customized demonstrations have their pros and cons. The pros include (1) better, more application-specific demonstrations to our potential customers, and (2) continuous technical improvement of our product and added application of our technology. However, as alluded to earlier in Section 3.6, customizations are time consuming. Particularly, half-baked customizations do not help while genuine customizations require us to (1) interact and communicate with our potential customers to find out what they want to see, (2) find a midway point between what we currently have and what they want to see where it is feasible for us to build before the demonstration, and (3) customize the software product. During the customization, we also need to design the use cases or test scenarios so that we can, in a short demo, clearly highlight what our software can do.

A demonstration should also be captivating and pertinent to the potential customers right from the start. Unlike a presentation or demonstration at a research conference or workshop, these demonstrations are usually to company executives who might not understand or might prefer to not be concerned with the underlying technology (e.g., the agent technology in our case) but who might appreciate what they could see and point-and-click in real-time. Thus, it is important to show what the bottom line is right from the start of the demo: what and how can the technology or product benefits them in the short term in particular, and in the long run in general.

4.5 Market Research Studies

Based on our experience, we realize how valuable it is to have the opportunity to work with a consulting company for those who are not experienced in commercializing an innovation. Our first market study was about e-learning. Initially, we supplied the consulting company a set of documents describing our product and technology. The consulting company then did the research and gave us the outcome, which is summarized in Section 3.5.1. Given this document and experience, we conducted our second market study about focus groups on our own. From the first study, we learned about the online resources to obtain necessary information and the strategies and approaches to such a study. Key components to research include market drivers, potential patent infringements, ongoing projects, competitors, customers, and promotion. Strategies include investigating the above components with a keen eye on distinguishing the uniqueness of our product or technology.

A market research study is time consuming and may require exhaustive, investigative searches online as well as in the libraries. For our second market study, it took more than 40 person-hours.

5. CONCLUSION

We have described our effort and lessons learned in commercializing an innovative infrastructure to support student participation and collaboration and help the instructor manage large or distance classrooms using multiagent system intelligence. The system, called I-MINDS, uses a multiagent framework to support teachers

and students. Our commercialization plan has three objectives: (1) to strengthen our understanding of potential customers, (2) to understand our competitors and alternative products, and (3) to examine and estimate the market potential for I-MINDS. Guided by these three objectives, we have methodically carried out six primary sets of activities: (1) identifying the intellectual property protection and the product to be protected, (2) improving the I-MINDS product and technology, (3) deploying and evaluating I-MINDS, (4) securing other sponsorships, (5) conducting comprehensive market research studies, and (6) giving customized demonstrations. Based on our year-long effort, we have had some lessons learned. We have found out that the one thing—the intelligent agent technology—that distinguishes our product is also the one thing that is difficult to “sell”. We have also found that a product that is cutting edge is not always commercially marketable. We have also learned that securing intellectual property protection should be done early, not only to protect our product and technology, but also to help shape the very “thing” that we want to market, that demonstrations to solicit joint R&D differ significantly from demonstrations in academia, and that for inexperienced people like us in devising a business plan, having a consulting company to work with is invaluable important.

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