Learning Objectives

So that you can encourage students to explore a wide variety of potential solutions before committing to a particular course of action, upon reading this chapter you should be able to:

- Define and understand the purpose of examining prior art
- Identify a variety of technical information sources of prior art
- List tips and strategies for searching scholarly and popular technical literature
- Utilize team processes for examining and applying prior art effectively
INTRODUCTION

Once a student design team has thoroughly explored the specific needs of the project stakeholders and the safety and performance constraints the team needs to meet, design team members start to formulate potential solutions. At this point, it is important for students to cast the widest net of possible solutions. In addition to using traditional intra-team techniques such as brainstorming, students need to look outside the immediate knowledge of the team and investigate how others have solved similar problems, an activity that is often referred to as investigating prior art. The investigation or study of prior art is a vital part of the design process because it encourages designers to discover and consider as many options as possible before they begin the process of choosing their own solution. Designers then have a decisive advantage for success because they will have gained an awareness of all the prevalent solutions in the market, not just the ones they might have been familiar with before the assignment. Once information is gathered and synthesized from prior art, designers can proceed with a comprehensive benchmarking process to choose the best solution possible for their project (see Chapter 11).

When design teams study prior art, they are essentially learning the state of the art related to their project. This understanding is gained through the systematic gathering of technical literature. To conduct a far-reaching literature search, undergraduate design teams explore all aspects of business and engineering literature collections. Books (monographs and series), encyclopedias, scholarly journal articles, conference papers, dissertations, patents, and standards are common information resources utilized by designers. Design projects are often related to consumer products or capital goods, so invaluable information may be accessed from material produced by and about corporations, such as press releases, product manuals, annual reports, trade publications, and industry blogs. Marketing collateral such as brochures, sales sheets, and catalogs may also provide useful technical information. Successful design teams collect and review as much relevant information as possible as they investigate the prior art.

COMMON CHALLENGES FOR STUDENTS

A key challenge for student design teams involves maintaining a proper attitude toward searching prior art. For example, in a typical senior design class, it is only natural for students to feel confident in and want to demonstrate the knowledge and skills they have gained through their classes and labs. Thus, engineering students frequently want to build solutions from first principles, rather than building on solutions or technologies that already exist. There is also a common tendency for design teams to choose a solution before they even start investigating the prior art, what is commonly known as design fixation (Dahl & Moreau, 2010). The team wants to jump into the solution without really embracing the problem, and as a result, they may get far along the path of prototyping a solution before they realize there might be a fundamental flaw in their approach, or another cheaper, more effective approach. The cost of changing approaches is much higher the farther along the design process one goes, so exploring the breadth of solutions up front is essential to save time and money and to ensure optimal performance of the artifact.
One reason student designers are susceptible to this mindset is that traditional undergraduate engineering curricula focus on working textbook problems rather than on open-ended, more authentic problem solving. Literature searching is often regarded as a soft skill, and engineering faculty rarely focus much class time preparing students to gather information before the capstone experience. Undergraduate engineering students may have examined some technical literature during their first three years of course work, but that is often the exception rather than the rule. The probability that students will instinctively place a higher value on technical literature research at the outset of their capstone course is also doubtful, if it has not been reinforced throughout the engineering curriculum. As a consequence, there is always a high risk that undergraduate design teams come into a course considering prior art research as a low priority.

Another key challenge student designers will face as they search prior art involves the time constraints related to capstone and other types of design projects. In many cases, capstone design projects must be completed during the course of only one or two semesters. Immediate pressure for progress exists at the outset of all capstone design projects, and unexpected delays in identifying stakeholder needs may compromise the start of the literature search. The student design team advisors also face
pressure to make certain their teams progress steadily toward producing a final artifact. For all of these reasons, time management is a vital task for design teams as they explore the prior art, and instructors need to emphasize the fact that time spent searching the literature up front will be as useful, or more so, as time spent in the lab constructing the final artifact.

Young engineers need to avoid these common pitfalls by maintaining a practical attitude toward the benefits they can receive from all of the available and relevant information resources. The careful study of prior art will help students proceed along the most promising path for a good solution. It will also provide documentation to help persuade stakeholders that the students’ design solution is based on the best practices approach to the problem (see Chapter 13 for more about communication with stakeholders). With strong information skills gained from this experience, students will also be more attractive to employers and confident in their ability to be lifelong learners (Strouse & Pollock, 2009).

**TECHNIQUES AND TOOLS FOR EFFECTIVE INFORMATION GATHERING**

The main focus of synthesizing solutions is to generate the broadest selection of potential solutions to the design problem. For example, students need to be thinking about ways to cross a river rather than how to build a bridge in this phase. This type of thinking opens up the design space to allow for a much richer set of solutions that might include ferries, kayaks, zip lines, stepping stones, and so forth instead of just different styles of bridges. Not all ideas will be practical or even desirable, but transformative products come from thinking outside the box. The key is for students to not become self-conscious about providing ideas—thus the common mantra *there are no bad ideas* when brainstorming. Much has been written about ideation and brainstorming techniques, with IDEO (Kelley, 2001) being a current model for best practices, and Frog Design’s (2013) Collective Action Toolkit providing activities to spur innovation and action at the community level.

When design teams are ready to begin the process of searching the prior art, they should adopt a systematic approach for determining what kinds of information they ought to gather. Techniques can be used to generate concepts and ideas. Attribute listing involves separating a problem into smaller elements and addressing each one separately (Morgan, 1993). Case-based reasoning involves the study of old designs to inspire new ones (Kolodner, 1993). Lateral thinking involves developing a radical statement about a problem or potential solutions to challenge designers to consider more diverse ideas (De Bono, 2009). Group brainstorming is a popular technique for capstone teams to generate a large quantity of creative and diverse ideas regardless of whether or not all of them may be used to solve a given problem (Wang, Cosley, & Fussell, 2010).

To make brainstorming systematic for groups, card-based tools are sometimes used to organize and focus the process. A good example of a card-based tool that might be worth trying is called an *ideation deck*. This method is distinctive among other card-based tools because it includes specific parameters directly related to a design problem. A team starts an ideation deck by clearly defining the design challenge in writing. Then the team must define a minimum of three factors most relevant to the design project. These factors can be abstract or specific. These three factors are then
known as *category suits*. A list of specific examples for these factors must be generated and used to make *instance cards* for each category suit. Then the team collaborates to develop content for the instance cards. Once content is established for the instance cards, the back of the cards can be color coded based on suit. At this point the ideation deck is now complete, and cards can be laid out in a grid that intermixes the instance cards. The design team can then discuss card combinations within specific categories and discover provocative options to consider. An exercise like this can help to improve creative thinking that will then expand the search through prior art (Golembewski & Selby, 2010).

Other examples of ideation techniques include Wodehouse and Ion’s (2012) ICR (inform, create, reflect) Grid method, which requires designers to find a piece of information, usually an image, in an Internet search and pass it on to the next designer, who applies it to the design problem. In their study, the approach led to more novel and detailed solutions than the non-information integrated approach, and they also found that information literacy instruction, not just familiarity with Internet searching, was important in sourcing high-quality information, leading to more robust solutions. IDEO’s Tech Box (Kelley, 2001), which is filled with technologies that designers can manipulate during ideation, similarly provides external sources of inspiration and the ability to make new connections from existing artifacts.

While information can be integrated using the simple methods mentioned, there is also value in conducting dedicated searches for potential solutions. Relying only on their prior knowledge can leave large holes in the solution space investigated by students. For example, when looking for water purification solutions for a remote village, if the students are only aware of natural percolation techniques, they will have missed out on all the distillation and disinfection options that might be much more cost-effective and efficient for the situation they are working with. Having students conduct a systematic survey of the current state of technology will avoid gaps in their analysis that can lead to uncomfortable questions in the students’ ultimate design presentation.

When carrying out such a search, even with a proper attitude and strong time management skills, novice designers face the challenge of quickly becoming efficient users of literature collections. As soon as design teams have a clear understanding of stakeholder needs, they should refresh their knowledge about the breadth of their institution’s literature collection and how to efficiently find information with online catalogs, subject guides, indices, and literature databases. Some universities provide library instruction seminars near the start of new capstone courses to refresh and update student awareness of the available technical literature collection. Other courses have designated embedded librarians who are available for consultation during class time or at appointed times outside of class. Design teams should take advantage of these resources to make the best use of their limited time. Even if library instruction sessions are not made available, design teams should establish a working relationship with engineering librarians right away. Subject librarians are often few in numbers even at the largest technical universities, so design teams need to start early in scheduling initial meetings and establishing collaboration.

When initial meetings do occur, design teams need to be prepared to thoroughly explain the project task to engineering librarians, including the team’s initial thoughts about what information they already know...
and what they still need to find out about their project task (see Figure 10.1). After conducting a reference interview, engineering librarians will provide some practical instruction about how to access the technical literature collection with database and catalog query demonstrations. All literature databases and indices have distinctive features, but Boolean logic, key words, date range control, controlled vocabulary, truncation, and search histories are examples of universal query elements that can be used with most online literature searching tools. Engineering librarians can help students identify the most relevant online tools and can demonstrate specific query tactics for effective use. Design teams must be responsible for conducting their own literature searches and be prepared for the possibility that their literature searching process will last a significant period of time. In some instances, searching, understanding, and integrating prior art for a capstone design project may require the majority of a semester to complete, and some institutions have a pre-design course that focuses on problem definition and prior art searching, with the formal capstone design course focused on the build portion of the design process. No matter the amount of time required for any specific design project’s literature search, design teams should always consult with engineering librarians at least a few times during the process. Engineering librarians can offer invaluable suggestions to improve queries and
identify resources designers may not have yet considered.

The quantity and types of technical literature required for specific design projects will always vary, but design teams should take it upon themselves to look at all types of engineering literature as they search the prior art. Figure 10.2 shows the life cycle of technical information.

**Books**

Books are probably the most familiar scholarly information format for young engineers to use after years of textbook-based learning. Technical books typically are the culmination of extensive effort to summarize research and organize it into a coherent narrative, making them often the best source to consult when attempting to master the fundamentals of a topic or concept. Reference books, such as technical encyclopedias and handbooks, similarly summarize research findings from a variety of sources, either core concepts or compilations of data. Encyclopedias typically only provide an overview of the topic, not at enough depth to gain competency, but enough so that the reader can get an idea of what a topic is about. Handbooks provide an easy way to access data from a variety of sources in one location. Books are increasingly available in electronic format, which allows for quick searching of the contents to find relevant passages.

When design teams begin reviewing books, engineering librarians can help identify subject headings that will produce effective catalog queries and help designers discover the prominent authors of the subject matter. A speedy gathering of materials is vital, so designers should quickly review features such as the table of contents and the indices of books to see if the book actually includes information directly related to the design project task. Whenever designers discover relevant books unavailable in either electronic or paper format, library staff can readily explain the procedures for accessing
materials stored in repositories or shared collections, or which can be borrowed from other libraries.

**Journals and Proceedings**

Journal articles and conference proceedings should be accessed when looking for more current research results because they are the primary way that scientists and engineers formally communicate with each other about their latest discoveries and inventions. Therefore, browsing or searching the recent literature can inform designers of the state of the art of a particular field. Scholarly journal articles and conference papers can quickly be discovered using appropriate library indices and databases. Most libraries now offer tools that search multiple databases at the same time, and designers should leverage the value of these resources, while remembering that many advanced search functions are only available in a database's native interface. Students can optimize the speed of gathering appropriate articles by reading through abstracts, rather than the entire article, to determine relevance. Careful reading can then wait until after the gathering process is completed.

A type of scholarly article, commonly referred to as a review article, can be invaluable for designers during the search process because review articles identify the most prolific scholars and prevalent research trends related to any given technical topic, summarizing the state of the art at the time the article was written. Indeed, some journals only publish review articles. In addition to aiding designers in gaining a strong awareness of relevant research issues, review articles include bibliographies that can be mined to identify useful papers. Engineering librarians can help designers quickly determine the most relevant conferences that discuss topics related to their design project task.

**Patents**

Patents (see Chapter 5) are rich sources of information about engineered objects. In exchange for disclosing the form and function, and often the method of production, of an invention, the patent allows the inventor the exclusive right to commercialize the product for a period of time. Much of the patent literature never appears in journals or other formal literature, so neglecting the patent literature will leave a big hole in the design team's literature review.

Patents are legal documents, which means they can be challenging to read and to locate. Inventors don’t necessarily want their patents to be found by competitors, so they use alternative language structures to describe their inventions (see Chapter 5). Consequently, a thorough patent search needs to include classification searching, as that provides the only uniform structure for characterizing inventions. A patent might be titled “Two-wheel human-powered transportation device” to obfuscate its true intentions, but it will be classified by the U.S. Patent and Trademark Office not only as a bicycle but, for example, by whether it has a side carrier, the arrangement of its wheels and steering fork, and whether it is collapsible or foldable. While commercial sites, such as Google Patents, provide quick and easy searches of the patent literature, and they can be good places to start to see what kinds of inventions are available, a comprehensive search can only be done using a structured database, such as the freely available U.S. Patent and Trademark Office’s database (http://www.uspto.gov), and Espacenet (http://worldwide.espacenet.com), which indexes patents from several countries.

Engineering librarians can play an invaluable role in helping students get started efficiently with their patent research by selecting the best database to search, by guiding students
in selecting appropriate classifications, and by selecting appropriate assignees and inventors within queries to help focus searching. Identifying the assignees of patents is extremely important because designers can then seek out relevant product information from other company information sources. Patents are a crucial type of technical literature to search for design projects because most, if not all, patents include state of the art summaries (i.e., mini–literature reviews). Designers can quickly gather abstracts and read the claims, which explain what exactly the patent is protecting, to select patents for further review.

Standards

Technical standards are probably the least familiar type of technical literature for capstone design teams, and some students may never have read a standard prior to their first major design project. The value of standards for design projects cannot be overstated because these information sources entail best practices for products and processes, essentially the collective wisdom of a variety of experts who have thought deeply about a topic over an extended period of time. (See Chapter 9 for more information about standards.) Standards should not limit designers, but rather provide structure for the set of requirements and test methods their project may need to fulfill, related to whatever types of materials, systems, components, or processes are pertinent to their project task. Standards can be readily accessed via library catalogs and databases, and they can be quickly selected by students after they read the scope of the standards, similar to an abstract, at the beginning of the document. Engineering librarians can be helpful at the start of the query process by identifying relevant types of standards for specific design projects, and, since standards are produced by many different organizations, librarians will know the best way to access a particular standard. Designers should also ask the key stakeholders for guidance because they will probably have a strong awareness of their industry compliance issues.

Product/Trade Literature

Popular literature provides vivid, easily readable (and viewable) content for inspiration during the brainstorming phase of solution synthesis. It is easy to locate a large volume of popular and trade literature via a general Internet search. However, since this information is very informal and fluid, and often has as its primary purpose to sell a product (i.e., only stating what a product does well and not what its limitations are), students need to use their evaluation skills to determine what information is actually contained in a particular resource and how they can independently verify the veracity of that source. (See Chapter 11 for strategies.) In particular, students often locate what they think is the perfect part for their project by doing a quick Web search. However, they may only read the headline “most energy efficient fluorescent bulb on the market,” without realizing that the advertisement is for a T1 style (three-foot-long) bulb, rather than a compact fluorescent that would be more appropriate for the personal reading lamp they are designing.

Students can be savvy about navigating trade literature by locating product spec sheets, manuals, and warranty details to see exactly how and how well a product works. Similarly, locating review sites, both consumer sites as well as industry magazines and blogs, will help students determine whether a product meets the specifications it alleges. Industry magazines and blogs can also highlight new technologies and popular products and can provide
TEAM PROCESSING OF PRIOR ART

Finding an initial quantity of diverse and relevant scholarly literature is one matter, but design teams will also need to read and understand the information as they conduct a thorough search of prior art. An effective practice involves design team meetings in which designers divide up the reading material and report on what they have read. Each team member then reports on the items he or she read with summaries that are three minutes or less in length. Whenever possible, the source of information should be displayed with a projector as designers deliver their summaries. For the sake of efficiency, all literature summaries should be delivered with the same key elements. A simple and effective approach involves answering a list of basic questions such as the following:

- What did you read?
- Who created the information?
- Why do you think it is credible?
- Why is it valuable for the project?
- How can you use the information in the design process?
- Should your fellow team members read it?
- Does it raise important questions to ask your advisor?
- Does it identify a need for more reading materials?

This can even be carried out as a small-group activity within the classroom, with instructors and librarians helping facilitate discussions among team members.

As decisive documents of value are identified, additional time can be provided for the team to observe the related figures as a group. Compiling the literature in a shared citation manager (see Chapter 6) will help the team keep all information organized and accessible.

This approach is particularly effective with patents because the detailed figures required within patents to define the processes and features of inventions provide an ideal way for designers to visualize prior solutions. In addition, once valuable information is identified, designers can take advantage of bibliographies from those sources to identify even more sources. Design teams ought to engage in follow-up meetings with engineering librarians, who can then offer practical recommendations about how to expand their searching efforts.

SUMMARY

The interconnectivity of the technical literature will become apparent to design teams as they engage in the search process. For example, a design team might discover a relevant manufacturing company they did not know about as they examine a patent in which the company is identified as the patent’s assignee. In addition to searching for all of the valuable patent information related to the company, the design team can then access information about the company’s technical product information via the Web. Likewise, the name of an executive engineer identified in a press release may serve as the basis of a query to find an associated patent. A press release might also indicate an important compliance issue for a specific standard the design team had not yet considered for their search. Marketing brochures might indicate technical specifications, warranty details, and product testing results that designers might not discover through reading patents and standards. Online demonstration videos of
products and processes might indicate details previously unknown to them. When design teams engage in this type of detective work, they develop a considerable expertise for making strong decisions further ahead in the design cycle process.

**SELECTED EXERCISE**

**Exercise 10.1**

A major league baseball player wants a maple baseball bat with the widest sweet spot, the lightest weight, and the strongest durability possible that is also legal for professional use. Have students brainstorm what kinds of scholarly and popular literature can be used to search the prior art for this topic. Have them discuss the possible information sources that could inform their knowledge and divide up the different literature types among the various team members. Each team member then spends 30 minutes searching for information in the source assigned to him or her. The team members read the materials they found independently and meet at a later time to report to each other, in 3 minutes or less, on what they learned. Have students determine which types of literature were the easiest and hardest to find, and which sources, if any, surprised them. Have them identify which types of information the team would look for if they were to continue their search.

**REFERENCES**


