

GEORGIA INSTITUTE OF TECHNOLOGY
CIVIL & ENVIRONMENTAL ENGINEERING

CEE 8824 SPECIAL TOPICS: ARTS & GEOMETRY

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COURSE DESCRIPTION

We will introduce students to the geometry of space and manifolds and how these concepts influenced modern arts and sciences, i.e. Cubism and Einstein's relativity. The realization of geometry is visualization. The course is integrated with weekly lab sessions taught by the Atlanta-based professional artist Rachel Grant, who will teach students fundamentals of several art mediums: pencil and charcoal drawing, oil painting, photography, three-dimensional (3D) sculptures and brainwave art using EEG technology. In particular, students will draw/sketch by hand in order to stimulate/enhance their visual memory, imagination and practice abstraction of geometric concepts. Special focus is put on both exact representation (Renaissance art) and geometric abstraction (cubism, modern Art). Students' artwork will be exhibited in the Mason Building.

WHY SHOULD YOU TAKE THIS COURSE?

Albert Einstein and Pablo Picasso, icons of the twentieth century have inspired generations of artists and scientists. Modern science is Einstein and modern art, Picasso. Albert Einstein's 1905 seminal paper on special relativity marks the beginning of modern sciences shaking the foundations of Newtonian physics. In 1907 Picasso had produced "Les Femmes d'Alger (O. J. R. M.)" the painting that brought art into the twentieth century and initiated the cubism movement. At the core of these rebellious changes was the debate about representation versus abstraction. In art, realism, perfection, figuration have dominated since the Renaissance. The twentieth century marked the emergence of a strong countermovement represented by the postimpressionism of Paul Cézanne. In Science, mathematicians started to explore exotic non-Euclidian geometries in dimensions greater than three, especially four-dimensional spaces, with its implication of motion in space or time. Furthermore, there was the discovery of the conceptual quality of African art that influenced Picasso and other artists enormously. All of these ideas helped Picasso to free himself from earlier constraints of thinking, perfection and exact perspectives. He undertook the intellectual quest of reducing forms to geometry, leading to cubism. Picasso's exploration of space in his groundbreaking Les Femmes d'Alger employed notions of four-dimensional space, non-Euclidean geometry, spacetime simultaneity and the fourth dimension. Picasso discovered geometry as the language of the new art thanks to Poincaré's insights on time and simultaneity. These were also inspirational to Einstein's discovery of relativity. Both Picasso and Einstein realized that we couldn't trust our senses when thinking about space and time. As a result, art and science become means for exploring the world surrounding us beyond perceptions, beyond appearances. Picasso believed that direct viewing, exact perspective and realism of the Renaissance art are deceiving and his cubism proposes a new notion of aesthetics. Picasso's new aesthetic for the Femmes was the reduction of forms to geometry. Einstein's approach to space and time was not primarily mathematical. To Einstein, the Maxwell equations missed an aesthetic symmetry, which was essential to his discovery of relativity.

LEARNING OBJECTIVES

Overall, a course on Arts and Geometry has the potential to foster a holistic learning experience that combines artistic creativity, mathematical rigor, and critical thinking, preparing students to apply these skills in various academic and professional pursuits.

- we aim at freeing students' minds from mechanistic concepts and recipes when they approach the solution of a problem towards an abstraction to the essential elements and forms of the solution.
- Enhance students' observational skills by drawing from life like Leonardo da Vinci and Vincent van Gogh did. Enhance students' engineering drawing skills to capture the essential elements of nature using gestures and geometry.
- Learn notions of differential geometry to understand non-Euclidean geometries and how these concepts influenced the breakthrough in Modern Sciences and Arts: Einstein's relativity and Picasso's cubism.
- Acquire a general understanding of concepts from a geometric perspective, in particular Einstein's general relativity and gravitational waves, Artificial Neural Networks (ANN), Machine learning (ML).

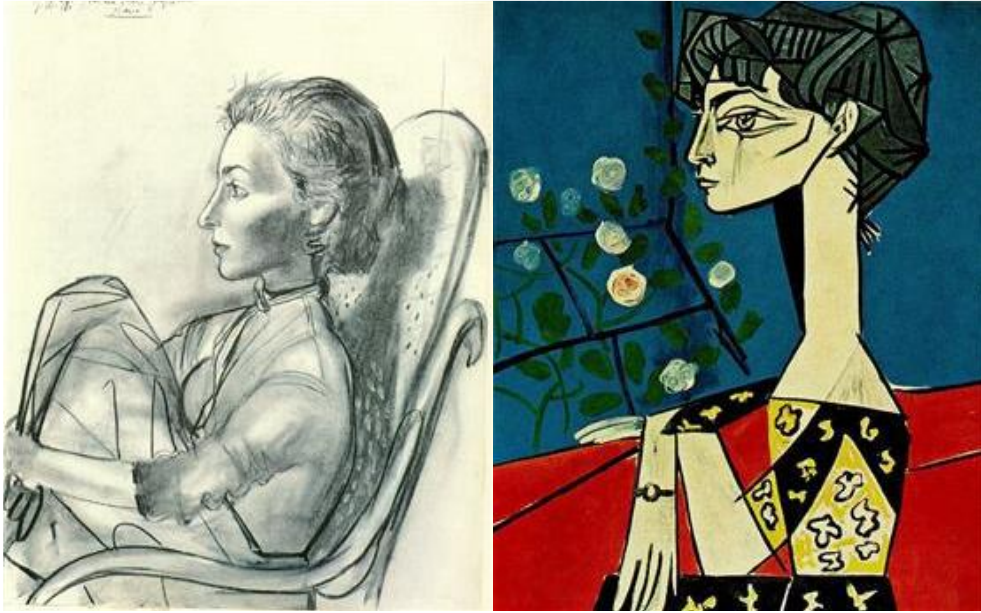


Figure 1: Picasso drawing (left) and painting (right)

LEARNING OUTCOMES

Teaching Arts and Geometry can lead to various learning outcomes, such as developing a deeper appreciation for the intersection of artistic creativity and mathematical principles, enhancing spatial reasoning skills, fostering critical thinking by analyzing geometric patterns in art, and inspiring students to create their own innovative artworks that incorporate geometric concepts.

Enhanced observational skills: students practice drawing from life like Leonardo da Vinci and Vincent van Gogh did. This enhances students' drawing skills to capture the essential elements of nature using gestures and geometry.

Enhanced Visual Communication: Students can improve their ability to visually communicate ideas through the use of geometric shapes and patterns, allowing them to convey complex concepts in a concise and engaging manner.

Cultural and Historical Awareness: Exploring art history and historical use of geometry in various art forms can deepen students' understanding of cultural contexts, enabling them to connect art to its historical and societal significance.

Interdisciplinary Thinking: The course can encourage students to think across disciplines, bridging the gap between art and mathematics and sparking innovative ideas that blend both fields.

Problem-Solving Skills: Analyzing and creating art using geometric principles can sharpen students' problem-solving skills as they work to balance aesthetic appeal with mathematical accuracy.

Creative Expression: By experimenting with arts, students can discover new ways to express themselves artistically, expanding their creative repertoire.

Spatial Visualization: Engaging with geometric concepts in art can improve students' ability to mentally manipulate and visualize three-dimensional objects and spaces.

Geometry Application: Students may gain practical knowledge of geometry's real-world applications, from architecture and design to computer graphics and engineering.

Artistic Exploration: The course can inspire students to explore different artistic mediums, from painting and sculpture to digital art and installations, all while integrating geometric principles.

Collaborative Learning: Assignments and discussions centered around Arts and Geometry can promote collaborative learning, where students exchange ideas and perspectives to enrich their understanding of both subjects.

Portfolio Development: Through the creation of original artworks, students can develop a portfolio showcasing their mastery of arts and geometric concepts

PAST ART EXHIBITS

- Dec 11, 2018 “Like Picasso & Einstein: lines, forms and dimensions” at *Kai Lin Art Gallery*, Atlanta

CEE News: <https://ce.gatech.edu/news/art-and-geometry-exhibition-features-student-art-inspired-einstein-and-picasso>

YOUTUBE video: <https://www.youtube.com/watch?v=c0WjBoWJQKo>

- Dec 11, 2019 “Form and Expression: Artistic Lines from Analytical” at *Georgia Tech School of Civil & Environmental Engineering, Mason Building* Atlanta

YOUTUBE video: <https://www.youtube.com/watch?v=lmRfgl5EORc>

- Dec 14, 2021 “Expressions of Analytical Minds” at *Georgia Tech School of Civil & Environmental Engineering, Mason Building* Atlanta

YOUTUBE video: <https://www.youtube.com/watch?v=zhVlnawkDCw>

- Science.Art.Wonder Campus Exhibit April 8, 2022: “**Mind Melody**” in the Hodges Room of the Centergy Building on Georgia Tech’s Campus. “Mind Melody” is a brain art performance of dance, painting, and geometry. It fuses art and EEG technology to explore brainwaves as inspiration for visual art, music, and movement.

YOUTUBE: <https://www.youtube.com/watch?v=ZB7Gk11VZFM>

- Science.Art.Wonder April 17, 2023: “**Mind Blues & Brain Turbulence**” in the Atlantic theater at Georgia Tech. A brain art performance of dance, piano, painting, and fluid mechanics. It fuses art and EEG technology to explore brainwaves as inspiration for visual art, music, and movement.

YOUTUBE: <https://www.youtube.com/watch?v=r8uh-JLxU4U>

- “Expressions of Analytical Minds” Student Art Exhibit Dec 14 2021 at *Mason building, Georgia Tech*, Atlanta in completion of the Special Topics Course “Arts & Geometry”

YOUTUBE: <https://www.youtube.com/watch?v=zhVlnawkDCw>

COURSE MATERIALS

- Fedele’s class notes.
- Arthur J. Miller 2001 Einstein, Picasso, Space, Time, and the Beauty That Causes Havoc. Perseus Books Group
- The Geometry of Physics: An Introduction 3rd Edition by Theodore Frankel
- Elie Cartan, [Lessons on Integral Invariants](#)
- Walt Reed The Figure: The Classic Approach to Drawing & Construction <https://www.amazon.com/Figure-Classic-Approach-Drawing-Construction/dp/0891340971>

GRADING

Geometry Homework	30%
Art Studio assignments	30%
Final Project	35%
In-Class attendance	5%

COURSE GRADING SCALE

$$90 < A \leq 100$$

$$80 < B \leq 90$$

$$70 < C \leq 80$$

$$60 < D \leq 70$$

$$F \leq 60$$

Mental Health and Well-Being

We will practice 5-min meditation at the beginning of class. Introducing meditation in the classroom can positively impact students' well-being by promoting relaxation, focus, and emotional regulation. It can help reduce stress and improve concentration, leading to a more conducive learning environment.

COURSE POLICY

- In-Class attendance: if you miss less than 4 classes (including art labs) you will receive 5% toward your grade. Signatures will be collected in class.
- Plagiarizing is defined by Webster's Dictionary as "to steal and pass off (the ideas or words of another) as one's own: use (another's production) without crediting the source." If caught plagiarizing, you will be dealt with according to the GT Academic Honor Code.
- Cheating off of another person's test is unethical and unacceptable. Cheating off of anyone else's work is a direct violation of the GT Academic Honor Code, and will be dealt with accordingly.
- For any questions involving these or any other Academic Honor Code issues, please consult the instructor or www.honor.gatech.edu.
- Homework and Art studio Lab assignments: We expect to receive your submissions posted in Canvas by the due time. Canvas automatically assigns a **zero grade** to a late submission.
- You may work with other classmates to solve/prepare homework and lab assignments. However, you must turn in separate versions with the following written on it: your name and the names of everyone you collaborated with.
- Unauthorized use of any previous semester course materials, such as tests, quizzes, homework, projects, and any other coursework, other than that provided by the instructor, is prohibited in this course. Using these materials will be considered a direct violation of academic policy and will be dealt with according to the GT Academic Honor Code. For any questions involving these or any other Academic Honor Code issues, please consult the instructor or www.honor.gatech.edu.
- **Office Hours:** to meet students' requirements, needs, and comfort levels, meetings and office hours will be offered in-person, virtually, or outdoors.
- Students are expected to be familiar with and abide by the Institute guidelines, information, and updates related to Covid-19. Find campus operational updates, Frequently Asked Questions, and details on campus surveillance testing and vaccine appointments on the [Tech Moving Forward site](#).
- **Recordings of Class Sessions and Required Permissions:** classes may not be recorded by students without the express consent of the instructor unless it is pursuant to an accommodation granted by the Office of Disability services. Class recordings, lectures, presentations, and other materials posted on Canvas or Piazza are for the sole purpose of educating the students currently enrolled in the course. Students may not record or share the materials or recordings, including screen capturing or automated bots, unless the instructor gives permission.

POLICY ON ART STUDIOS, HOMEWORK AND FINAL PROJECT

- Fundamentals of several art mediums will be taught during the weekly art labs: pencil and charcoal drawing, painting, sculptures, photography and brainwave art using EEG technology.
- There will be two kinds of homework. Art homework will be assigned to assess students' comprehension of Art history and to learn about the life and artwork of famous artists and masters. Geometry homework will be assigned to assess students' comprehension of geometrical concepts to describe manifolds and their applications to solid body mechanics and relativity.
- Art studio assignments consist on the execution of sculptures, photography, brain arts, paintings and drawings of various kinds (still life objects, perspectives, figure drawing portraits, etc.) using graphite, charcoal or ink.
- The final project consists on the execution of a still life drawing, oil painting self-portrait, 3d sculptures, and photography as well as brain arts. At the end of the semester, students' artwork will be then exhibited in the Mason building.

AI-based Assistance POLICY

We treat AI-based assistance, such as Open AI ChatGPT, Dall-e, etc., the same way we treat collaboration with other people: you are welcome to talk about your ideas and work with other people, both inside and outside the class, as well as with AI-based assistants.

However, all work you submit must be your own. You should never include in your assignment anything that was not written directly by you without proper citation (including quotation marks and in-line citation for direct quotes).

Including anything you did not write in your assignment without proper citation will be treated as an academic misconduct case. If you are unsure where the line is between collaborating with AI and copying AI, we recommend the following heuristics:

Heuristic 1: Never hit "Copy" within your conversation with an AI assistant. You can copy your own work into your own conversation, but do not copy anything from the conversation back into your assignment.

Instead, use your interaction with the AI assistant as a learning experience, then let your assignment reflect your improved understanding.

Heuristic 2: Do not have your assignment and the AI agent open at the same time. Similar to the above, use your conversation with the AI as a learning experience, then close the interaction down, open your assignment, and let your assignment reflect your revised knowledge.

This heuristic includes avoiding using AI directly integrated into your composition environment: just as you should not let a classmate write content or code directly into your submission, so also you should avoid using tools that directly add content to your submission.

Deviating from these heuristics does not automatically qualify as academic misconduct; however, following these heuristics essentially guarantees your collaboration will not cross the line into misconduct.

OFFICE OF DISABILITY SERVICES

The Georgia Institute of Technology has policies regarding disability accommodation, which are administered through The Office of Disability Services (<http://disabilityservices.gatech.edu/>). For students with disabilities, please contact this Office to request classroom accommodations.

COMMUNICATION PROTOCOL

- All questions regarding lectures/homework will be addressed through the venue of PIAZZA (www.piazza.com).
- I will ONLY reply to emails concerning topics/issues that cannot be addressed via PIAZZA.
- Students are strongly encouraged to participate to discussions in PIAZZA so they can learn from their peer colleagues.
- SUBJECT line in email: SUBJECT: CEE8824- Meaningful Tag Line. Family name

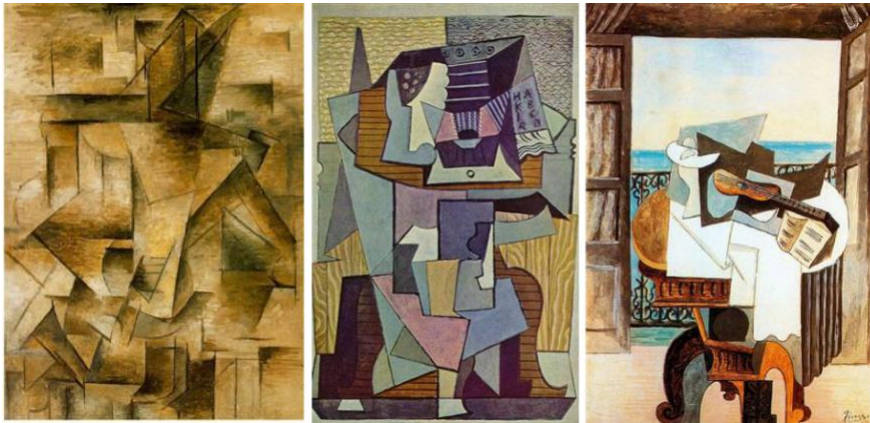


Figure 2: Picasso paintings

COURSE TOPICS

HISTORY OF THE ARTS

Week 1: From the Renaissance to the Modern Art period.

Weeks 2: Studying the Masters of Arts: Giotto, Botticelli, Leonardo da Vinci, Raffaello, Michelangelo, Rubens, Bernini, Caravaggio, Titian, Giorgione

Weeks 3: Studying the Masters of Arts: Vincent Van Gogh, August Renoir, Claude Monet, Eduard Manet, Berthe Morisot, Paul Cezanne, Pablo Picasso, George Braque, Amedeo Modigliani, Henri Matisse, Marc Chagall, Andre' Lhote, Tamara de Lempicka, Edward Hopper, Wassily Kandinsky, Piet Mondrian, Giorgio de Chirico, Mark Rothko, Jackson Pollock

Week 4: Einstein versus Picasso. Picasso artwork: blue period, rose period, African period, Analytical and synthetic Cubism period, late years; Influence of geometric and esthetics concepts on both sciences and arts. Poincaré's insights on time and simultaneity and their influence on the discovery of Einstein's relativity and Picasso's cubism.

GEOMETRY

Week 5: Vector spaces, scalar and wedge products, covariant and contravariant vectors, dual spaces

Week 6: Dual spaces, covectors, Cartan's differential forms, variational calculus.

Week 7: Geometry of manifolds: intrinsic formulation, the concepts of chart and atlas, Tangent and Cotangent spaces, tangent and cotangent bundles, concept of metric

Week 8: Covariant derivative, fiber bundles, geometric connections, parallel transport, geodesics, geodesic equations

Week 9: geodesic deviations, Riemannian curvature tensor, Ricci tensor, Bianchi's identity.

APPLICATIONS

Week 10-11: Geometric approach of rigid-body mechanics; Lagrangian and Hamiltonian of a free particle and rigid bodies, holonomic and non-holonomic constraints.

Week 12: Special relativity, time and space are relative

Week 13-14: General relativity and Einstein's equations

Week 15: Wave phenomena: what is a wave? Definitions, Properties, Wave dispersion and physical examples, Einstein's gravitational waves

ART LABS**Week 1:** Skill Assessment, Introductory Exercises

Class introductions, art materials

Exercise 1: Still life assessment

Exercise 1: Upside-down line drawing

Exercise 2: left hand

Introduction to photographing your artwork

Assignment 1: Line Drawing & Practicing your photos.

Week 2: Introduction Elements and Principles of Design

Introduction to positive and negative space

Exercise 3: negative space drawing with charcoal

Introduction into critique.

Exercise: critique artist work

Exercise: critique negative space exercise.

Assignment 2: Negative space drawing

Week 3: Contour Line Drawing

Viewfinder

Pencil angle

Shapes at an angle

Exercise: shapes and perspective

Assignment 3: Shoe Drawing

Week 4: Perspective

1, 2, 3 point perspective, atmospheric perspective & foreground, middle ground and background

Exercise perspective 1 point

Exercise perspective 2 point & 3

Introduction to Picasso's multiple perspectives

Assignment 4: Multi-perspective Drawing (Picasso inspired)

Week 5: Value and shading with graphite

Introduction into Value, Shading and Chiaroscuro

Exercise: Gradient scale with charcoal

Introduction to shading techniques: hatching, cross hatching, stippling, and blending

Exercise: 4 graphite gradient scales

Light on a sphere

Exercise: light on a sphere

Assignment 5: Chiaroscuro Shape Drawing

Week 6: Gesture Drawing:

Introduction to gesture figure drawing & proportion

Exercises: Figure Drawing

Assignment 5: 3- 30 min multigure gesture drawings showing movement

Week 7: Color theory

Introduction to Primary, secondary and tertiary colors, shades and tints, analogous & compliments, and mark making

Exercises: Color wheel, shades, and tints, compliments, and mark making

Assignment 6: Add Shades and tints to 1 gesture drawing

Week 8-9: Self Portrait

Introduction into working with a grid.

Exercise: One grid square collaborative group exercise

Assignment 6: Brainstorm Worksheet (self portrait ideas realism/symbolic, added distortion), practice sketch

Week 10: Idea discussion and Self Portrait work time

Individual student meetings with instructor during class

Worktime: Grid and begin self-portrait (Student Choice: Regular grided portrait or distorted grid portrait realistic or symbolic)

Assignment 9: Complete line drawing of self portrait and paint self portrait

Week 11: Paper Clay

Sculpture Introduction & Armature and form

Exercise- joining techniques and form

Assignment: 3 joined forms sculpture

Week 12-14: Brain Art

Introduction To Brain Art

Week 15: Art show preparation,

Still Life growth of skill assessment

Final critique of grided self-portrait lesson

Presentation of Brain Art

Choosing and preparing work for final show

Art Material list

Art Supplies	Details	Links
Vine Charcoal	Soft *Bring to first day	Blick Studio Vine Charcoal - Soft, Box of 12 BLICK Art Materials (dickblick.com)
Compressed Charcoal		Alphacolor Charcoal - Black , Pack of 3 BLICK Art Materials (dickblick.com)
Charcoal Pencil		
Pack of 6 drawing pencils	8B,6B,4B,2B,B,HB, 2H 4H *Bring to first day	Blick Studio Drawing Pencils - Set of 12 BLICK Art Materials (dickblick.com)
Kneaded eraser brand?	3 small	Blick Kneaded Eraser - Small BLICK Art Materials (dickblick.com)
White eraser	*Bring to first day	Prismacolor Magic Rub Eraser BLICK Art Materials (dickblick.com)
Pencil sharpener	*Bring to first day	
ruler	*Bring to first day	
Blender/gray paper stump	*Bring to first day	Pro Art Blending Stumps - Medium, Pack of 3 BLICK Art Materials (dickblick.com)
Spray Fixative (hairspray is a substitute)		Krylon Workable Matte Fixatif BLICK Art Materials (dickblick.com)
Newsprint pad	Size: 18"x24" *Bring to first day	Blick Studio Newsprint Pad - 18" x 24", 100 Sheets BLICK Art Materials (dickblick.com)
One 5x7 notecard or stiff paper	Viewfinder [we will review making this in class] Cut 4" x 3" rectangle window from 5" x 7" notecard or stiff paper	
Strathmore 400 Series Drawing Paper Pad	Size: 18 x 24" *Bring to first day	Strathmore 400 Series Drawing Paper Pad - 18" x 24", 24 Sheets BLICK Art Materials (dickblick.com)
Roll of Paper Towels		
Carboard easel or nicer easel	You can make this yourself. *Bring to first day	https://www.artbarblog.com/diy-cardboard-easel/
Will not need these until October 6		
Acrylic Paint	<i>Blick Studio Paints</i> <i>Red: cadmium red medium, primary red</i> <i>Yellow: primary yellow, cadmium yellow</i>	https://www.dickblick.com/products/daler-rowney-graduate-acrylics/ (good starter set but smaller amounts)

	<i>Blue: primary, ultramarine blue</i> <i>White: titanium white,</i> <i>Brown: burnt umber</i> <i>Black Ivory</i>	Or you need the colors listed in the column to the right. I recommend Blick Studio Paints but other brands are fine, some of the names might be different.
Plastic cup	Can be disposable, for paint water	
Synthetic Paint brushes	One large flat brush, ¾ or 1 inch wide One medium filbert brush (I like a ½ and ¼ inch for detail) One small/medium bright brush two small round brush <i>Ensure that they are for acrylic paints</i>	Blick Scholastic Wonder White Brushes, Set of 6 BLICK Art Materials (dickblick.com) Or Blick Essentials Brown Nylon Value Brush Sets BLICK Art Materials (dickblick.com) Or Princeton Real Value Brush Set - 9140, White Taklon, Short Handle, Set of 6 BLICK Art Materials (dickblick.com)
Dura-lar Wet media film	20" x 25" 2 sheets	https://www.dickblick.com/items/grafix-wet-media-film-pad-20-x-25/
Canvas	11" x 14"	Blick Academic Cotton Stretched Canvas Pack - 11" x 14", Pkg of 2 BLICK Art Materials (dickblick.com)
Pallet knife		Richeson Plastic Painting Knife - 3", Trowel Offset BLICK Art Materials (dickblick.com)
Pallet paper pad	9"x12"	Blick Palette Paper Pad - 9" x 12", 50 Sheets BLICK Art Materials (dickblick.com)
Paper Clay	4oz or 8oz, depends on size of project	https://www.dickblick.com/products/creative-paperclay/
Optional Materials:	Details	Links
Portfolio to hold artwork	19" x 26"	Blick Mesh Zipper Bag - 24" x 32" BLICK Art Materials (dickblick.com)
Graphite stick		General's Wide Compressed Graphite Sticks BLICK Art Materials (dickblick.com)
Clip Drawing Board	23 x 26"	https://www.dickblick.com/items/blick-sketch-pad-board-23-12-x-26/
Clips	Exacto bulldog (you really only need 4)	X-Acto Bulldog Clip - No. 4 Clips, Box of 12 BLICK Art Materials (dickblick.com)
easel	Listed a few options. There are much nicer	https://www.dickblick.com/items/jullian-table-easel-jt3/

	ones available if you have the budget/desire for it. These are just easily portable tabletop options that are fairly low-cost	or https://www.dickblick.com/products/blick-studio-table-easel-by-jullian/ or any one you want really https://www.dickblick.com/products/blick-studio-table-easel-by-jullian/
Sketchbook	Unlined paper, 8.5" x 11"	
Suggested Retailers:	Website	Address
Blick	Art Supplies BLICK Art Materials (dickblick.com)	878 Peachtree St NE, Atlanta, GA 30309
Sam Flax	Sam Flax Atlanta	1495 Northside Drive NW Suites B and C, Atlanta, GA 30318
Jerry's Artarama	Art Supplies and Materials Jerry's Artarama (jerrysartarama.com)	Online Retailer
Michaels	Michaels Stores – Art Supplies, Crafts & Framing Michaels	2625 Piedmont Rd NE, Atlanta, GA 30324
Hobby Lobby	Hobby Lobby Arts & Crafts Stores	2955 Cobb Pkwy SE, Atlanta, GA 30339