

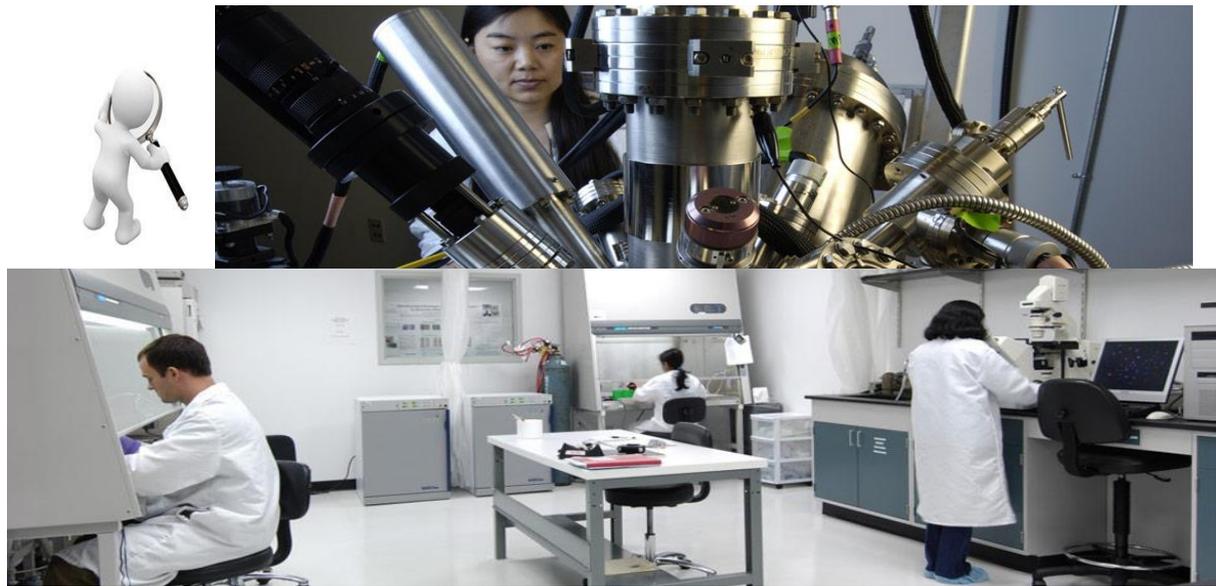
EIE 510 LECTURE NOTES
RESEARCH METHODOLOGY

1 UNIT

Course Details

- **INTRODUCTION:** Definition of Research, definition of development, reasons for research, difference between research and development.
- Literature survey, Research proposal writing, data collection and analysis, data mining, presentation of technical information and Technical report writing
- Intellectual property and patents, Turning research findings into useful products, Prototyping and copyright transfer.
- Generating theorems from Research findings.

What is Research?



Research is a systematic inquiry to describe, explain, predict and control the observed phenomenon. To research is to purposely and methodically search for new knowledge and practical solutions in the form of answers to questions formulated beforehand. Research is also defined as a systematic inquiry that investigates hypotheses, suggests new interpretations of data or texts, and poses new questions for future research to explore.

Usually Research consists of:

- Asking a question that nobody has asked before;
- Doing the necessary work to find the answer; and
- Communicating the knowledge you have acquired to a larger audience.

Research is not a solitary activity –but an act of community. As a member of the research community, you are building on the knowledge that others have acquired before you and providing a road map for those who come after you. You are adding to a body of work that will never be complete. Research is an ongoing, collaborative process with no finish line in sight.

According to Babbie, 1998, Research involves inductive and deductive methods. Inductive methods analyze the observed phenomenon and identify the general principles, structures, or processes underlying the phenomenon observed; deductive methods verify the hypothesized principles through observations. The purposes are different: one (inductive method) is aimed at or directed to develop explanations, and the other (deductive method) is aimed at or directed to test the validity of the explanations.

Types of Knowledge that Research Contributes to Education:

The following are the types of knowledge that research contributes to education:

1. *Description*: Results of research can describe natural or social phenomenon, such as its form, structure, activity, change over time, relationship to other phenomena, etc. The descriptive function of research relies on instrumentation for measurement and observations. The descriptive research results in our understanding of what happened. It sometimes produces statistical information about aspects of education. For example if I carry out a research to describe the throughput obtained in IEEE802.11b WLAN System, one of the major contributions to knowledge will be descriptive data which describes the throughput based on certain agreed or defined parameters.
2. *Prediction*: Prediction research is intended to predict a phenomenon that will occur at time Y from information at an earlier time X. It could also be to predict parameter A (dependent variable) based on parameter B (independent variable). This usually requires that models or equations be developed from collected data which can predict the dependent variable from the independent variable. In educational research, researchers have been engaged in:
 - Acquiring knowledge about factors that predict students' success in schools and in the world of work
 - Identifying students who are likely to be unsuccessful so that prevention programs can be instituted.
3. *Improvement*: This type of research is mainly concerned with the effectiveness of intervention. The research approach includes experimental design and evaluation research. It is aimed at providing improvement on an already established research or fact.
4. *Explanation*: This type of research subsumes the other three: if the researchers are able to explain an educational phenomenon, it means that they can describe, can predict its consequences, and know how to intervene to change those consequences.

What are the Purposes of Research?

Patton (1990) pointed out the importance of identifying the purpose in a research process. He classified four types of research based on different purposes:

1. *Basic Research*: The purpose of this research is to understand and explain, i.e. the research is interested in formulating and testing theoretical construct and propositions that ideally generalize across time and space. This type of research takes the form of a theory that explains the phenomenon under investigation to give its contribution to knowledge. This research is more descriptive in nature exploring what, why and how questions.
2. *Applied Research*: The purpose of this research is to help people understand the nature of human problems so that human beings can more effectively control their environment. In other words, this type of research pursues potential solutions to human and societal problems. This research is more prescriptive in nature, focusing on how questions.
3. *Evaluation Research* (summative and formative): Evaluation research studies the processes and outcomes aimed at attempted solution. The purpose of formative research is to improve human intervention within specific conditions, such as activities, time, and groups of people; the purpose of summative evaluation is to judge the effectiveness of a program, policy, or product.

4. *Action Research*: Action research aims at solving specific problems within a program, organization, or community. Patton (1990) described that design and data collection in action research tend to be more informal, and the people in the situation are directly involved in gathering information and studying themselves.

What is Development?

Development is a complex issue, with many different and sometimes contentious definitions. A basic perspective equates development with economic growth. The United Nations Development Programme uses a more detailed definition- according to them development is ‘to lead long and healthy lives, to be knowledgeable, to have access to the resources needed for a decent standard of living and to be able to participate in the life of the community’. In other words, development has occurred if people are able to live a longer and healthier life, are more knowledgeable, are more able to access the resources needed for a decent standard of living and are more able to participate in the life of the community.

Achieving human development is linked to a third perspective of development which views it as freeing people from obstacles that affect their ability to develop their own lives and communities. **Development, therefore, is empowerment**: it is about local people taking control of their own lives, expressing their own demands and finding their own solutions to their problems.

Research and Development

Let's begin with a question that has an obvious answer. What's the difference between a wall phone (circa 1907) and an iPhone 5? Their functions, size and their composition are very different



A couple of things come to mind; email, digital photos, internet, Wi-Fi, GPS, texting, and mobile conversations. But, the real question is: how did we get from the wall phone to the iPhone 5? The answer is, of course, **Research and Development (R&D)**.

Let's take a closer look at the concept. Research and development refers to a wide range of business, governmental, and academic activities designed to gather new knowledge. Sometimes, the new knowledge leads to new products or processes, and sometimes it doesn't. The purpose of R&D is to expand the frontiers of human understanding and to improve our society as a whole. In other words, to supply the innovations that took us

from the wall phone to the iPhone 5 R&D activities has to take place. R & D can be subdivided into three categories: Pure research, Applied research, and Development activities.

Pure or Basic Research

Pure (or basic) research is directed at understanding what something is or how it works. There is no immediate expectation of a short-term payoff. Basically, pure research is an attempt to satisfy our curiosity about something unknown. Hopefully, there will be marketable products further down the line, but there is no guarantee this will happen. For example, engaging in a research program to develop brain implants to help people with brain injuries and disorders requires an initial research to be directed at learning how the medical issues are reflected in brain activity. If that can be determined, then perhaps advanced medical technology can be invented. But first, they have to find out more about how the brain works which is simply pure or basic research.

Applied Research

Applied research is any fact gathering project that is conducted with a focus to acquire and apply knowledge that will address a specific problem or meet a specific need within the scope of an entity. Just about any business entity or community organization can benefit from engaging in this type of research. It is a form of systematic inquiry involving the practical application of science. Examples of applied research are:

- Investigating why some Landmark University students resume late and determining which factors most prominently affect student's resumption so as to develop new management policies that will reduce late resumption on campus.
- Investigating which treatment approach is the most effective for reducing anxiety
- Researching which strategies work best to motivate workers
- Studying different keyboard designs to determine which is the most efficient and ergonomic
- Analyzing what type of prompts will inspire people to volunteer their time to charities

Development activities

Development activities refer to a wide range of business, governmental, and academic activities designed to use new or old knowledge to produce new products or processes, so that people are able to live a longer and healthier life, are more knowledgeable, are more able to access the resources needed for a decent standard of living and are more able to participate in the life of the community.

Literature Survey

A literature review or survey is an organised write up showing previous work done concerning a research topic or question in your field. The aim of a literature review is to show your reader (e.g. your supervisor) that you have read and that you have a good grasp of the main published work concerning a particular topic or question in your field. This work may be in any format, including online sources. It may be a separate assignment, or one of the introductory sections of a report, dissertation or thesis. In the latter cases in particular, the review will be guided by your research objective or by the issue or thesis you are arguing and will provide the framework for your further work.

It is very important to note that your review should not be simply a description of what others have published in the form of a set of summaries, but should take the form of a critical discussion, showing insight and an awareness of differing arguments, theories and approaches. It should be a synthesis and analysis of the relevant published work, linked at all times to your own purpose and rationale.

A good literature review, therefore, is critical of what has been written, identifies areas of controversy, raises questions and identifies areas which need further research. According to Caulley (1992) of La Trobe University, the literature review should do the following:

- compare and contrast different authors' views on an issue
- group authors who draw similar conclusions
- criticise aspects of methodology
- note areas in which authors are in disagreement
- highlight exemplary studies
- highlight gaps in research
- show how your study relates to previous studies
- show how your study relates to the literature in general
- conclude by summarising what the literature says

The general purposes of the review are to:

- help you define and limit the problem you are working on
- help you place your study in an historical perspective
- help you avoid unnecessary duplication
- help you evaluate promising research methods
- help you relate your findings to previous knowledge and suggest further research

If you make a good literature review you will have the following advantages:

1. It shows that you do not only understand what you have done, but you understand what others have done related to your subject in a broader context. Several researchers have already done lots of work on your subject. If you can tell people about what research has already been done and what methods already exist, then your readers will think that at least you are interested in your topic, have some self-initiative and are informed and up-to-date on your research area.
2. It shows that you are intelligent enough to evaluate the quality of the other research work done on the subject, i.e., it shows that you are capable of thinking critically and identifying strengths and weakness.
3. It gives you the opportunity to tell how your research is related to previous work done by others on the subject.
4. It tells the reader if you are simply going to duplicate others' work simply to gain a better understanding, or whether your focus is to improve upon others' work or perhaps combine the methodology of two or more existing approaches to solving a problem.

Tips for Writing a Literature Survey

1. **BE A HUNTER!** Go online and search for articles, books and papers related to your subject. Be creative and persistent in your keyword search until you hunt down good references or examples. It is important, therefore, to try and decide on the

parameters of your research. What exactly are your objectives and what do you need to find out? In your review, are you looking at issues of theory, methodology, policy, quantitative research, or what? Before you start reading it may be useful to compile a list of the main areas and questions involved, and then read with the purpose of finding out about or answering these. Unless something comes up which is particularly important, stick to this list, as it is very easy to get sidetracked, particularly on the internet. You can use Landmark University subscription pass word to journals and other data bases as presented below:

LU CLR E-Resources

A. EBSCO-

Website address: <http://search.epnet.com>

User ID: ns214213

Password: Landmark03

B. Sciencedirect

www.sciencedirect.com

a) College of Agriculture: Username: caslmu@yahoo.com ; P/w: Spirituality123

b) Business: Username: cbslmu@yahoo.com; P/w: Integrity123

c) Science and Engineering: Username: cselmu@yahoo.com; P/w: Diligence123

C. Ebrary (E-Books)

<http://landmark.bravecontent.com>

User ID: Staff ID number (case sensitive)

Password: password (to be changed at a date that would be announced)

D. AGORA- Access to Global Online Research in Agriculture

Website address: <http://www.aginternetwork.org/en/>

User ID: ag-nga190

Password: wispenecy

E. JSTOR

Website address: <http://www.jstor.org>

No user ID or Password needed.

F. MIT OPEN COURSEWARE: <http://ocw.mit.edu/>

G. HINARI

Website address: www.who.int/hinari

User ID: NIE342

Password: 96195

H. ARDI-Access to Research for Development and Innovation

Website address: <http://ardi.wipo.int>

User ID: ardi-ng003

Password: gw2vg21q

I. Bioline

Website address: <http://www.bioline.org.br/journals>

User ID & Password are not required

J. Directory of Open Access Journals (DOAJ):

Website address: <http://www.doaj.org/>

User ID & Password are not required

K. Nigerian Virtual Library

Website address: <http://www.nigerianvirtuallibrary.com>

L. 100 Time Saving Search Engines for Serious Scholars

Website address: <http://www.onlineuniversities.com/blog/2010/03/100-time-saving-search-engines-for-serious-scholars>

M. Electronic Thesis/Dissertation

Website address: <http://www.thesis.patent-invent.com/> and <http://www.openthesis.org/>

N. OARE -Online Access to Research in the Environment

Website address: www.oaresciences.org

UserID: NIE711

Password: 46298

O. OPAC (Online Public Access Catalogue)

Website address 10.0.7.20 (Intranet Based)

2. Ask your supervisor for recommendations (but don't totally rely only on these!). When you read some literature that you think is useful and related, first record the citation on your list of references, using the APA style.
3. When you read some literature that is not very useful, do not include it on your list of references. More references do not mean a better list of references. Useless references only confuse a careful reader and make you lose credibility.
4. In each document, identify the approach(es)/method(s) for solving problem(s), and compare this/these with what you already know.
5. Identify which approaches and/or methods you will use and omit in your research.
6. A good literature review needs a clear line of argument. You therefore need to use the critical notes and comments you made whilst doing your reading to express an academic opinion. After you feel satisfied that you know most of the existing approaches/methods, do the following:
 - List out all the approaches/methods, in a logical sequence (perhaps in chronological order), including both those you will use and those you will omit. There is always a clear link between your own arguments and the evidence uncovered in your reading. You always acknowledge opinions which do not agree with your thesis. If you ignore opposing viewpoints, your argument will in fact be weaker
 - For each approach/method:
 - Describe how it works and what its components are
 - Tell what kinds of problems it is good at solving
 - Tell what kinds of problems it is poor or limited at solving
 - Mention other strengths and/or weakness of each approach
 - Tell if you will use or omit the approach for your research and why or why not
 - Your review must be written in a formal, academic style. Keep your writing clear and concise, avoiding colloquialisms and personal language. You should always aim to be objective and respectful of others' opinions; this is not the place for emotive language or strong personal opinions. If you thought something was rubbish, use words such as "inconsistent", "lacking in certain areas" or "based on false assumptions"!
 - And remember at all times to avoid plagiarising your sources. Always separate your source opinions from your own hypothesis. Making sure you consistently reference the literature you are referring to. When you are doing your reading and making notes, it might be an idea to use different colours to distinguish between your ideas and those of others.
7. In addition read "Writing a Research Paper" @ <http://owl.english.purdue.edu/owl/resource/658/01/> by Purdue University's Online Writing Lab (OWL). OWL suggests that you think about the following:

- What facts does the reader need to know in order to understand the discussion that follows?
- Who has done previous work on this problem?
- What theory or model informed your project?
- What facts are already known that support or don't fit the theory?
- What will the reader know about the subject already, and what will you need to tell them so they can understand the significance of your work?

Final checklist

Here is a final checklist on your literature survey, courtesy of the University of Melbourne:

Selection of Sources

- Have you indicated the purpose of the review?
- Are the parameters of the review reasonable?
- Why did you include some of the literature and exclude others?
- Which years did you exclude?
- Have you emphasised recent developments?
- Have you focussed on primary sources with only selective use of secondary sources?
- Is the literature you have selected relevant?
- Is your bibliographic data complete?

Critical Evaluation of the Literature

- Have you organised your material according to issues?
- Is there a logic to the way you organised the material?
- Does the amount of detail included on an issue relate to its importance?
- Have you been sufficiently critical of design and methodological issues?
- Have you indicated when results were conflicting or inconclusive and discussed possible reasons?
- Have you indicated the relevance of each reference to your research?

Interpretation

- Has your summary of the current literature contributed to the reader's understanding of the problems?
- Does the design of your research reflect the methodological implications of the literature review?

Note

- The literature review will be judged in the context of your completed research.
- The review needs to further the reader's understanding of the problem and whether it provides a rationale for your research.

HOW TO WRITE A RESEARCH PROPOSAL

Most students and beginning researchers do not fully understand what a research proposal means, nor do they understand its importance. To put it bluntly, one's research is only as good as one's proposal. An ill-conceived proposal dooms the project even if it somehow gets through the Thesis Supervisory Committee. A high quality proposal, on the other hand, not only promises success for the project, but also impresses your Thesis Committee about your potential as a researcher.

A research proposal is intended to convince others that you have a worthwhile research project and that you have the competence and the work-plan to complete it. Generally, a research proposal should contain all the key elements involved in the research process and include sufficient information for the readers to evaluate the proposed study.

Regardless of your research area and the methodology you choose, all research proposals must address the following questions: What you plan to accomplish, why you want to do it and how you are going to do it. The proposal should have sufficient information to convince your readers that you have an important research idea, that you have a good grasp of the relevant literature and the major issues, and that your methodology is sound.

The quality of your research proposal depends not only on the quality of your proposed project, but also on the quality of your proposal writing. A good research project may run the risk of rejection simply because the proposal is poorly written. Therefore, it pays if your writing is coherent, clear and compelling.

This paper focuses on proposal writing rather than on the development of research ideas under the following areas:

Title of Project:

It should be concise and descriptive. For example, the phrase, "An investigation of . . ." could be omitted. Often titles are stated in terms of a functional relationship, because such titles clearly indicate the independent and dependent variables. However, if possible, think of an informative but catchy title. An effective title not only pricks the reader's interest, but also predisposes him/her favourably towards the proposal.

Abstract:

It is a brief summary of approximately 300 words. It should include the research question, the rationale for the study, the hypothesis (if any), the method and the main findings. Descriptions of the method may include the design, procedures, the sample and any instruments that will be used.

Introduction:

The main purpose of the introduction is to provide the necessary background or context for your research problem. How to frame the research problem is perhaps the biggest problem in proposal writing. If the research problem is framed in the context of a general, rambling literature review, then the research question may appear trivial and uninteresting. However, if

the same question is placed in the context of a very focused and current research area, its significance will become evident.

Unfortunately, there are no hard and fast rules on how to frame your research question just as there is no prescription on how to write an interesting and informative opening paragraph. A lot depends on your creativity, your ability to think clearly and the depth of your understanding of problem areas. However, try to place your research question in the context of either a current "hot" area, or an older area that remains viable. Secondly, you need to provide a brief but appropriate historical backdrop. Thirdly, provide the contemporary context in which your proposed research question occupies the central stage. Finally, identify "key players" and refer to the most relevant and representative publications. In short, try to paint your research question in broad brushes and at the same time bring out its significance.

The introduction typically begins with a general statement of the problem area, with a focus on a specific research problem, to be followed by the rationale or justification for the proposed study. The introduction generally covers the following elements:

1. State the research problem, which is often referred to as the purpose of the study.
2. Provide the context and set the stage for your research question in such a way as to show its necessity and importance.
3. Present the rationale of your proposed study and clearly indicate why it is worth doing.
4. Briefly describe the major issues and sub-problems to be addressed by your research.
5. Identify the key independent and dependent variables of your experiment. Alternatively, specify the phenomenon you want to study.
6. State your hypothesis or theory, if any. For exploratory or phenomenological research, you may not have any hypotheses. (Please do not confuse the hypothesis with the statistical null hypothesis.)
7. Set the delimitation or boundaries of your proposed research in order to provide a clear focus.
8. Provide definitions of key concepts. (This is optional.)

Literature Review:

Sometimes the literature review is incorporated into the introduction section. However, most professors prefer a separate section, which allows a more thorough review of the literature.

The literature review serves several important functions:

1. Ensures that you are not "reinventing the wheel".
2. Gives credits to those who have laid the groundwork for your research.
3. Demonstrates your knowledge of the research problem.
4. Demonstrates your understanding of the theoretical and research issues related to your research question.
5. Shows your ability to critically evaluate relevant literature information.
6. Indicates your ability to integrate and synthesize the existing literature.
7. Provides new theoretical insights or develops a new model as the conceptual framework for your research.

8. Convinces your reader that your proposed research will make a significant and substantial contribution to the literature (i.e., resolving an important theoretical issue or filling a major gap in the literature).

Most students' literature reviews suffer from the following problems:

- Lacking organization and structure
- Lacking focus, unity and coherence
- Being repetitive and verbose
- Failing to cite influential papers
- Failing to keep up with recent developments
- Failing to critically evaluate cited papers
- Citing irrelevant or trivial references
- Depending too much on secondary sources

Your scholarship and research competence will be questioned if any of the above applies to your proposal.

There are different ways to organize your literature review. Make use of subheadings to bring order and coherence to your review. For example, having established the importance of your research area and its current state of development, you may devote several subsections on related issues as: *theoretical models, measuring instruments, cross-cultural and gender differences, etc.*

It is also helpful to keep in mind that you are telling a story to an audience. Try to tell it in a stimulating and engaging manner. Do not bore them, because it may lead to rejection of your worthy proposal. (Remember: Professors and scientists are human beings too.)

Methods:

The Method section is very important because it tells your Research Committee how you plan to tackle your research problem. It will provide your work plan and describe the activities necessary for the completion of your project. The guiding principle for writing the Method section is that it should contain sufficient information for the reader to determine whether methodology is sound. Some even argue that a good proposal should contain sufficient details for another qualified researcher to implement the study.

You need to demonstrate your knowledge of alternative methods and make the case that your approach is the most appropriate and most valid way to address your research question. Please note that your research question may be best answered by qualitative research. However, since most mainstream psychologists are still biased against qualitative research, especially the phenomenological variety, you may need to justify your qualitative method.

Furthermore, since there are no well-established and widely accepted canons in qualitative analysis, your method section needs to be more elaborate than what is required for traditional quantitative research. More importantly, the data collection process in qualitative research has a far greater impact on the results as compared to quantitative research. That is another reason for greater care in describing how you will collect and analyze your data.

For quantitative studies, the method section typically consists of the following sections:

1. Design -Is it a questionnaire study or a laboratory experiment? What kind of design do you choose?
2. Subjects or participants - Who will take part in your study ? What kind of sampling procedure do you use?
3. Instruments - What kind of measuring instruments or questionnaires do you use? Why did you choose them? Are they valid and reliable?
4. Procedure - How do you plan to carry out your study? What activities are involved? How long does it take?

Results:

Obviously you do not have results at the proposal stage. However, you need to have some idea about what kind of data you will be collecting, and what statistical procedures will be used in order to answer your research question or test you hypothesis.

Discussion:

It is important to convince your reader of the potential impact of your proposed research. You need to communicate a sense of enthusiasm and confidence without exaggerating the merits of your proposal. That is why you also need to mention the limitations and weaknesses of the proposed research, which may be justified by time and financial constraints as well as by the early developmental stage of your research area.

Common Mistakes in Proposal Writing

1. Failure to provide the proper context to frame the research question.
2. Failure to delimit the boundary conditions for your research.
3. Failure to cite landmark studies.
4. Failure to accurately present the theoretical and empirical contributions by other researchers.
5. Failure to stay focused on the research question.
6. Failure to develop a coherent and persuasive argument for the proposed research.
7. Too much detail on minor issues, but not enough detail on major issues.
8. Too much rambling -- going "all over the map" without a clear sense of direction. (The best proposals move forward with ease and grace like a seamless river.)
9. Too many citation lapses and incorrect references.
10. Too long or too short.
11. Failing to follow the APA style.
12. Slopping writing.

Engr. Oghogho I. credits this article on "How to write a research proposal" to Paul T. P. Wong, Ph.D., C.Psych. Research Director, Graduate Program in Counselling Psychology Trinity Western University Langley, BC, Canada

DATA COLLECTION AND ANALYSIS

Data Collection is an important aspect of any type of research study. Inaccurate data collection can impact the results of a study and ultimately lead to invalid results. **Data collection** is the process of gathering and measuring information on variables of interest, in an established systematic fashion that enables one to answer stated research questions, test hypotheses, and evaluate outcomes. The data collection component of research is common to all fields of study including physical and social sciences, humanities, business, etc. While methods vary by discipline, the emphasis on ensuring accurate and honest collection remains the same.

Data collection methods for impact evaluation vary along a continuum. At one end of this continuum are quantitative methods and at the other end of the continuum are Qualitative methods for data collection.

In collecting the data, the researcher must decide:

1. Which data to collect
2. How to collect the data
3. Who will collect the data
4. When to collect the data

The selection of the chosen data collection method should be based on the following:

1. The identified hypothesis or research problem.
2. The research design
3. The information gathered about the variables being studied.

The methods of data collection vary according to:

1. The degree of structure
2. Degree of quantifiability
3. Degree of obtrusive (conspicuousness, un-mistakeableness)
4. Degree of objectivity

Different ways of collecting evaluation data are useful for different purposes, and each has advantages and disadvantages. Various factors will influence your choice of a data collection method: the questions you want to investigate, resources available to you, your timeline, and more. (<http://dmc.umn.edu/evaluation/data.shtml>)

The Quantitative data collection methods,

They rely on random sampling and structured data collection instruments that fit diverse experiences into predetermined response categories. They produce results that are easy to summarize, compare, and generalize.

Quantitative research is concerned with testing hypotheses derived from theory and/or being able to estimate the size of a phenomenon of interest. Depending on the research question, participants may be randomly assigned to different treatments. If this is not feasible, the researcher may collect

data on participant and situational characteristics in order to statistically control for their influence on the dependent, or outcome, variable. If the intent is to generalize from the research participants to a larger population, the researcher will employ probability sampling to select participants.

Typical quantitative data gathering strategies include:

- Experiments/clinical trials.
- Observing and recording well-defined events (e.g., counting the number of patients waiting in emergency at specified times of the day).
- Obtaining relevant data from management information systems.
- Administering surveys with closed-ended questions (e.g., face-to face and telephone interviews, questionnaires etc). (http://www.achrn.org/quantitative_methods.htm)

Qualitative data collection methods

They play an important role in impact evaluation by providing information useful to understand the processes behind observed results and assess changes in people's perceptions of their well-being. Furthermore qualitative methods can be used to improve the quality of survey-based quantitative evaluations by helping generate evaluation hypothesis; strengthening the design of survey questionnaires and expanding or clarifying quantitative evaluation findings. These methods are characterized by the following attributes:

- they tend to be open-ended and have less structured protocols (i.e., researchers may change the data collection strategy by adding, refining, or dropping techniques or informants)
- they rely more heavily on interactive interviews; respondents may be interviewed several times to follow up on a particular issue, clarify concepts or check the reliability of data
- they use triangulation to increase the credibility of their findings (i.e., researchers rely on multiple data collection methods to check the authenticity of their results)
- generally their findings are not generalizable to any specific population, rather each case study produces a single piece of evidence that can be used to seek general patterns among different studies of the same issue

Regardless of the kinds of data involved, data collection in a qualitative study takes a great deal of time. The researcher needs to record any potentially useful data thoroughly, accurately, and systematically, using field notes, sketches, audiotapes, photographs and other suitable means. The data collection methods must observe the ethical principles of research.

The qualitative methods most commonly used in evaluation can be classified in three broad categories:

- **indepth interview**
- **observation methods**
- **document review**

The following link provides more information on the above three methods.

<http://www.worldbank.org/poverty/impact/methods/qualitative.htm#indepth>

The Research Instrument

The research instrument or a tool is described as a device used to collect the data. It facilitates variable observation and measurement. The type of instrument suitable for use by the researcher depends on the data collection method selected. Instrument selection and development require a high degree of research expertise because the instrument must be reliable and valid.

Ways of searching for Research Instrument

1. Read professional journals so as to learn (i) what kind of instruments are being used for similar studies (ii) their format (iii) their style (iv) how they are used by the writers.
2. Read books that provide a description or an actual copy of various instruments for the reader.
3. Talk with other researchers who may know of certain tools they have developed for themselves or who may have used tools developed by others.
4. Combine or adapt one or more tools used by other researchers.
5. Develop his/her own instrument to fulfil a specific need

Guidelines for developing an instrument

1. The instrument must be suitable for its function
2. The research tool will only be effective only as it relates to its particular purpose.
3. The instrument must be based on the theoretical framework selected for the study.
4. The instrument must be valid
5. The content of the instrument must be appropriate to test the hypothesis or answer the question being studied.
6. The instrument should be reliable
7. The devised research tool should provide comparable data every time the subject uses the instrument.
8. An instrument should include an item that directly asks questions on the hypothesis.
9. The research tool should be designed and constructed in such a way that cheating is minimized.
10. The instrument should be free of bias
11. A good instrument is free of build-in clues.
12. The instrument should not contain measures that function as hints for desired responses.
13. The researcher may need to read extensively to identify which aspects of the theory are appropriate for investigation.
14. The researcher through the instrument must be able to gather data that are appropriate in order to test the hypothesis or to answer the question under investigation.
15. The researcher should gather a group of items from such sources such as persons knowledgeable in the field, accepted theories or hypothesis, personal experience, or materials from studies reported in books and professional journals.
16. The response given by the respondent in the research study should solely be his/her own. There should be no contamination through outside influences such as someone

else's ideas or products. Therefore the respondent who agrees to participate in a study is responsible for supplying information or for exhibiting behaviour that is truly his/her own.

Types of Research Instruments

1. Questionnaire
2. Check list
3. Distribution
4. Interview
5. Observation
6. Records
7. Experimental Approach
8. Survey Approach

QUESTIONNAIRE

Questionnaire is a series of questions designed to elicit information which is filled in by all participants in the sample. This can be gathered either by oral interview or by written questionnaire. Questionnaire is the most common type of research instrument.

Paper-pencil-questionnaires can be sent to a large number of people and saves the researcher time and money. People are more truthful while responding to the questionnaires regarding controversial issues in particular due to the fact that their responses are anonymous. But they also have drawbacks. Majority of the people who receive questionnaires don't return them and those who do might not be representative of the originally selected sample. (Leedy and Ormrod, 2001)

Web based questionnaires : A new and inevitably growing methodology is the use of Internet based research. This would mean receiving an e-mail on which you would click on an address that would take you to a secure web-site to fill in a questionnaire. This type of research is often quicker and less detailed. Some disadvantages of this method include the exclusion of people who do not have a computer or are unable to access a computer. Also the validity of such surveys are in question as people might be in a hurry to complete it and so might not give accurate responses.
(<http://www.statcan.ca/english/edu/power/ch2/methods/methods.htm>)

Questionnaires often make use of Checklist and rating scales. These devices help simplify and quantify people's behaviors and attitudes. A **checklist** is a list of behaviors, characteristics, or other entities that the researcher is looking for. Either the researcher or survey participant simply checks whether each item on the list is observed, present or true or vice versa. A **rating scale** is more useful when a behavior needs to be evaluated on a continuum. They are also known as Likert scales. (Leedy and Ormrod, 2001)

Advantages of Questionnaire

1. Relatively simple methods of collecting or obtaining data.

2. Consumes less time
3. Allows researcher to collect data from a widely scattered sample.

Disadvantages of Questionnaire

1. Responses to a Questionnaire lack depth.
2. Respondent may omit or disregard any item he/she chooses.
3. Some items may force the respondent to select responses that are not his/her actual choice.
4. Length of the questionnaire is limited according to the respondent's interest.
5. Printing may be costly especially if it is lengthy.
6. Data are limited to the information that is voluntarily supplied by the respondents.
7. Some items may be misunderstood.
8. The sample is limited to those who are literate.

Techniques for developing Questionnaires

1. Researcher may read literature about the topic, look through available questionnaire or obtain help from experts.
2. Open ended questions are preferable than closed ended questions since they reflect respondent's attitudes and feelings which are expressed in his own words.
3. If yes – no questions are used, additional information may be gained by leaving space for respondent's own ideas.
4. The possibility of a middle ground statement is also important.
5. Every item on the questionnaire should relate to the topic under study.

Criteria of a good Questionnaire

1. Clarity of Language. It must meet the level of understanding of the respondents in order to generate needed responses.
2. Singleness of objective. An item must have one and only one answer.
3. One-to-One correspondence. The questionnaire as a whole must correspond with the objectives of the study.
4. Correct Grammar, Spelling and Construction. The questionnaire must be constructed by observing grammatically correct sentences, correctly spelled words, coherence in construction of sentences, etc.

Characteristics of a good Questionnaire.

1. It has a well stated title.
2. It has a statement of purpose
3. It assures the respondents about the confidentiality of responses.
4. It is designed to achieve the objective of the study.
5. It has a clear direction
6. There are no double-negative questions.
7. It avoids double-barrels questions.
8. The design corresponds to an easy tabulation of data.

Degree of structure questions

1. **Open-Ended Questions:** This gives the respondents the ability to respond to the questions in their own words.
2. **Closed-Ended Questions:** This allows the subject to choose one of the given alternatives.

Specific types of Closed ended questions.

1. Dichotomous questions. This requires the respondents to make a choice between two responses such as yes/no, male/female, married or unmarried, etc.
Example
(i) Have you travelled outside Nigeria (a) yes (b) No
2. Multiple questions. This offers the respondents more than one choice.
Example
(i) How favourable is it to you to become pregnant at this time? (a) Very favourable (b) favourable (c) Not sure (d) unfavourable (e) Very unfavourable.
3. Cafeteria Questions. This is a special type of multiple choice question where the respondents are required to select a response according to their own point of view.
Example
People have different views on “family planning. Which of the following best represents your view?
(a) Family planning is necessary to quality life.
(b) Family planning is immoral and should be totally banned.
(c) Family planning has undesirable side effects that suggest need for caution.
(d) Family planning has beneficial effects that merit its practice.
(e) Family planning is moral and should be practiced.
4. Rank-Order Questions. The respondents are asked to choose a response from the “most” to the “least”.
Example
Why must family planning be practiced? Rank your answer from the 1-most reasonable to 5-least reasonable?
(a) It limits maternal disabilities.
(b) Gives parents more time to meet family needs.
(c) Helps maintain financial viability of the family.
(d) Afford more working hours for couples.
(e) Ensures family capabilities to educate all the children in the future.
5. Rating Questions. The respondents are asked to judge something along an ordered dimension. This is typically bipolar in nature with the end points specifying the opposite extremes of a continuum.
Example:
On the scale of 1-5 where 1 means strongly disagree and 5 means strongly agree, the health centre in Landmark University provides you with the best of health services.
Scale
5. Strongly agree 4. Agree. 3. Uncertain. 2. Disagree 1. Strongly disagree.

CHECK LIST.

Check list are items that comprise several questions on a topic and require the same response format.

Example: here are some characteristics of birth control devices that are of varying importance to different people. How important are these in choosing a birth control method?

Characteristics of birth control devices	Of very great importance	Of great importance	Of some importance	Of no importance
1. Comfort				
2. Cost				
3. Ease of use				
4. Effectiveness				
5. Non-interference of spontaneity				
6. Safety				
7. Safety to partner				

INTERVIEW

This involves either structured or unstructured verbal communication between the researcher and the subject during which information is obtained for a study. In Quantitative research (survey research), interviews are more structured than in Qualitative research. (<http://www.stat.ncsu.edu/info/srms/survpamphlet.html>)

Types of Interviews

1. Unstructured Interviews.

These are more conversational, very long (sometimes hours) and are conducted in a usual situation. It allows the researcher flexibility in questioning the subject.

2. Structured Interviews.

These always operate within formal written instrument referred to as interview schedule. The researcher designed the questions to be asked and their order prior to the interview. The questions are asked orally either face-to-face or telephone format.

In a structured interview, the researcher asks a standard set of questions and nothing more.(Leedy and Ormrod, 2001)

Face -to -face interviews have a distinct advantage of enabling the researcher to establish rapport with potential participants and therefor gain their cooperation. These interviews yield highest response rates in survey research. They also allow the researcher to clarify ambiguous answers and when appropriate, seek follow-up information. Disadvantages include impractical when large samples are involved time consuming and expensive.(Leedy and Ormrod, 2001)

Telephone interviews are less time consuming and less expensive and the researcher has ready access to anyone on the planet who has a telephone. Disadvantages are that the response rate is not as high as the face-to-face interview but considerably higher than the mailed questionnaire. The sample may be biased to the extent that people without phones are part of the population about whom the researcher wants to draw inferences.

Computer Assisted Personal Interviewing (CAPI): is a form of personal interviewing, but instead of completing a questionnaire, the interviewer brings along a laptop or hand-held computer to enter the information directly into the database. This method saves time involved in processing the data, as well as saving the interviewer from carrying around hundreds of questionnaires. However, this type of data collection method can be expensive to set up and requires that interviewers have computer and typing skills.

Advantages of Interview

1. Data from interview are usable.
2. Depth of response can be assured.
3. In an exploratory study, the interview technique provides basis for the formation of questionnaire.
4. Clarification is possible.
5. No items are overlooked.
6. Higher proportion of responses is obtained.
7. Greater amount of flexibility is allowed.

Disadvantages of Interview

1. It consumes time
2. Biases may result
3. It is usually costly

OBSERVATION

Observation is most commonly used in qualitative research. In observation the researcher usually has some prior knowledge about the behaviour or occurrence of interest.

Types of Observation:

1. **Unstructured Observation.** This is a method of collecting research data that has both opponents and proponents.
2. **Structured Observation.** This involves preparation of record keeping forms such as category systems, check lists and rating scales.

Advantages of observation.

1. Produces large quantities of data with relative ease.
2. All data obtained from observation are usable.
3. Relatively inexpensive.
4. All subjects are potential respondents.
5. Subjects are usually available.

6. The observation technique can be stopped or begun at any time.
7. Observations may be recorded at the time they occur thus eliminating the possibility of bias due to recall.

Disadvantages of observation.

1. Accurate prediction of a situation or event to be observed is unlikely to occur.
2. Interviewing selected subjects may provide more information, economically than waiting for the spontaneous occurrence of the situation.
3. The presence of an observer gives the subject a quality normally absent.
4. Observed events are subject to biases.
5. Extensive training is usually needed.

RECORDS

A record refers to all the numbers and statistics that institutions, organizations and people keep as a record of their activities. Sources of records include:

1. Census data
2. Educational data or records
3. Hospital/Clinic records.

Advantages of Records

1. Records are unbiased
2. Records often cover a long period of time.
3. Records are inexpensive.

Disadvantages of Records

1. All the researcher can have is what has been recorded. If the record is incomplete, there is no way it can be completed.
2. No one can be sure of the conditions under which the records were collected.
3. There is no assurance of the accuracy of the records.

EXPERIMENTAL APPROACH

This is a powerful design for testing hypothesis of causal relationships among variables. In experimental approach, the researcher controls the independent variable and watches the effect on the dependent variable. There are two groups of experimental approach:

1. Treatment/Experimental group
2. Control group.

Disadvantages of Experimental Approach

1. It is difficult to minimize all the variables in which the control and experimental groups might differ.
2. Causal relationships are difficult if not impossible to establish.
3. The time element may confound the results of experimental research.

4. In an experimental Laboratory setting, it may be difficult to obtain subjects, especially subjects who are unaware of the experiment.

SURVEY APPROACH

We have two types of survey approach:

1. Non experimental type in which the researcher investigates the community or a group of people.
2. Formulative or explorative research

Advantages of survey Approach

1. It can provide information about the possibilities of undertaking different types of research methods.
2. It provides data about the present.
3. It has a high degree of representativeness.
4. It is quite easy to get respondents who are willing to supply information by expressing their true reaction to the questions.

Disadvantages of Survey approach

1. Yields a low degree of control over extraneous variables.
2. Verbal behaviour is quite unreliable especially when it involves people.

MEASUREMENT OF VARIABLES

Measurement is the process by which the researcher assigns specific number to the collected data.

Levels of Measurement.

1. Nominal level (The lowest level). This level includes assignment of numbers simply to classify characteristics into categories. It usually involves assigning a code to a label. For example in relation to marital status, 0 might represent single and 1 might represent married. Nominal level variables include sex, marital status, health status, etc.
2. Ordinal level (the second lowest level). This level permits the sorting of objects on the basis of their standing on an attribute relative to each other. Data are categorised and ranked order from “most” to “least” according to frequency of occurrence. It represents the rank order 1st, 2nd, 3rd, etc. Different scales used in ordinal level are: (i) Likert scale (ii) Guttman scale (iii) Graphic rating scale (iv) Semantic differential scale.
- 3.

What is Intellectual Property

Intellectual property refers to creations of the mind: inventions; literary and artistic works; and symbols, names and images used in commerce. Intellectual property is divided into two categories:

1. Industrial Property

Includes patents for inventions, trademarks, industrial designs and geographical indications.

2. Copyright

Covers literary works (such as novels, poems and plays), films, music, artistic works (e.g., drawings, paintings, photographs and sculptures) and architectural design. Rights related to copyright include those of performing artists in their performances, producers of phonograms in their recordings, and broadcasters in their radio and television programs.

What are intellectual property rights?

Intellectual property rights are like any other property right. They allow creators, or owners, of patents, trademarks or copyrights to benefit from their own work or investment in a creation. These rights are outlined in Article 27 of the Universal Declaration of Human Rights, which provides for the right to benefit from the protection of moral and material interests resulting from authorship of scientific, literary or artistic productions.

The importance of intellectual property was first recognized in the Paris Convention for the Protection of Industrial Property (1883) and the Berne Convention for the Protection of Literary and Artistic Works (1886). Both treaties are administered by the World Intellectual Property Organization (WIPO).

Why promote and protect intellectual property?

There are several compelling reasons. First, the progress and well-being of humanity rest on its capacity to create and invent new works in the areas of technology and culture. Second, the legal protection of new creations encourages the commitment of additional resources for further innovation. Third, the promotion and protection of intellectual property spurs economic growth, creates new jobs and industries, and enhances the quality and enjoyment of life.

An efficient and equitable intellectual property system can help all countries to realize intellectual property's potential as a catalyst for economic development and social and cultural well-being. The intellectual property system helps strike a balance between the interests of innovators and the public interest, providing an environment in which creativity and invention can flourish, for the benefit of all.

How does the average person benefit?

Intellectual property rights reward creativity and human endeavor, which fuel the progress of humankind. Some examples:

1. The multibillion dollar film, recording, publishing and software industries – which bring pleasure to millions of people worldwide – would not exist without copyright protection.
2. Without the rewards provided by the patent system, researchers and inventors would have little incentive to continue producing better and more efficient products for consumers.
3. Consumers would have no means to confidently buy products or services with reliable, international trademark protection and enforcement mechanisms to discourage counterfeit and piracy.

What is a Patent?

A patent is an exclusive right granted for an invention – a product or process that provides a new way of doing something, or that offers a new technical solution to a problem. Generally speaking, a patent provides the patent owner with the right to decide how - or whether - the invention can be used by others. A patent provides patent owners with protection for their inventions. In exchange for this right, the patent owner makes technical information about the invention publicly available in the published patent document. Protection is granted for a limited period, generally 20 years

Why are patents necessary?

Patents provide incentives to individuals by recognizing their creativity and offering the possibility of material reward for their marketable inventions. These incentives encourage innovation, which in turn enhances the quality of human life.

What kind of protection do patents offer?

Patent protection means an invention cannot be commercially made, used, distributed or sold without the patent owner's consent. Patent rights are usually enforced in courts that, in most systems, hold the authority to stop patent infringement. Conversely, a court can also declare a patent invalid upon a successful challenge by a third party.

What rights do patent owners have?

A patent owner has the right to decide who may – or may not – use the patented invention for the period during which it is protected. Patent owners may give permission to, or license, other parties to use their inventions on mutually agreed terms. Owners may also sell their invention right to someone else, who then becomes the new owner of the patent. Once a patent expires, protection ends and the invention enters the public domain. This is also known as becoming off patent, meaning the owner no longer holds exclusive rights to the invention, and it becomes available for commercial exploitation by others.

What role do patents play in everyday life?

Patented inventions have pervaded every aspect of human life, from electric lighting (patents held by Edison and Swan) and sewing machines (patents held by Howe and Singer), to magnetic resonance imaging (MRI) (patents held by Damadian) and the iPhone (patents held by Apple). In return for patent protection, all patent owners are obliged to publicly disclose information on their inventions in order to enrich the total body of technical knowledge in the world. This ever-increasing body of public knowledge promotes further creativity and innovation. Patents therefore provide not only protection for their owners but also valuable information and inspiration for future generations of researchers and inventors.

How is a patent granted?

The first step in securing a patent is to file a patent application. The application generally contains the title of the invention, as well as an indication of its technical field. It must include the background and a description of the invention, in clear language and enough detail that an individual with an average understanding of the field could use or reproduce the invention. Such descriptions are usually accompanied by visual materials – drawings, plans or diagrams – that describe the invention in greater detail. The application also contains various “claims”, that is, information to help determine the extent of protection to be granted by the patent.

What kinds of inventions can be protected?

An invention must, in general, fulfill the following conditions to be protected by a patent. It must be of practical use; it must show an element of “novelty”, meaning some new characteristic that is not part of the body of existing knowledge in its particular technical field. That body of existing knowledge is called “prior art”. The invention must show an “inventive step” that could not be deduced by a person with average knowledge of the technical field. Its subject matter must be accepted as “patentable” under law. In many countries, scientific theories, mathematical methods, plant or animal varieties, discoveries of natural substances, commercial methods or methods of medical treatment (as opposed to medical products) are not generally patentable.

Who grants patents?

Patents are granted by national patent offices or by regional offices that carry out examination work for a group of countries – for example, the European Patent Office (EPO) and the African Intellectual Property Organization (OAPI). Under such regional systems, an applicant requests protection for an invention in one or more countries, and each country decides whether to offer patent protection within its borders. The WIPO-administered Patent Cooperation Treaty (PCT) provides for the filing of a single international patent application that has the same effect as national applications filed in the designated countries. An applicant seeking protection may file one application and request protection in as many signatory states as needed.

What are Copyright and Related Rights?

Copyrights are rights given to authors, artist and other creators which enable them to have some degree of control on the use of their literary and artistic creations, generally referred to as “works”.

Copyright laws grant authors, artists and other creators protection for their literary and artistic creations or works. A closely associated field is “related rights” or rights related to copyright that

encompass rights similar or identical to those of copyright, although sometimes more limited and of shorter duration. The beneficiaries of related rights are:

- (i) Performers (such as actors and musicians) in their performances;
- (ii) Producers of phonograms (for example, compact discs) in their sound recordings;
- (iii) Broadcasting organizations in their radio and television programs.

Works covered by copyright include, but are not limited to: novels, poems, plays, reference works, newspapers, advertisements, computer programs, databases, films, musical compositions, choreography, paintings, drawings, photographs, sculpture, architecture, maps and technical drawings.

What rights do copyright and related rights provide?

The creators of works protected by copyright, and their heirs and successors (generally referred to as “right holders”), have certain basic rights under copyright law. They hold the exclusive right to use or authorize others to use the work on agreed terms. The right holder(s) of a work can authorize or prohibit: its reproduction in all forms, including print form and sound recording; its public performance and communication to the public; its broadcasting; its translation into other languages; and its adaptation, such as from a novel to a screenplay for a film. Similar rights of, among others, fixation (recording) and reproduction are granted under related rights. Many types of works protected under the laws of copyright and related rights require mass distribution, communication and financial investment for their successful dissemination (for example, publications, sound recordings and films). Hence, creators often transfer these rights to companies better able to develop and market the works, in return for compensation in the form of payments and/or royalties (compensation based on a percentage of revenues generated by the work).

The economic rights relating to copyright are of limited duration – as provided for in the relevant WIPO treaties – beginning with the creation and fixation of the work, and lasting for not less than 50 years after the creator’s death. National laws may establish longer terms of protection. This term of protection enables both creators and their heirs and successors to benefit financially for a reasonable period of time. Related rights enjoy shorter terms, normally 50 years after the performance, recording or broadcast has taken place. Copyright and the protection of performers also include moral rights, meaning the right to claim authorship of a work, and the right to oppose changes to the work that could harm the creator’s reputation.

Rights provided for under copyright and related rights laws can be enforced by right holders through a variety of methods and fora, including civil action suits, administrative remedies and criminal prosecution. Injunctions, orders requiring destruction of infringing items, inspection orders among others, are used to enforce these rights.

What are the benefits of protecting copyright and related rights?

Copyright and related rights protection is an essential component in fostering human creativity and innovation. Giving authors, artists and creators incentives in the form of recognition and fair economic reward increases their activity and output and can also enhance the results. By ensuring the existence and enforceability of rights, individuals and companies can more easily invest in the creation, development and global dissemination of their works. This, in turn, helps to increase access to and enhance the enjoyment of culture, knowledge and entertainment the world over, and also stimulates economic and social development.

How have copyright and related rights kept up with advances in technology?

The field of copyright and related rights has expanded enormously during the last several decades with the spectacular progress of technological development that has, in turn, yielded new ways of disseminating creations by such forms of communication as satellite broadcasting, compact discs and DVDs. Widespread dissemination of works via the Internet raises difficult questions concerning copyright and related rights in this global medium. WIPO is fully involved in the ongoing international debate to shape new standards for copyright protection in cyberspace. In that regard, the Organization administers the WIPO Copyright Treaty (WCT) and the WIPO Performances and Phonograms Treaty (WPPT), known as the “Internet Treaties”. These treaties clarify international norms aimed at preventing unauthorized access to and use of creative works on the Internet.

How are copyright and related rights regulated?

Copyright and related rights protection is obtained automatically without the need for registration or other formalities. However, many countries provide for a national system of optional registration and deposit of works. These systems facilitate, for example, questions involving disputes over ownership or creation, financial transactions, sales, assignments and transfer of rights.

Many authors and performers do not have the ability or means to pursue the legal and administrative enforcement of their copyright and related rights, especially given the increasingly global use of literary, music and performance rights. As a result, the establishment and enhancement of collective management organizations (CMOs), or “societies”, is a growing and necessary trend in many countries. These societies can provide their members with efficient administrative support and legal expertise in, for example, collecting, managing and disbursing royalties gained from the national and international use of a work or performance. Certain rights of producers of sound recordings and broadcasting organizations are sometimes managed collectively as well.

Generating Theorems

In mathematics, a **theorem** is a statement that has been proven on the basis of previously established statements, such as other theorems—and generally accepted statements, such as axioms. The proof of a mathematical theorem is a logical argument for the theorem statement given in accord with the rules of a deductive system. The proof of a theorem is often interpreted as justification of the truth of the theorem statement. In light of the requirement that theorems be proved, the concept of a theorem is fundamentally *deductive*, in contrast to the notion of a scientific theory, which is *empirical*.

Many mathematical theorems are conditional statements. In this case, the proof deduces the conclusion from conditions called **hypotheses**. In light of the interpretation of proof as justification of truth, the conclusion is often viewed as a necessary consequence of the hypotheses, namely, that the conclusion is true in case the hypotheses are true, without any further assumptions. However, the conditional could be interpreted differently in certain deductive systems, depending on the meanings assigned to the derivation rules and the conditional symbol.

Although they can be written in a completely symbolic form, for example, within the propositional calculus, theorems are often expressed in a natural language such as English. The same is true of proofs, which are often expressed as logically organized and clearly worded informal arguments, intended to convince readers of the truth of the statement of the theorem beyond any doubt, and from which a formal symbolic proof can in principle be constructed. Such arguments are typically easier to check than purely symbolic ones—indeed, many mathematicians would express a preference for a proof that not only demonstrates the validity of a theorem, but also explains in some way *why* it is obviously true. In some cases, a picture alone may be sufficient to prove a theorem. Because theorems lie at the core of mathematics, they are also central to its aesthetics. Theorems are often described as being “trivial”, or “difficult”, or “deep”, or even “beautiful”. These subjective judgments vary not only from person to person, but also with time: for example, as a proof is simplified or better understood, a theorem that was once difficult may become trivial. On the other hand, a deep theorem may be simply stated, but its proof may involve surprising and subtle connections between disparate areas of mathematics. Fermat's Last Theorem is a particularly well-known example of such a theorem.

Theorems in mathematics and theories in science are fundamentally different in their epistemology. A scientific theory cannot be proven; its key attribute is that it is falsifiable, that is, it makes predictions about the natural world that are testable by experiments. Any disagreement between prediction and experiment demonstrates the incorrectness of the

scientific theory, or at least limits its accuracy or domain of validity. Mathematical theorems, on the other hand, are purely abstract formal statements: the proof of a theorem cannot involve experiments or other empirical evidence in the same way such evidence is used to support scientific theories.

As a researcher, scientific theories relating two or more variables to each other can be developed from collected data. Usually, one of the variables is a dependent variable while the other or others are independent variables. The conditions, methods and type of research instrument used will affect the correctness of the theories.

Nonetheless, there is some degree of empiricism and data collection involved in the discovery of mathematical theorems. By establishing a pattern, sometimes with the use of a powerful computer, mathematicians may have an idea of what to prove, and in some cases even a plan for how to set about doing the proof. For example, the Collatz conjecture has been verified for start values up to about 2.88×10^{18} . The Riemann hypothesis has been verified for the first 10 trillion zeroes of the zeta function. Neither of these statements is considered proven.

Such evidence does not constitute proof. For example, the Mertens conjecture is a statement about natural numbers that is now known to be false, but no explicit counter example (i.e., a natural number n for which the Mertens function $M(n)$ equals or exceeds the square root of n) is known: all numbers less than 10^{14} have the Mertens property, and the smallest number that does not have this property is only known to be less than the exponential of 1.59×10^{40} , which is approximately 10 to the power 4.3×10^{39} . Since the number of particles in the universe is generally considered less than 10 to the power 100 (a googol), there is no hope to find an explicit counterexample by exhaustive search.

Note that the word "theory" also exists in mathematics, to denote a body of mathematical axioms, definitions and theorems, as in, for example, group theory. There are also "theorems" in science, particularly physics, and in engineering, but they often have statements and proofs in which physical assumptions and intuition play an important role; the physical axioms on which such "theorems" are based are themselves falsifiable.

Terminology

A number of different terms for mathematical statements exist, these terms indicate the role statements play in a particular subject. The distinction between different terms is sometimes rather arbitrary and the usage of some terms has evolved over time.

- An **axiom** or **postulate** is a statement that is accepted without proof and regarded as fundamental to a subject. Historically these have been regarded as "self-evident", but more recently they are considered assumptions that characterize the subject of study. In classical geometry, axioms are general statements while postulates are statements about geometrical objects. A definition is also accepted without proof since it simply gives the meaning of a word or phrase in terms of known concepts.
- A **proposition** is a generic term for a theorem of no particular importance. This term sometimes connotes a statement with a simple proof, while the term **theorem** is usually reserved for the most important results or those with long or difficult proofs. In classical geometry, a proposition may be a construction that satisfies given requirements; for example, Proposition 1 in Book I of Euclid's elements is the construction of an equilateral triangle.

- A **lemma** is a "helping theorem", a proposition with little applicability except that it forms part of the proof of a larger theorem. In some cases, as the relative importance of different theorems becomes more clear, what was once considered a lemma is now considered a theorem, though the word "lemma" remains in the name. Examples include Gauss's lemma, Zorn's lemma, and the Fundamental lemma.
- A **corollary** is a proposition that follows with little or no proof from one other theorem or definition.
- A **converse** of a theorem is a statement formed by interchanging what is given in a theorem and what is to be proved. For example, the isosceles triangle theorem states that if two sides of a triangle are equal then two angles are equal. In the converse, the given (that two sides are equal) and what is to be proved (that two angles are equal) are swapped, so the converse is the statement that if two angles of a triangle are equal then two sides are equal. In this example, the converse can be proven as another theorem, but this is often not the case. For example, the converse to the theorem that two right angles are equal angles is the statement that two equal angles must be right angles, and this is clearly not always the case.

List of Tools for Generating Scientific Theories from Collected Data

1. Microsoft excel.
2. MATLAB
3. Statistical packages for Social Sciences (SPSS)