Supplement

This supplement provides additional information on corpus identification, sampled courses, and coding procedures.

S1.Corpus Identification and Screening Process

This study used purposive multiple-case sampling to identify information-rich courses that illustrate how Earth observation (EO) and associated geospatial knowledge and practices, including remote sensing, Digital Earth, and GIS-supported geospatial analysis, are incorporated into broad-access undergraduate curricula in selected APEC higher-education contexts. Case identification followed a dual-path workflow: (1) exploratory searching and known-item verification (Path A), and (2) systematic keyword searching and staged screening (Path B). Both paths were subjected to final document verification against the inclusion criteria. The appendix provides the search strings, screening procedures, and corpus formation records underlying the final sample of 20 courses.

TableS1. Keyword Search Strings Used in Path B

Search ID	Final Search String	Search Purpose	Search Date
S01	“earth observation” “general education” university course	EO + GE course identification	27–28 April 2026
S02	“remote sensing” “general education” undergraduate course	Remote sensing + GE course identification	27–28 April 2026
S03	“GIS” “general education” undergraduate course	GIS + GE course identification	27–28 April 2026
S04	“geospatial data” “general education” university course	Geospatial data + GE course identification	27–28 April 2026
S05	“remote sensing” “general education” “Asia Pacific” course	Regional supplementary search	27–28 April 2026
S06	“Digital Earth” “general education” “Asia Pacific” course	Regional supplementary search	27–28 April 2026
S07	“GIS” undergraduate course syllabus “general education”	Course-document retrieval	27–28 April 2026
S08	“geospatial data” “liberal education” university course	Alternative GE terminology search	27–28 April 2026
S09	“earth observation” “general education” “Asia Pacific”	Regional EO + GE search	27–28 April 2026
S10	“GIS” “general education” “Asia Pacific” university	Regional GIS + GE search	27–28 April 2026
S11	“Digital Earth” undergraduate course university	Digital Earth supplementary search	27–28 April 2026
S12	“earth observation” “Asia Pacific” university course	Regional EO supplementary search	27–28 April 2026

TableS2. Dual-Path Corpus Identification and Screening Process

Path	Stage	Description	Number
Path A: Exploratory search and known-item verification	Initial identification	Exploratory Google and institutional website searches used to identify potential information-rich cases.	13 candidate courses
Path A: Exploratory search and known-item verification	Verification	Courses verified against official webpages, course titles, course codes, and institutional records.	13 retained
Path B: Systematic keyword searching and staged screening	Initial retrieval	Records identified through 12 targeted keyword searches.	360 records
Path B: Systematic keyword searching and staged screening	Deduplication	Duplicate URLs, repeated records, and cross-listed entries removed.	340 unique records
Path B: Systematic keyword searching and staged screening	Round 1 screening	Records screened for undergraduate course relevance and visible EO/geospatial content.	76 records advanced to Round 2 screening
Path B: Systematic keyword searching and staged screening	Round 2 screening	Eligibility screening based on inclusion criteria and documentary availability.	7 courses retained
Combined corpus	Final sample	Verified courses from both paths combined for qualitative document analysis.	20 courses (13 Path A + 7 Path B)

Table S3. Inclusion and Exclusion Criteria

Criterion	Included	Excluded
Educational level	Undergraduate courses	Graduate-level or professional training courses
Course orientation	Broad-access/general education courses or courses designed for non-specialist undergraduate audiences	Major-specific technical training courses
Content relevance	Substantive engagement with EO-derived information, satellite imagery, remote sensing, Digital Earth, GIS-supported geospatial analysis, or related spatial evidence practices	Courses without meaningful engagement with EO or geospatial evidence-related learning.
Institutional scope	Courses offered by higher-education institutions in selected APEC contexts	Institutions outside the study scope
Documentation availability	Publicly accessible syllabi, course descriptions, handbooks, or official curriculum pages	Insufficient public documentation for qualitative analysis

S2.Final Sampled GE Courses and Documentary Sources

This appendix lists the 20 undergraduate general education (GE) courses included in the final corpus. The table records institutional information, course characteristics, and the publicly available documentary sources used for qualitative analysis. Documentary evidence was collected from official institutional materials, with course syllabi used where available and supplemented by official course webpages, university catalogues, teaching handbooks, general education listings, or other relevant institutional documents when syllabi were not publicly accessible.

Table S4. Sampled courses and documentary sources

Sample ID	Institution	Country/ Region	Course code and title	GE orientation	Documentary source type(s)	Source link(s)
C01	The Hong Kong University of Science and Technology (HKUST)	Hong Kong, China	CIVL1180: Monitoring Changing Climate from Space	GE course for non-specialist undergraduates	Syllabus	https://seng.hkust.edu.hk/sites/default/files/IMCE/UG/Course%20Syllabus/Fall_2025-2026/CIVL1180_Fall_25-26.pdf
C02	The University of Hong Kong (HKU)	Hong Kong, China	CCST9083: Earth as Seen by Satellite	Common Core GE course for non-specialist undergraduates	Course webpage; Program-level syllabus	https://commoncore.hku.hk/ccst9083/ https://www4.hku.hk/pubunit/drcd/files/ugdr2025-26/All/Common_Core.pdf
C03	The Chinese University of Hong Kong (CUHK)	Hong Kong, China	UGEB2132: Earth as Seen from Space	GE course for non-specialist undergraduates	Course webpage; Official curriculum documents; Supplementary teaching-development report	https://www.grm.cuhk.edu.hk/en/general-education-courses/ https://rgsntl.rgs.cuhk.edu.hk/aqs_prd_applx/public/handbook/view_document.aspx?id=1622&lang=en&seq=1 https://www.cuhk.edu.hk/eLearning/c_tnl/cdgs/2019-22%28Round%201%29/report/004%20Final%20report.pdf
C04	Salem State University	USA	GPH 344: Remote Sensing: Studying the Earth From Space	Scientific Reasoning GE course for non-specialist undergraduates	Course webpage; Course catalogue	https://www.salemstate.edu/geography/courses https://catalog.salemstate.edu/preview_course_nopop.php?catoid=62&coid=97738
C05	The University of Iowa	USA	SEES:1035: Our Digital Earth	GE course for non-specialist undergraduates	Course webpage; Course catalogue	https://catalog.registrar.uiowa.edu/courses/sees/ https://myui.uiowa.edu/my-ui/courses/course-search.page?query.courseSubject=SEES1035&query.onlyOffered=false&query.sessionCode=20253&search=
C06	University of Oregon	USA	GEOG 181: Our Digital Earth	GE course for non-specialist undergraduates	Course catalogue; General education listing; Course webpage; Historical syllabus	https://catalog.uoregon.edu/courses/crs-geog/ https://catalog.uoregon.edu/genedcourses/ https://duckweb.uoregon.edu/duckweb/hwskdhnt.p_viewdetl?crn=12259&term=202401 https://cpb-us-e1.wpmucdn.com/blogs.uoregon.edu/dist/3/5358/files/2014/01/Geography_181_Syllabus-ynywal.pdf

C07	The Pennsylvania State University	USA	GEOG 160: Mapping Our Changing World	General Education course (Social and Behavioral Sciences) for non-specialist undergraduates	Course catalogue; Syllabus	https://bulletins.psu.edu/search/?search=GEOG+160&psusearchname=%2Fsearch%2F&caturl=%2Funiversity-course-descriptions https://www.e-education.psu.edu/geog160/syllabus
C08	University of Maryland	USA	GEOG 172: Earth from Space	GE course for non-specialist undergraduates	Syllabus; Course webpage	https://exst.umd.edu/sites/default/files/2024-06/tys_GEOG172_sample_syllabus.pdf https://exst.umd.edu/sites/default/files/2021-07/tys_GEOG172_course_syllabus_21.pdf https://app.testudo.umd.edu/soc/202601/GEOG/GEOG172
C09	The Hong Kong Polytechnic University (PolyU)	Hong Kong, China	LSGI1001： Big Earth Data and Geospatial AI	Level 1 GE course for non-specialist undergraduates	Syllabus	https://www.polyu.edu.hk/lsgi/-/media/department/lsgi/content/study/lsgi-subject-pdf/level-1/lsgi1001_jun-2022.pdf
C10	San Diego State University (SDSU)	USA	GEOG 104: Geographic Information Science and Spatial Reasoning	GE course for non-specialist undergraduates (Quantitative Reasoning)	Course webpage; Syllabus; Course catalogue	http://map.sdsu.edu/geog104/ https://map.sdsu.edu/geog104/syllabus.html https://catalog.sdsu.edu/preview_course_nopop.php?catoid=11&coid=81103
C11	The University of Texas at Dallas (UT Dallas)	USA	GISC 2305: Spatial Thinking and Data Analytics	GE-oriented course for non-specialist undergraduates	Course catalogue; Historical syllabi	https://catalog.utdallas.edu/2024/undergraduate/courses/gisc2305 https://dox.utdallas.edu/syl113746 https://dox.utdallas.edu/syl56138
C12	San José State University (SJSU)	USA	GEOG 107: Mapping the World	GE course for non-specialist undergraduates	Course catalogue; Syllabus	https://catalog.sjsu.edu/preview_course_nopop.php?catoid=10&coid=43149 https://www.sjsu.edu/urbanplanning/docs/syllabi/spring-2025/25SpGEOG107-01_Ren.pdf
C13	North Carolina State University (NC State)	USA	ES 113: Earth from Space	GEP course for non-specialist undergraduates	Course catalogue; Course webpage; GEP listings	https://catalog.ncsu.edu/course-descriptions/es/ https://wolfware.ncsu.edu/courses/details/ https://catalog.ncsu.edu/undergraduate/gep-category-requirements/gep-natural-sciences/ https://catalog.ncsu.edu/undergraduate/gep-category-requirements/gep-global-knowledge/
C14	Hirosaki University	Japan	The World of Engineering: remote sensing	Liberal education course for non-specialist undergraduates	Syllabus	https://gkm.hirosaki-u.ac.jp/syllabus/syllabus_2024/syllabus_2024_13/13/13_1242100059_ja_JP.html
C15	University of	New	ENV 103: Digital Earth	Stage 1	Course catalogue;	https://study.auckland.ac.nz/ords/r/uoa/catalogue/course?p6_code=ENV+

	Auckland	Zealand		broad-access undergraduate course for non-specialist learners	School of Environment webpage	103 https://www.auckland.ac.nz/en/science/about-the-faculty/school-of-environment/New-stage-one-courses.html
C16	University of Victoria	Canada	GEOG 104: Our Digital Earth	Introductory undergraduate course for non-specialist learners	Course outline; Department course webpage	https://www.uvic.ca/socialsciences/geography/_assets/docs/course-outline/2025/spring-2025/geog_104_202501_outline_boulangerlapointe.pdf https://www.uvic.ca/socialsciences/geography/students/undergraduate-courses/index.php
C17	University of Washington	USA	GEOG 495C: Critical Remote Sensing	GE course for undergraduate students	Course webpage; Syllabus	https://geography.washington.edu/courses/2023/winter/geog/495/c
C18	University of Washington	USA	ESRM190 / ENVIR295: Digital Earth	100-level broad-access undergraduate course for non-specialist learners	Course webpage	https://sites.uw.edu/digitalearth/
C19	The University of Texas at Dallas (UT Dallas)	USA	GEOS/EPPS/GISC 2307: Digital Earth	Core curriculum course for non-specialist undergraduates	Course catalogue; Syllabus	https://catalog.utdallas.edu/2025/undergraduate/courses/epps2307 https://dox.utdallas.edu/syl159987
C20	Missouri State University	USA	GEO 200: Exploring Our Digital Earth	GE course for non-specialist undergraduates	Course catalogue; General Education documentation	https://catalog.missouristate.edu/preview_course_nopop.php?catoid=14&coid=48769 https://www.missouristate.edu/Advising/_Files/_GenEdPDFs/2022-2023/GenEd/4PublicAffairs/GEC116_GEO200_12092022.pdf

Note. Documentary source type(s) indicate the categories of public materials used for analysis. Multiple sources are listed where more than one official document was available.

S3. Coding Criteria, Decision Rules, and Cross-case Analytical Matrix

Table S5. Coding framework and decision rules

Analytical mechanism	Coding dimension	Coding focus	Decision rules
Knowledge transformation	Course positioning	Whether the course explicitly positions EO and geospatial knowledge as accessible curriculum content for broader undergraduate audiences.	Strong: The curriculum documents explicitly identify the course as general education, common core, liberal education, broad-access, or intended for broader undergraduate audiences. Partial: Broader accessibility is implied, but the course positioning or intended audience is not fully specified. Not evident: No clear evidence of broader undergraduate accessibility is visible, or the course is primarily positioned as specialist training.
Knowledge transformation	EO and geospatial integration	Whether EO and geospatial data are integrated into course aims, content, learning activities, or assessment.	Strong: EO and geospatial data are explicitly identified as central components of course aims, content, learning activities, or assessment. Partial: EO and geospatial data are included but appear as one component within broader geospatial, environmental, or technological content. Not evident: EO and geospatial data are absent or mentioned only generally without substantive curricular integration.
Knowledge transformation	Application context	Whether EO and geospatial data are connected to environmental, sustainability, climate, disaster, urban, social, or other real-world contexts.	Strong: The curriculum explicitly connects EO and geospatial data with real-world environmental, social, or sustainability-related contexts. Partial: Relevant contexts are mentioned, but the relationship between EO/geospatial data and these contexts remains general or insufficiently developed. Not evident: No clear application context involving EO and geospatial data is visible.
Task transformation	Learning outcomes for spatial evidence use	Whether learning outcomes define expectations for students' interpretation, evaluation, justification, or communication of spatial information.	Strong: Learning outcomes explicitly require interpretation, analysis, evaluation, justification, or communication of spatial information derived from EO and geospatial data. Partial: Learning outcomes mention EO, geospatial data, mapping, or spatial analysis skills, but evidence-oriented reasoning is not explicit. Not evident: No relevant learning outcomes related to EO/geospatial data use or spatial interpretation are visible.
Task transformation	Evidence-based task design	Whether assignments or projects require students to use EO and geospatial data to develop spatial analyses, interpretations, or claims.	Strong: Tasks explicitly require students to analyze, interpret, communicate, or justify spatial information using EO and geospatial data. Partial: Spatial tasks or products are visible, but expectations for interpretation, justification, or evidence use remain implicit. Not evident: No relevant spatial task, project, or activity is documented.
Task transformation	Assessment alignment	Whether assessment practices evaluate students' engagement with spatial information.	Strong: Assessment criteria explicitly evaluate interpretation, evaluation, justification, or communication of spatial information. Partial: EO/geospatial-related assessments are visible, but

Analytical mechanism	Coding dimension	Coding focus	Decision rules
			evidence-related criteria are incomplete or unclear. Not evident: No visible connection between assessment and EO/geospatial data use.
Evidence transformation	Scaffolding for spatial evidence reasoning	Whether the course provides support for interpreting, evaluating, and communicating spatial evidence.	Strong: The curriculum explicitly provides support for spatial interpretation, uncertainty awareness, evidence evaluation, or justification of spatial claims. Partial: Instructional support is visible, but its role in developing spatial evidence reasoning remains implicit. Not evident: No visible support mechanism related to spatial evidence reasoning is identified.

S3.1 Pattern assignment rules

Pattern assignment follows conservative decision rules grounded in the theoretical framework. First, following constructive alignment theory (Biggs, 1996), the overall rating for each transformation mechanism is assigned according to the lowest rating across its constituent dimensions. This reflects the principle that alignment requires coherence among relevant curriculum components.

Second, pattern assignment follows a hierarchical logic reflecting the progressive development of evidentiary alignment across the three transformations. Knowledge transformation concerns how EO and geospatial knowledge is recontextualized for learners; task transformation concerns how students engage with spatial information through curriculum activities; and evidence transformation concerns how students are supported in interpreting, evaluating, and communicating spatial evidence.

Pattern assignments therefore represent the overall evidentiary alignment profile of a course rather than a direct translation of any single mechanism rating. The four patterns distinguish increasing levels of integration, from contextualized exposure to integrated spatial evidence reasoning.

Table S6. Pattern assignment rules

Pattern	Pattern label	Knowledge transformation	Task transformation	Evidence transformation
Pattern 1	Contextualized EO Exposure	Strong	Not evident	Not evident
Pattern 2	Application-Oriented Spatial Interpretation	Strong	Partial	Partial / Not evident
Pattern 3	Guided Spatial Evidence Production	Strong	Partial / Strong	Partial
Pattern 4	Integrated Spatial Evidence Reasoning	Strong	Strong	Strong

Note. Pattern assignments reflect the dominant evidentiary alignment profile across all three transformation mechanisms, rather than any single dimension. The typology is derived from the observed distribution in the purposive sample; future research may need to expand the classification if cases with weak Knowledge Transformation are identified.

S3.2 Full coding matrix

Table S7. Knowledge transformation coding

Case	Course positioning	EO and geospatial data integration	Application context
C01	S	S	S
C02	S	S	S

Case	Course positioning	EO and geospatial data integration	Application context
C03	S	S	S
C04	S	S	S
C05	S	S	S
C06	S	P	P
C07	S	S	S
C08	S	S	S
C09	S	S	S
C10	S	S	S
C11	S	S	S
C12	S	S	S
C13	S	S	S
C14	S	S	P
C15	S	S	S
C16	S	P	S
C17	S	S	S
C18	S	S	S
C19	S	S	S
C20	S	S	S

Note. S = strong; P = partial; NE = not evident. Codes reflect documentary visibility in collected public artifacts.

Table S8. Task transformation coding

Case	Learning outcomes for spatial evidence use	Evidence-oriented task design	Assessment alignment
C01	S	S	S
C02	S	S	P
C03	P	P	NE
C04	NE	P	NE
C05	P	S	P
C06	P	S	P
C07	S	S	S
C08	S	S	S
C09	S	S	S
C10	S	S	S
C11	S	S	P
C12	S	S	S
C13	P	NE	NE
C14	P	P	P
C15	S	P	P

Case	Learning outcomes for spatial evidence use	Evidence-oriented task design	Assessment alignment
C16	S	S	S
C17	S	S	P
C18	S	S	S
C19	S	S	S
C20	P	P	NE

Note. S = strong, P = partial, NE = not evident. The overall task-transformation rating is assigned according to the weakest dimension (i.e., a case receives the lowest rating across the three coding dimensions), reflecting the principle that constructive alignment holds only when coherence extends across learning outcomes, task design, and assessment alignment (Biggs, 1996).

Table S9. Evidence transformation

Case	Scaffolding	Evidence rigor
C01	S	S
C02	S	P
C03	NE	P
C04	NE	NE
C05	S	P
C06	P	P
C07	S	P
C08	S	P
C09	S	P
C10	S	P
C11	S	P
C12	S	P
C13	NE	NE
C14	P	P
C15	S	P
C16	P	P
C17	S	P
C18	S	P
C19	S	P
C20	P	P

S3.3 Case-level coding justification

Table S10. Case-level coding justification

Case	Course	Coding justification
C01	CIVL1180: Monitoring Changing Climate from Space	Knowledge transformation: Strong. The course is positioned as a broad-access undergraduate course and introduces Earth observation and satellite remote sensing as accessible knowledge for understanding climate and environmental change. EO and geospatial data are central to the course content, including satellite data processing, climate monitoring, and analysis of environmental changes. Task transformation: Strong. The course requires students to engage with spatiotemporal satellite data through data processing, analysis, and interpretation activities. Learning outcomes and assessment tasks emphasize the use of quantitative information to examine climate-related issues and communicate analytical findings. Evidence transformation: Strong. The course provides explicit support for interpreting and evaluating spatial information through data analysis activities, technical reporting, and discussion of the limitations of climate-related analyses. Students are supported in using EO-derived information as evidence for understanding environmental change. Pattern assignment: Pattern 4: Integrated Spatial Evidence Reasoning.
C02	CCST9083: Earth as Seen by Satellite	Knowledge transformation: Strong. The course is offered within the Common Core Curriculum and is designed for undergraduate students beyond specialist geospatial programs. EO and satellite remote sensing are integrated as interdisciplinary knowledge for understanding Earth systems, environmental change, and sustainability-related issues. Task transformation: Strong. The course involves students in working with Big Earth Data, cloud-based geospatial analysis, and satellite data applications. Learning activities require students to engage with EO-related analytical approaches and apply geospatial information to investigate environmental and societal issues. However, assessment information provides less explicit evidence of how evidence-based reasoning is evaluated. Evidence transformation: Partial. The course supports students in applying EO data to sustainability and environmental problems, but publicly available documents provide limited evidence of explicit scaffolding for uncertainty interpretation, data limitations, or justification of spatial claims. Pattern assignment: Pattern 3：Guided Spatial Evidence Production.
C03	UGEB2132: Earth as Seen from Space	Knowledge transformation: Strong. The course is positioned as a General Education course and transforms satellite remote sensing knowledge into interdisciplinary content for broader undergraduate audiences. EO is connected with sustainability themes, including land-cover change, urban environmental issues, natural disasters, and climate change. Task transformation: Partial. The course uses case-based learning materials and interactive activities to introduce EO applications in real-world contexts. However, available curriculum documents provide limited evidence that students are required to complete structured spatial analysis tasks, produce evidence-based outputs, or justify interpretations using EO data.

Case	Course	Coding justification
		Evidence transformation: Partial. The course supports students' understanding of how EO contributes to monitoring and interpreting environmental change. However, explicit support for uncertainty, data limitations, validation, and justification of spatial evidence is not clearly documented. Pattern assignment: Pattern 2: Application-Oriented Spatial Interpretation.
C04	GPH 344: Remote Sensing: Studying the Earth From Space	Knowledge transformation: Strong. The course fulfills a General Education Scientific Reasoning requirement and is accessible to undergraduate students without prerequisites. EO and satellite remote sensing constitute the central course content, including satellite imaging, visual interpretation, and digital analysis of imagery. The course connects remote sensing with Earth and environmental science issues. Task transformation: Not evident. Although the course description indicates that students engage with visual and digital analysis of satellite imagery, publicly available curriculum materials do not provide sufficient evidence of structured learning tasks, project requirements, or assessment practices requiring students to interpret or communicate spatial evidence. Evidence transformation: Not evident. Available documents demonstrate the introduction and application of remote sensing techniques but do not show explicit scaffolding for spatial evidence reasoning, including uncertainty awareness, evidence evaluation, or justification of spatial claims. Pattern assignment: Pattern 1: Contextualized EO Exposure.
C05	SEES:1035: Our Digital Earth	Knowledge transformation: Strong. SEES:1035 is positioned as a broad-access undergraduate course satisfying General Education requirements in quantitative reasoning and sustainability. The course explicitly integrates GIS, remote sensing, and geospatial data as accessible approaches for understanding environmental and sustainability issues. Task transformation: Partial. The course provides structured opportunities for students to use geospatial tools and analyze environmental problems through assignments and a final project. However, available documents provide limited evidence that learning outcomes or assessment criteria explicitly require students to evaluate, justify, or communicate spatial evidence. Evidence transformation: Partial. The course provides structured learning support through modules combining concepts, tools, demonstrations, and applied activities. However, explicit scaffolding for uncertainty interpretation, evidence qualification, and justification of spatial claims is not clearly documented. Pattern assignment: Pattern 2: Application-Oriented Spatial Interpretation.
C06	GEOG 181: Our Digital Earth	Knowledge transformation: Strong. The course is positioned as an undergraduate introductory course that makes geospatial knowledge accessible to a broad student audience. It introduces students to how geospatial data and technologies shape contemporary society through digital mapping, satellite imagery, crowdsourcing, and mobile technologies. Although EO-related content is embedded within a broader Digital Earth framework rather than positioned as the central focus of the course, the course transforms geospatial knowledge into accessible interdisciplinary content connected with social and environmental contexts. Task transformation: Partial. The course provides opportunities for students to engage with and apply spatial information through mapping assignments,

Case	Course	Coding justification
		community-oriented analyses, crowdsourcing activities, and a final digital atlas project. These activities demonstrate application-oriented engagement with geospatial technologies and spatial information. However, available documents provide limited evidence that learning outcomes and assessment criteria explicitly require students to evaluate spatial evidence, justify claims, or address data limitations. Evidence transformation: Partial. The course provides instructional support through lectures, readings, tutorials, and sequential assignments that introduce students to geospatial technologies and spatial applications. However, explicit scaffolding for uncertainty interpretation, evidence evaluation, and justification of spatial claims is not clearly documented. Pattern assignment: Pattern 2: Application-Oriented Spatial Interpretation.
C07	GEOG 160: Mapping Our Changing World	Knowledge transformation: Strong. The course is positioned as a general education GIS&T course that introduces geographic information and technologies to a broad undergraduate audience beyond future GIS specialists. It transforms geospatial knowledge into accessible content by introducing geographic data, satellite remote sensing, GIS, and map interpretation in relation to social and environmental issues. Task transformation: Strong. The course requires students to work with geographic data through assignments, projects, and applied activities. Learning objectives emphasize identifying appropriate geographic information, acquiring and processing data, assessing data quality, and critically interpreting maps. These activities demonstrate structured engagement with spatial information. Evidence transformation: Partial. The course provides substantial instructional support through online lessons, course materials, assignments, and progressive project activities. However, available documents provide limited evidence of explicit scaffolding for uncertainty interpretation, evidence qualification, or justification of spatial claims. Pattern assignment: Pattern 3: Guided Spatial Evidence Production.
C08	GEOG 172: Earth from Space	Knowledge transformation: Strong. The course introduces Earth observation as accessible knowledge for undergraduate learners by presenting satellite missions, remote sensing principles, image interpretation methods, and applications of satellite data to environmental and societal issues. EO is positioned as a means of understanding global environmental change rather than merely as a technical tool. Task transformation: Strong. The course organizes student engagement through worksheets, guest lecture summaries, article reviews, and a group Story Map project. Students are required to investigate environmental issues using remote sensing data and communicate how EO contributes to understanding or managing those issues. Evidence transformation: Partial. The course provides substantial scaffolding through structured project stages, technical guidance, and communication-oriented assignments. However, available documents provide limited evidence of explicit expectations regarding uncertainty evaluation, evidence validation, or systematic assessment of spatial data quality. Pattern assignment: Pattern 3: Guided Spatial Evidence Production.
C09	LSGI1001: Big Earth Data and Geospatial AI	Knowledge transformation: Strong. The course is designed as a general education subject introducing Earth observations and Geospatial Artificial Intelligence to

Case	Course	Coding justification
		undergraduate learners. It transforms advanced geospatial knowledge into accessible interdisciplinary content by introducing satellite imagery, Big Earth Data, geospatial analytics, and GeoAI applications across environmental, social, and sustainability-related contexts. Task transformation: Strong. The course provides structured engagement with EO and geospatial data through lectures, laboratory exercises, quizzes, and e-learning activities. Lab exercises require students to apply geospatial analytics approaches to real-world problems, supporting the development of practical skills in working with Earth observation data and spatial information. Evidence transformation: Partial. The course provides substantial procedural and technical scaffolding through lectures, hands-on laboratory exercises, and guided learning modules. However, available documents provide limited evidence of explicit support for uncertainty interpretation, evidence evaluation, or justification of spatial claims. Pattern assignment: Pattern 3: Guided Spatial Evidence Production.
C10	GEOG 104: Geographic Information Science and Spatial Reasoning	Knowledge transformation: Strong. The course is explicitly positioned as a General Education course that introduces geographic information science to undergraduate learners. It transforms geospatial knowledge into accessible curriculum content by integrating GIS, GPS, cartography, remote sensing, and spatial statistics. Task transformation: Strong. The course organizes structured engagement with geospatial information through web-based GIS exercises, focus group presentations, and applied problem-solving activities. Students use GIS, remote sensing, and GPS technologies to investigate environmental and social issues, including climate change, hazards, and community problems. Evidence transformation: Partial. The course provides substantial procedural scaffolding through lectures, online exercises, and guided GIS activities. However, available documents provide limited evidence of explicit support for uncertainty evaluation, spatial data limitations, or systematic justification of spatial claims. Pattern assignment: Pattern 3：Guided Spatial Evidence Production.
C11	GISC 2305: Spatial Thinking and Data Analytics	Knowledge transformation: Strong. The course positions spatial thinking and geospatial data analysis as interdisciplinary knowledge accessible across science, engineering, mathematics, arts, and humanities. It introduces students to geospatial data sources and technologies, including GPS, remote sensing, GIS, spatial analysis, and mapping. Task transformation: Strong. The course requires students to apply spatial thinking through laboratory exercises, map-based activities, and a Story Map project. Students produce and communicate spatial information through mapping, spatial analysis, and visualization tasks. Evidence transformation: Partial. The course provides substantial procedural scaffolding through laboratory exercises, workshops, and guided mapping activities. However, available documents provide limited evidence of explicit support for uncertainty interpretation, evidence evaluation, or justification of spatial claims. Pattern assignment: Pattern 3: Guided Spatial Evidence Production.

Case	Course	Coding justification
C12	GEOG 107: Mapping the World	Knowledge transformation: Strong. The course is positioned as a General Education Earth and Environment course that introduces geographic data visualization, online mapping, and spatial analysis to undergraduate learners. It transforms geospatial knowledge into accessible forms through digital Earth resources, interactive maps, and environmental applications. Task transformation: Strong. The course requires students to engage with spatial information through ArcGIS Online, StoryMaps, virtual explorations, and map critique activities. The final Story Map project asks students to integrate scientific data, map layers, narratives, and multimedia to communicate geographic and environmental issues. Evidence transformation: Partial. The course provides strong procedural scaffolding through online modules, mapping tutorials, Story Map guidance, peer review, and requirements to use reputable GIS layers and properly cite sources. However, available documents provide limited evidence of explicit support for uncertainty evaluation, spatial data limitations, or systematic justification of evidence quality. Pattern assignment: Pattern 3: Guided Spatial Evidence Production.
C13	ES 113: Earth from Space	Knowledge transformation: Strong. The course is positioned as a general education undergraduate course that introduces Earth observation and remote sensing concepts to non-specialist learners. It transforms satellite-based observations into accessible knowledge by explaining how satellite sensor systems reveal changes in Earth systems and support understanding of natural resource challenges. Task transformation: Not evident. Although the course introduces satellite observation concepts and remote sensing applications, available course documents provide limited evidence of structured tasks requiring students to analyze, produce, or communicate spatial information. Evidence transformation: Not evident. Available documents do not provide clear evidence of scaffolding for spatial evidence reasoning, including uncertainty interpretation, evidence evaluation, or justification of spatial claims. Pattern assignment: Pattern 1: Contextualized EO Exposure.
C14	The World of Engineering: remote sensing	Knowledge transformation: Strong. The course is offered as a general education subject and introduces remote sensing concepts as accessible knowledge for undergraduate learners. The course transforms remote sensing principles, satellite imagery, sensor systems, and engineering applications into introductory content for students beyond specialist training. Task transformation: Partial. The course provides structured engagement with remote sensing through sequential lectures covering satellite image interpretation, sensor systems, and applications. However, available documents provide limited evidence of student-centered spatial analysis tasks or explicit requirements for producing spatial information products. Evidence transformation: Partial. The course provides instructional support through lectures, examples, textbook materials, and report-based assessment. However, explicit support for uncertainty interpretation, evidence evaluation, and justification of spatial claims is not clearly documented. Pattern assignment: Pattern 2: Application-Oriented Spatial Interpretation.

Case	Course	Coding justification
C15	ENV 103: Digital Earth	Knowledge transformation: Strong. The course is positioned as a Stage 1 undergraduate course that introduces Digital Earth concepts through accessible interdisciplinary approaches. It transforms geospatial knowledge into curriculum content by integrating GIS, remote sensing, mapping, modelling, and GeoAI to examine environmental and societal systems. Task transformation: Strong. The course engages students in structured spatial data activities through laboratories, analytical exercises, mapping, modelling, and geospatial data applications. Students are expected to collect, manage, analyse, and visualize environmental and social datasets to understand Earth systems and address contemporary challenges. Evidence transformation: Partial. The course provides substantial scaffolding through lectures, online materials, laboratories, and practical exercises. It also introduces students to the limitations of quantitative datasets. However, available documents provide limited evidence of explicit support for uncertainty evaluation, validation, and justification of spatial evidence claims. Pattern assignment: Pattern 3: Guided Spatial Evidence Production.
C16	GEOG 104: Our Digital Earth	Knowledge transformation: Strong. The course introduces Digital Earth concepts and geospatial technologies as accessible undergraduate knowledge. It transforms geospatial information into curriculum content by focusing on location-based data, digital mapping, and spatial technologies that shape understanding of places and societies. Task transformation: Strong. The course engages students in producing and communicating spatial information through web maps, mobile mapping applications, and location-based data activities. Students apply geospatial technologies to explore how spatial information can be used to understand real-world issues. Evidence transformation: Partial. The course provides support for working with geospatial technologies through structured activities and digital mapping practices. However, available documents provide limited evidence of explicit attention to uncertainty, spatial data limitations, or systematic evaluation of evidence quality. Pattern assignment: Pattern 3: Guided Spatial Evidence Production.
C17	GEOG 495C: Critical Remote Sensing	Knowledge transformation: Strong. The course is positioned as an undergraduate general education course that introduces remote sensing knowledge beyond specialist training. It transforms remote sensing concepts into accessible curriculum content by integrating satellite imagery, remote sensing processes, data collection, analysis, and applications. The course explicitly addresses how satellite data are produced, interpreted, and used in geographical contexts. Task transformation: Strong. The course requires students to engage with remote sensing data through practical activities using Google Earth Pro and Google Earth Engine. Learning objectives include performing basic remote sensing analysis and critically evaluating the use of satellite imagery. Exercises involving imagery analysis, classification, and change detection demonstrate structured engagement with spatial information. Evidence transformation: Partial. The course provides substantial scaffolding through lectures, readings, software demonstrations, exercises, and critical

Case	Course	Coding justification
		discussions of satellite imagery. However, although the course emphasizes critical data literacy, available documents provide limited evidence of explicit frameworks for uncertainty evaluation, validation, or systematic justification of spatial evidence. Pattern assignment: Pattern 3: Guided Spatial Evidence Production.
C18	ESRM190 / ENVIR295: Digital Earth	Knowledge transformation: Strong. The course is designed as an introductory undergraduate pathway that introduces geospatial science to a diverse student population. It transforms Earth observation and geospatial technologies into accessible knowledge by integrating satellite imagery, aerial imagery, LiDAR, and digital Earth concepts within environmental applications. Task transformation: Strong. The course provides structured learning activities through topic–concept–tool–demo modules and requires students to apply geospatial technologies in practical contexts. Activities include aerial imagery interpretation, Landsat analysis, classification, change detection, data fusion, and final projects using geospatial tools. Evidence transformation: Partial. The course provides extensive scaffolding through interactive modules, demonstrations, tool-based activities, and guided exercises. Students are introduced to concepts such as spatial, spectral, and temporal resolution. However, explicit attention to evidence validation, uncertainty assessment, and justification of spatial claims remains limited. Pattern assignment: Pattern 3: Guided Spatial Evidence Production.
C19	GEOS/EPPS/GISC 2307: Digital Earth	Knowledge transformation: Strong. The course introduces Digital Earth concepts as undergraduate-level interdisciplinary knowledge by integrating geospatial data sources, remote sensing, GIS, GPS, and digital mapping. It frames geospatial technologies as tools for understanding physical and social systems and addressing real-world problems. Task transformation: Strong. The course requires students to collect, compile, analyze, and visualize geospatial data. Learning outcomes emphasize spatial problem-solving, digital map creation, and communication of research outcomes. Laboratory assignments involving Google Earth, QGIS, cartography, raster analysis, and Story Maps provide structured opportunities for spatial data production. Evidence transformation: Partial. The course provides strong procedural scaffolding through laboratory assignments, software practice, and visualization activities. However, available documents do not indicate explicit instruction on uncertainty, evidence quality assessment, or systematic evaluation of spatial claims. Pattern assignment: Pattern 3: Guided Spatial Evidence Production.
C20	GEO 200: Exploring Our Digital Earth	Knowledge transformation: Strong. The course is positioned as a general education Public Issues course and introduces Digital Earth concepts to broader undergraduate audiences. It transforms geospatial technologies into accessible curriculum content by introducing geospatial data, digital mapping, GIS, GPS, and remote sensing as tools for understanding the physical world and human society. Task transformation: Partial. The course description indicates that students learn how Earth phenomena can be captured, processed, visualized, and analyzed through geospatial technologies. However, available documents provide limited evidence of structured assignments, spatial analysis tasks, or student-produced geospatial outputs.

Case	Course	Coding justification
		Evidence transformation: Not evident. Available course documents do not provide clear evidence of scaffolding for spatial evidence reasoning, including uncertainty interpretation, evidence evaluation, or justification of spatial claims. Pattern assignment: Pattern 2: Application-Oriented Spatial Interpretation.