The Rise of Next Generation Science Standards
For many years there has been a push to shift styles of teaching from the traditional lecture type of classroom to a more hands-on approach for students. Kansas’ own state science standards previous to the Next Generation Science Standards (NGSS) included “Science as Inquiry” as a separate standard to be integrated into all others (KSDE 2007). In a similar fashion, the NGSS, which are developed from the National Research Council’s A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, require teachers to weave the practices used in science (e.g. asking questions, carrying out investigations, constructing explanations, etc.) throughout the curriculum.

In September 2014, the “Educators Evaluating the Quality of Instructional Products (EQuIP) Rubric for Lessons & Units: Science” was released to evaluate the alignment of lessons and/or units to NGSS and their inherent quality. Throughout the rubric, criteria that are indicative of a quality NGSS-aligned lesson go beyond demonstration of knowledge and require opportunities for students to make sense, develop explanations, and design solutions to experienced phenomena (Achieve 2014)—all being key components to the Scientific and Engineering Practices. In short, exploratory lessons and activities are the main focus.

Active Learning as the Curriculum Focus
Problem- and Project-based Learning are two terms that have been used—sometimes interchangeably—to describe curricula that focus on engaging students through individual or group investigations. Both exemplify forms of inquiry-based active learning, which sees the students questioning, observing, and analyzing the world around them (NRC 1996). Problem-based Learning is often guided by a teacher or tutor (Bédard et al 2012) and leads towards providing many different solutions for a given problem (Hmelo-Silver 2004). Whereas Project-based Learning allows the students to relish in increasing autonomy on developing and designing an investigation (Bédard et al 2012) that utilizes more methods and skills to arrive to a conclusion through more extensive testing (English and Kitsantas 2013). To paint a picture of distinction between Problem-based Learning and Project-based Learning, Problem can be viewed as a type of introductory activity or precursor to Project. Problem-based Learning can easily be incorporated into each lesson, but Project-based Learning will require more time and focus from the teacher and students. The Problem lessons can ease students into a mindset of asking questions and wondering about the world they observe.

Reasoning for a shift to pedagogy utilizing active learning is multifaceted, including an increase in science literacy and interest in science, technology, engineering, and mathematics (STEM) careers. Being scientifically literate goes beyond using reading strategies to comprehend science writings. Science
literacy also instills a different mindset that requires constant questioning and analyzing of information. Instead of rote memorization of things read or noted, students must be able to apply their knowledge to solving problems or designing investigations (NRC 2015). In the process of pursuing inquiry, the students must go deeper in their learning to strengthen their understanding in a particular topic or area of science. Framework for K-12 Science Education points towards a deeper knowledge as its goal and gives the indication that when students becomes experts, “[they] understand the core principles and theoretical constructs of their field, and they use them to make sense of new information or tackle novel problems,” whereas students with only a surface knowledge “tend to hold disconnected and even contradictory bits of knowledge as isolated facts and struggle to find a way to organize and integrate them” (NRC 2012). Therefore, students who are literate in science are comfortable and confident to use the skills and practices gained from their investigations and apply them throughout their science education career and even for individual and social purposes (AAAS 1993).

Many students may experience a disconnect between science learned in a classroom and science experienced in their personal lives. Throughout Framework there is an emphasis on equity in education, or a strive towards supporting all students to reach the same higher level of science knowledge. This approach goes beyond just educational equality by addressing and using the culture (social and educational) of each student to engage the learner. The use of “inclusive instructional strategies encompass a range of techniques and approaches that build on students’ interests and backgrounds so as to engage students more meaningfully and support them in sustained learning” (NRC 2015). As students become more engaged, application of their growing knowledge can be used to spark interest in pursuing higher learning and STEM careers (NRC 1996). By meeting students where they are with phenomena or problems they experience and observe, the content of their education becomes more practical and personal.

The Roles of Teacher and Project in the Classroom

When a classroom focused on active learning is helpful in building and establishing an environment that fosters deeper learning and interest, then a research project is a valuable tool used with the curriculum. A fully developed project that incorporates research, writing, and presenting into the inquiry process utilizes common scientific practices to develop scientific knowledge (Cervetti and Pearson 2012). Additionally, a study that spans across lessons (possibly across units) benefits students to form a better-developed project by allowing more time to analyze and test their design (Khourey-Bowers et al 2012). When students are able to experience the complete process of forming a plan to investigate and find a solution for a problem, they begin to take ownership of the project and, consequently, the learning. Moreover, outside review of their projects and additional opportunities to communicate their findings further motivates students to evaluate and reflect on their work (English and Kitsantas 2013). For this purpose, science fairs become instrumental in students’ scientific growth.

A class project does not need to be one project to which every student contributes, nor is it a narrow topic that each student must then develop and carry out his or her own research. Both types may restrict students from pursuing issues that pique their interest, and, thus, their motivation. Students should be posed a question or theme that is broad enough to allow multiple sub-questions or categories for exploration (Krajcik 2015). Along with their personally selected topic, students should be given the
autonomy to design and carry out their research in order to create an open and stress-reduced environment (Bédard et al 2010). However, the students will need support as self-regulation in Project-based Learning is a learned process (English and Kitsantas 2013).

Carrying out an independent scientific investigation may be a new endeavor for a student. This is when the role of advisor, a characteristic of a Project-based Learning environment, is required. The teacher works to guide students into understanding and using the NGSS Scientific and Engineering Practices throughout their inquiry. Traditionally students have been instructed in utilizing the “Scientific Method” as a process to define, test, and evaluate a problem’s solution. However, this focus on a predetermined set list of steps in experimental design often overshadows the true aim of developing a deeper knowledge of science (NRC 2012). The Practices outline in Framework are not meant to be taught separate from science content, instead the Practices are meant to be used to aid students in researching and explaining phenomena (NRC 2000). The teacher does not direct students on how to develop and test ideas, but rather helps students naturally determine what information they need and what to do with it.

Designing a Classroom-integrated Research Project
For incorporating a research project into the class curriculum, the teacher may choose how to accomplish this in a way that best enables students to deepen their science knowledge. However, here is a list of suggested criteria for designing the activity:

1. **The student chooses his or her own research topic.** Many students may experience difficulty deciding on a topic. In this case, the teacher can help in formulating possible ideas, but the final topic must be appealing to the student on a somewhat personal level.

2. **Research should be done individually or in very limited groups.** If a group becomes too large, then work may not be distributed evenly, or a student may end up “along for the ride.” By keeping numbers small, it helps to ensure that the topic is of particular interest to those researching it.

3. **Other activities in the classroom should be in preparation for the final project.** Students should already have ample exposure to credible sources and mini-projects to ease them into a research project. Also, if students give a final oral presentation (recommended), then students should feel at ease presenting to their peers. Short activities promoting class interaction, group discussion and communication can help with this task.

4. **Students start working on the research project at the beginning of the school year.** The students will most likely not have the information or skills to start planning and performing testing, but they are capable to begin formulating questions. As the class progresses, the students will be able to develop their ideas even more.

5. **Provide a timeline of “check-ups.”** Periodic checks with students’ projects allow the teacher to recognize where help is needed. Furthermore, students may feel stress levels decrease later in the project timeline by requiring different parts finished over time.

These same criteria could be applied to research projects done in an extracurricular club, assuming that the club meets regularly.
Proper Usage of Laboratory Notebooks

Laboratory notebooks or research journals are important tools used by scientists to document their work. The notebook is used to store information—procedures, equipment specifications, data, and source references—to provide a central location to trace back all research and results. Guidelines for keeping a notebook can be tedious in order to provide integrity and legal credibility to the work recorded. Below are rules for keeping a laboratory notebook that can be omitted or modified as the teacher sees fit for the class:

1. **A laboratory notebook must have pages that are bound.** Loose-leaf pages in a 3-ring notebook or folder can be easily removed or misplaced.
2. **All entries must be written in permanent ink.** This is to prevent any data from being erased.
3. **Any corrections made to written data must have the original data crossed out with a single line, then signed and dated.** All work—including misspelled words, incorrectly transcribed information, or calculation errors—must still be legible to prevent any doubt as to why data was changed. An extra precaution would be to provide a brief explanation (at least two words) as to why the correction was made.
4. **The first page in the notebook includes the title for the project, the name of the researcher, and start/finish dates.** The start date refers to when the notebook is first written in. The finish date is added later when the book is full, or the project has been finished.
5. **Every page has a heading that includes the page number and the notebook title.** This prevents confusion while looking through the book, and the page is already titled in case a photocopy must be made.
6. **Each entry must begin with a date.** This provides a time reference for the work, and the researcher has verified the work as his or her own.
7. **Any additional sheets added to the notebook must be taped on one side, signed on a different side, and not covering anything written on the page.** Only taping one side of the sheet allows a reviewer to easily flip up the page to look for anything underneath. When signing on the side of the sheet, the signature must overlap onto the notebook page to give a reference for the original placement of the addition. Post-it notes are treated as additional sheets to be taped in the notebook in order to prevent any loss of data.
8. **Every page must be signed and dated when completed.** If a large space on the page is left blank, then a single line to slash through the area is drawn and signed/dated to prevent extra data from being added later.
9. **All materials must be listed with brand/manufacturer, lot number, and expiration date (if applicable).** Who made a material and when the material was made can have an effect on how that material performs. Including this information adds to the reproducibility of an experiment.
10. **Data kept electronically must use software that includes an audit trail.** The audit trail will keep track of what and when changes are made. The location of the data can be referenced in the notebook.
11. **After a page has been finished, the work (including any calculations) must be verified by an uninvolved person.** The verifier is not part of the research and will check for information that has been left out. In addition, the verifier will double-check all calculations.
Composition notebooks are used as laboratory notebooks in a school setting. In a corporate or industrial setting, notebooks specifically for laboratory use are ordered, and they already include sections on pages for necessary bookkeeping information (e.g. book title, page numbers, signature lines). For a single research project, a composition notebook might seem wasteful as the student most likely will not use the majority of the pages. Furthermore, as the student may be learning to use a laboratory notebook for the first time, graphic organizers may be more useful to guide the student with knowing what information must be included on the page. Though this contradicts the first rule in using a laboratory notebook (pages must be bound), an example graphic organizer is included as Attachment #1. Each page of the organizer can be used for a different day of collecting data, then all pages can be kept in a binder.

**Timelines to Guide Research**

Project timelines are useful for the student and teacher. As previously stated, using a project timeline helps break up the work for students and allows teachers to see where help may be needed. For every science research project, there are two main parts: 1) the background research, and 2) the experimental project. The background research is just as important as the actual experimentation as it helps the students conceptualize and refine what to test, and it requires time and guidance to enable the students to fully understand the various dimensions of scientific exploration. Below are two timeline proposals for the two main parts of a science research project. Deadlines are determined to prepare for participation in the Kansas Junior Academy of Science program with experimentation being performed in November, December, and January.

<table>
<thead>
<tr>
<th>Research Timeline</th>
<th>Project Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. List 3 possible topics—early September</td>
<td>1. List 3 different investigations from topic—late October</td>
</tr>
<tr>
<td>2. Find 1 source for each topic—early September</td>
<td>2. Find 1 source for each investigation—late October</td>
</tr>
<tr>
<td>3. Choose topic—mid September</td>
<td>3. Choose investigation, find 2 more sources (include journals)—early November</td>
</tr>
<tr>
<td>4. Give 5 sources (include journals)—late September</td>
<td>4. Turn in experimental design (investigation, controls &amp; variables, materials, procedure)—early November</td>
</tr>
<tr>
<td>5. Give 5 more sources (include expert interview)—early October</td>
<td>5. Turn in graphical display of findings—early February</td>
</tr>
<tr>
<td>6. Form Investigative Question/Problem—mid October</td>
<td>6. Turn in Abstract and rough draft of report for peer edit (≥2 peer edits)—mid February</td>
</tr>
<tr>
<td>7. Turn in outline of paper—late November</td>
<td>7. Turn in final draft of report—early March</td>
</tr>
<tr>
<td>8. Write Introduction/Background Information for paper—December</td>
<td>8. Turn in poster of project—early March</td>
</tr>
<tr>
<td>9. Turn in rough draft for peer edit (≥2 peer edits)—mid January</td>
<td>9. Present project to class—mid March</td>
</tr>
<tr>
<td>10. Turn in final draft of Introduction—late January</td>
<td></td>
</tr>
</tbody>
</table>

The Research and Project Timelines overlap as it is natural for some of the deadlines to correspond with each other. Both timelines begin by helping the student think of multiple ideas for his or her project, checking to see what additional information is already out there for the ideas, then narrowing down to
The Research Timeline focuses on “topics,” whereas the Project Timeline focuses on “investigations.” The two terms seem to be similar concepts, but are different in this case. See the following definitions of the bolded terms (in the order as seen in the timelines) for clarification.

1. **Topics.** The Topic is a broad category of observable traits, phenomena, or organisms. Once a singular topic is chosen, it should easily give way to an Investigative Question or Problem. Examples of topics include athletic performance, household cleaners, and plant species of the plains.

2. **Sources.** Sources can be a variety of media that the students use as references. However, students must take care to insure that their sources are credible. In the case of Scientific Evidence, journals are excellent sources as the material goes through editing and peer review. Scientific Evidence stems from research that provides statistical analysis over data to give accuracy to the results, as opposed to Anecdotal Evidence which usually does not have statistical significance due to lack of data. Though Anecdotal Evidence is not the best reference material to use for a scientific research paper, it can spark a curiosity over a topic to lead to choosing an investigation. Any first-hand or second-hand Anecdotal Evidence (from interviews or blogs) must be either supported or refuted with Scientific Evidence. Different from the Anecdotal Evidence, but still not able to stand on its own credibility is Wikipedia. Wikipedia pages are edited by a community of contributors who may or may not carry the necessary credentials to be experts. However, Wikipedia can be useful for finding sources through the “References” section on each page.

3. **Journals.** Science Journals are the best source for Scientific Evidence as they are peer reviewed and consistently released or published. Many journals are not free to access by the general public, but can be accessed online through school or public libraries. Students must be able to read the whole article to use it as a source, not just the abstract.

4. **Expert Interview.** This interview may be done in person, phone, or email. Not only is the expert interview helpful to students by providing direct answers to questions they may have, but it also serves as a way for students to learn more about possible job opportunities in a science field they find interesting.

5. **Investigative Question/Problem.** As sources are found for the topic, a student will gain more information on the topic and be able to pose a question that might not be answered specifically in his or her background research. An Investigative Question or Problem differs from a Hypothesis by not proposing a certain outcome to a problem. Referring to the aforementioned topic examples, an Investigative Problem for athletic performance could deal with sleep patterns or diet; household cleaners may include looking into the effectiveness of “green” and all-natural cleaners; and a look into invasive species on the indigenous plants of the plains can spark an investigation.

6. **Outline.** Assigning an Outline for the research paper is to aid the student. The students should organize the information researched and include quotes and paraphrases in the outline.

7. **Introduction/Background Information.** The introduction from the Research Timeline is more than a paragraph of information. This part is an actual research paper complete with citing of sources to show the researcher’s depth of knowledge on the topic that he or she has chosen.
a typical essay paper, a thesis is used to set the stage for the information presented. For this paper, the Investigative Question/Problem may act as the thesis. The purpose for requiring an in-depth look into a topic before deciding what to investigate specifically is to aid the student in making that decision.

8. **Peer Edit.** An important skill to have in science is the ability to examine and evaluate information. Peer Editing helps the writer and the editor. The writer will get feedback on their research and writing, and the editor will be stretched to analyze and critique another’s work. Editors should be required to leave comments to insure their completion of the task. See Attachments #2 and #3 for a possible Peer Edit Form.

9. **Investigations.** An Investigation is more specific than the Topic—it is the problem the student will be testing in his or her experiment. The Investigation is derived from the Investigative Question or Problem, and it serves as the next step to defining the Hypothesis (if needed). Using the example Investigative Problem of invasive species of plants, possible Investigations include the effect of urban sprawl on plant diversity, weather patterns and the amount of invasive species, or field burning and indigenous plant populations.

10. **Experimental Design.** This is the plan for the experimental project. Students must state exactly what they are testing by referring to the Investigation, controls, and variables. Students also outline the different testing done to ensure thorough research. It is crucial that students receive feedback from teachers on the design before they start experimentation. Feedback from peers might also be beneficial.

11. **Graphical Display.** The type of graphical display will be dependent on the testing done. However, a chart or table of numbers will not be sufficient. The display should be able to present data in a picture that will give the analyst and reader an overall view for comparison or trending.

12. **Abstract.** The abstract essentially acts as a summary to the report of the project. The abstract cannot be written until all work is completed the results have been analyzed. It is usually one paragraph long and includes information about the project, how it was carried out, and the results. Readers should be able to determine relevancy of a project to their own research based on reading the abstract.

13. **Report.** The Report is the final paper to be written by the student. It includes the Abstract, the Introduction, the Experimental Design (in paragraph form with citations), and the Graphical Display. All of these components have already been completed beforehand. Students must now include the results, analyses, and conclusions from their experimentation.

14. **Poster.** The Poster is an optional component to the research project. However, requiring it to be due before the final presentation can help promote the work and presentations if having a science fair. Posters include most of the information and graphics from the final report.

15. **Present.** Scientific work and discoveries would not be beneficial without sharing the information. Students will have assigned times to present their topic, investigation, and results to their peers and invited guests.

These terms and their placements in the timeline are modeled from the NGSS Scientific and Engineering Practices. Instead of providing a rigid project structure based on the more traditional Scientific Method,
students are guided to gain knowledge of their topics to form a full-developed plan of investigation that requires a transparency in their work, results, and conclusions. It is important to note that a Hypothesis is not included in the Timelines as it is not necessary in order to perform exploratory research.

Additional Resources

www.google/sciencefair.com
The Google Science Fair is an international science fair for middle and high school students. This website includes information for the fair as well has many interactive resources to aid students in their research process.

www.intel.com/education
The Intel site includes information on the Intel ISEF and STS. There are also many resources that teachers and students can use to help organize and sort information while researching.

www.nextgenscience.org
The Next Generation Science Standards were adopted in 2013 by Kansas. Teachers can find interactive versions of the standards on the website, as well as other articles and rubrics for incorporating the standards into the classroom.

www.npr.org
If students are needing more sources to provide inspiration for a topic, NPR has several programs that share science-related news stories. RadioLab is one program that features episodes dedicated to one topic or theme, and presents the information in a more entertaining way than a news report.

www.pbslearningmedia.org
The PBS Learning site includes many lesson plans and videos that can be used in a classroom. Students may use the videos to develop ideas for a science project.

www.sciencebuddies.org
Science Buddies features many resources for science activities, but also has a focus on science projects. The site features tools to develop a project idea and guides for performing a research experiment, then reporting the results.

www.societyforscience.org
The Society for Science and the Public was founded almost a century ago. It is a source of information on a few of the most prestigious science fairs (Including the Intel ISEF, STS, and Broadcom MASTERS), and it includes news and research resources for students.

www.understandingscience.org
Understanding Science is a joint effort by The University of California Museum of Paleontology and various scientists and teachers to communicate the nature of science. This site includes information about how science works and flowcharts for carrying out investigations.
References


Attachment #2: Introduction/Background Information Peer Edit Form

Paper Title__________________________________________

____________________________________________________________________________

Researcher(s)__________________________________________________________

What is the Topic of the paper?

What is the Investigative Question/Problem of the paper?

Did the paper cite at least 10 sources? -Yes- or -No- (circle one)

Number of Journals__________

Numbers of Expert Sources__________

Did the paper cite all sources within the body from the reference list? (Please list sources not cited.)

Did the paper address all Anecdotal Evidence with Scientific Evidence? (Please comment on Evidence addressed well or not addressed.)

Edited by _____________________________ | _____________________________
(Signature) (Print)
Attachment #3: Report Peer Edit Form

Paper Title

Researcher(s)

What was the Investigation?

Was the Method of the investigation understandable and easy to repeat? (Please leave comments here.)

Did the Graphical Display(s) allow you to easily compare or trend results without having to read over a data table? (Please leave comments here.)

Did the Conclusions of the research include an explanation to results (expected or otherwise)?

Did the report convey a “thoroughness” in the research, testing, and reporting of results? (Please leave comments here.)

Edited by ________________________________ | ________________________________

(Signature) | (Print)