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Obrazovanje o ublažavanju klimatskih promena i veštačka inteligencija – kritička i empirijska analiza[1]

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Apstrakt *Veštačka inteligencija (VI) donosi niz novih pretnji i mogućnosti u brojnim kritičnim javnim sektorima, uključujući obrazovanje. Iako težnja za razvojem VI koja u centar stavlja čoveka može izgledati kao puka proklamacija, na globalnom nivou se sve veći resursi posvećuju ovom cilju. Još jedan globalno značajan problem je ublažavanje klimatskih promena; međutim, većina univerzitetskih nastavnih planova se nedovoljno bavi ovom temom, ili je potpuno prenebregava. Ovaj članak kritički istražuje rizike i potencijale VI u obrazovanju u oblasti klimatskih promena, fokusirajući se na analizu da li su i u kojoj meri alati bazirani na VI u ovoj oblasti interdisciplinarni, dostupni i uticajni. Da bi se procenila uloga VI u obrazovanju, učenju i metodama nastave (VIOUM), autor je primenio dva osnovna metodološka pristupa, postavljajući u centar naučne analize pitanja vezana za interakcije između VIOUM sistema i ljudi kao donosilaca odluka, kao i za primenljivost ovih sistema u obrazovanju o ublažavanju klimatskih promena. Prvo, sproveden je kritički pregled literature o VIOUM, sa naglaskom na njihov odnos sa različitim obrazovnim programima i metodama usmerenim na ublažavanje klimatskih promena; kada je u pitanju mesto VI u obrazovnom sistemu, recentna istraživanja su najviše kritika uputila ključnim ekonomskim i, u nešto manjoj meri, političkim razlozima koji su doveli do uvođenja novih metoda. Drugo, evaluacija uticaja VI na obrazovanje o klimatskim promenama sprovedena je kroz dva posebno koncipirana upitnika, uz korišćenje deskriptivne i deduktivne statističke metode za obradu prikupljenih podataka. Rezultati ukazuju da su obrazovni alati potpomognuti VI, a koji su specijalno prilagođeni ublažavanju klimatskih promena, značajno efikasniji u postizanju pedagoških ciljeva od opštih alata baziranih na VI, te stoga zaslužuju širu primenu u praksi. Međutim, ostaju izazovi u pogledu dostupnosti i interoperabilnosti, što trenutno ograničava njihovo šire usvajanje i istinski uticaj na kvalitet obrazovnog procesa.*

Ključne reči: *obrazovanje, ublažavanje klimatskih promena, veštačka inteligencija u obrazovanju, održivi razvoj.*

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Uvod – svrha i kontekst istraživanja

Nakon usvajanja Agende 2030 za održivi razvoj od strane država članica Ujedinjenih nacija, 17 ciljeva održivog razvoja (COR), razloženih na 169 potciljeva, postali su „zajednički nacrt za mir i prosperitet za ljude i planetu" (Ujedinjene nacije [UN], The 17 Goals, 2015). Iako su neki pripadnici naučne zajednice izrazili određene kritike u pogledu načina na koji su COR formulisani – procenjujući da su „nekonzistentni, teško merljivi, teški za primenu i praćenje" (Swain, 2018, str. 341), ali i kritikujući ih „zbog reprodukcije univerzalnog šablona zasnovanog na zapadnoj i neoliberalnoj ideologiji" (Arora-Jonsson, 2023, str. 2) – teško je poreći da COR predstavljaju dobru globalnu i univerzalno poznatu zajedničku osnovu, kako za aktivnosti vlada tako i za aktivnosti civilnog društva, kao i za dalja razmatranja u najširim stručnim i naučnim forumima.

Moto COR broj 13 (*Klimatska akcija*) glasi: „preduzeti hitne mere za borbu protiv klimatskih promena i njihovih posledica." Niko ozbiljan ne negira sve štetnije posledice klimatskih promena širom sveta, pri čemu su „klimatski rekordi […] oboreni 2023. godine [a] zajednice širom sveta trpe posledice ekstremnih vremenskih uslova, koji svakodnevno uništavaju živote i egzistencije" (UN - Progress towards the Sustainable Development Goals, 2024, str. 19). Kao jedan od tri potcilja u okviru COR 13, potcilj 13.3 (unapređenje obrazovanja, podizanje svesti i ljudskih i institucionalnih kapaciteta u vezi sa ublažavanjem klimatskih promena, prilagođavanjem, smanjenjem uticaja i ranim upozoravanjem) bavi se jednim od ključnih pitanja klimatske akcije – potrebom da se prilagodi način na koji učimo, predajemo i informišemo o ublažavanju klimatskih promena. Nažalost, rezultati postignuti u ovoj oblasti su veoma skromni. Prema najnovijem izveštaju generalnog sekretara UN, „studija iz 2023. godine koja je obuhvatila više od 530 nastavnih planova i programa za 9. razred iz prirodnih i društvenih nauka pokazala je da 69% ne sadrži nikakvu referencu na klimatske promene, a 66% ne pominje održivost" (UN - Progress towards the Sustainable Development Goals, 2024, str. 20). Ovi razočaravajući rezultati su donekle ublaženi činjenicom da je „tri četvrtine zemalja prijavilo da ima planove da revidira svoje nastavne programe u naredne tri godine kako bi se više fokusirali na klimatske promene i održivost". Međutim, ne navodi se na koji način te „tri četvrtine zemalja"nameravaju da revidiraju nastavne programe, na kojim nivoima, u kontekstu kojih predmeta i, iznad svega, uz primenu kakvih obrazovnih metoda i tehnika. Ipak, važno je napomenuti da je proces reforme nastavnih programa u ovom pravcu stidljivo pokrenut u nekim zemljama, dok je potencijal alata VI u obrazovanju o klimatskim promenama nesumnjivo istaknut u novijoj naučnoj literaturi (Allam et al., 2025; Tapalova & Zhiyenbayeva, 2022; Tarlan & Gerstlberger, 2025). Na primer, u izveštaju objavljenom 4. septembra 2024. godine, *Oxford, Cambridge and RSA Examinations* pozvao je na stvaranje nezavisnog tela koje bi održavalo „mnogo savremeniji i usmereniji ka budućnosti" nastavni program („England's school curriculum…", 2024), sa većim fokusom na klimatske promene i održivost, ali i uz insistiranje na potrebi obrazovanja o pravilnoj upotrebi VI.

Veštačka inteligencija ima nespornu sposobnost da služi kao alat za unapređenje obrazovanja, učenja i nastavnih metoda (OUM). Cilj ovog rada je da proceni specifičan uticaj veštačke inteligencije na potcilj 13.3, sa fokusom na obrazovanje o ublažavanju klimatskih promena. U tu svrhu, autor je koristio dve glavne metode. S jedne strane, istraživanje je zasnovano na kritičkom ispitivanju postojećih naučnih radova posvećenih OUM, sa posebnim osvrtom na njegovu primenljivost u različitim obrazovnim programima i metodama posvećenim ublažavanju klimatskih promena; glavni rezultati predstavljeni su u poglavlju „Stanje istraživanja…" ovog članka. S druge strane, procena budućeg potencijalnog uticaja OUM na obrazovanje o ublažavanju klimatskih promena bila je i kvalitativna i kvantitativna, zasnovana na dva prilagođena upitnika; glavni rezultati ovog aspekta istraživanja predstavljeni su u poglavljima „Rezultati i diskusija" i „Projekcije i zaključci".

Metodološki pristup

Dok je mnoštvo studija već procenilo moguće prednosti i nedostatke VI kao alata za unapređenje obrazovanja, učenja i nastavnih metoda (Alfayez & Rasool, 2025; Edam, 2024; Yuskovych-Zhukovska et al., 2022; Zawacki-Richter et al., 2019), praktično ne postoje studije koje su isključivo posvećene naučno utemeljenom i dobro dokumentovanom proučavanju uticaja OUM na ublažavanje klimatskih promena. Međutim, značajan broj novijih radova sadrži važne nalaze o upotrebi VI u nastavi i učenju o održivosti (Abulibdeh et al., 2024; Leal Filho et al., 2025), ali se takođe bavi pitanjem mesta VI u obrazovanju i praksi u oblasti životne sredine, društva i upravljanja (Correia & Água, 2024; Gupta & Agarwal, 2025; Tarlan & Gerstlberger, 2025).

Ključni element analize na koju se oslanja istraživanje predstavljeno u ovom radu je kvalitativna i kvantitativna procena uticaja VI u oblasti obrazovanja o ublažavanju klimatskih promena. Zasniva se na dva prilagođena upitnika (U1 i U2, više detalja o rezultatima ankete u poglavlju „Rezultati i diskusija") i na specifičnim alatima za obradu prikupljenih podataka, pri čemu su za obradu podataka korišćene deskriptivne i inferencijalne statističke metode. Zbog nedostatka dovoljno brojnih i detaljnih podataka objavljenih u recenziranim naučnim radovima, neki od korišćenih izvora su renomirani mediji i izveštaji međunarodnih organizacija.

Neki od ključnih kriterijuma za utvrđivanje i merenje uticaja OUM na ostvarivanje potcilja 13.3 COR bili su:

1. Nivo uključenosti obrazovnih alata zasnovanih na VI u postojeće nastavne programe visokog obrazovanja;
2. Nivo interoperabilnosti navedenih alata u prirodnim i društvenim naukama; i
3. Povratne informacije nastavnika u njihovim odgovorima na U2. Dobijeni rezultati putem anketa su detaljno analizirani i kvantfikovani.

Istraživanje se zasnivalo na dva velika izvora podataka. Ovakav pristup je bio uslovljen složenošću mogućih interakcija između OUM sistema i ljudskih donosilaca odluka (Gupta & Agarwal, 2025; Hostein & Doroudi, 2022), kao i prirodom međudejstva između automatizovanog i ljudskog donošenja odluka (Yuan et al., 2023).

Prvi skup podataka (v. poglavlje „Stanje istraživanja...") prikupljen je kritičkim ispitivanjem brojnih postojećih studija koje su već procenjivale moguće prednosti i nedostatke OUM; prikupljeni podaci su zatim analizirani kako bi se utvrdilo da li je (i, ako jeste, u kojoj meri) OUM uticao ili bi mogao da utiče na ostvarivanje potcilja 13.3.

Drugi vredan izvor podataka (vidi poglavlje „Rezultati i diskusija") prikupljen je putem dva različita, namenski kreirana upitnika (U1 i U2).

Upitnik 1, namenjen istraživačima koji su već postigli značajne rezultate u oblasti istraživanja VI, osmišljen je sa ciljem da izdvoji aspekte postojećih studija OUM koji se odnose na klimatske promene. U1 se sastoji od 16 pitanja, usmerenih na to kako VI može unaprediti obrazovanje uopšte, a posebno obrazovanje o klimatskim promenama, uključujući njenu trenutnu upotrebu, percipirani uticaj i budući potencijal. Od ispitanika se, takođe, traži da procene promene u nastavnim programima, regulatorni razvoj u vezi sa potciljem 13.3 i interoperabilnost alata VI u različitim akademskim disciplinama. Istraživači kojima su upitnici upućeni odabrani su na osnovu tri kombinovana kriterijuma: 1) nedavno (2018–2024) objavljeni radovi (poželjno u časopisima indeksiranim u WoS) ili međunarodno priznate knjige i/ili učešće u renomiranim naučnim projektima koji se odnose na upotrebu VI u obrazovanju ili na šira društvena, etička ili tehnička pitanja povezana sa OUM; 2) relativno ravnomerna geografska raspodela; 3) uključivanje istraživača iz različitih naučnih oblasti, uključujući tehničke nauke (uz razumljivu prednost društvenih nauka). Zbog ograničenog vremenskog okvira i veoma selektivnih kriterijuma, upitnik je poslat samo na adrese 14 istraživača; ovaj uzorak je relativno mali i ne omogućava dovoljnu teritorijalnu i disciplinarnu raznovrsnost, ali je obezbedio solidne povratne informacije iz dovoljno raznovrsnog spektra istraživača. Više detalja o stopi odziva, mogućim razlozima za nju, kao i tumačenju rezultata može se naći u poglavlju „Rezultati i diskusija".

Upitnik 2 (U2) poslat je predstavnicima 52 odabrane obrazovne i istraživačke institucije širom sveta i bio je usmeren na najnovije i najrelevantnije uticaje VI u obrazovanju i podizanju svesti o ublažavanju klimatskih promena. U2 se sastoji od 14 pitanja koja su ispitivala da li institucija ispitanika koristi VI u obrazovanju ili istraživanju, da li se teme povezane sa VI pojavljuju u nastavnim programima i da li se VI smatra korisnom za unapređenje nastave i učenja. Takođe se fokusira na ulogu VI u obrazovanju o ublažavanju klimatskih promena, ispitujući trenutnu upotrebu, promene u nastavnim programima, interdisciplinarnu interoperabilnost, kao i buduće prilike i rizike alata zasnovanih na VI u obrazovanju vezanom za klimu. Institucije kojima su upitnici poslati odabrane su na osnovu tri kombinovana kriterijuma:

1. Relativno ravnomerna geografska raspodela (nijedan kontinent nije zanemaren); međutim, uprkos ovom nastojanju, stopa odziva sa evropskih i azijskih univerziteta bila je nesrazmerno veća;
2. Inter- ili trans-disciplinarnost u obrazovnoj i/ili naučnoj misiji institucije; i
3. Procenjena reputacija institucije, ali nezavisno od njene izvrsnosti u oblasti obrazovnih ili istraživačkih metoda zasnovanih na VI.

Upitnik je poslat na adrese 52 institucije, a odgovorilo je tek oko polovine; ovaj uzorak, iako ograničen, omogućava dobar nivo teritorijalne i disciplinarne raznovrsnosti. Više detalja o stopi odziva, mogućim razlozima i tumačenju rezultata nalazi se u poglavlju „Rezultati i diskusija".

Ključna istraživačka pitanja koja stoje u osnovi celokupne analize i obezbeđuju komplementarnost U1 i U2 su sledeća:

1. Kada se uporede u pogledu zahteva za postizanjem obrazovnih ciljeva, koja je ključna razlika između tradicionalnih, opštih obrazovnih alata uz podršku VI i obrazovnih alata uz podršku VI prilagođenih obrazovanju o ublažavanju klimatskih promena?
2. Da li obrazovni alati uz podršku VI prilagođeni obrazovanju o ublažavanju klimatskih promena mogu postići viši stepen interdisciplinarnosti i biti prilagodljiviji složenom globalnom socio-ekonomskom kontekstu od tradicionalnih i opštih alata uz podršku VI?

Glavni alati korišćeni za obradu i predstavljanje prikupljenih podataka bili su deskriptivne i inferencijalne statističke metode, dok su četiri centralna pitanja u odnosu na koja su rezultati anketa sistematizovani (od opšteg ka specifičnom): 1) opšti stav prema VI u obrazovanju; 2) potencijal alata zasnovanih na VI u obrazovanju o ublažavanju klimatskih promena; 3) procena regulatornih promena u vezi sa sadržajem nastavnih programa; 4) prisustvo tema povezanih sa VI u nastavnim programima. Opšti rezultati (navedena pitanja 1 – 3) zasnovani su na kombinovanim rezultatima anketa (U1 i U2), dok se prisustvo tema povezanih sa VI u nastavnim programima odnosi samo na institucionalne ispitanike.

Stanje istraživanja o VI u obrazovanju i njihova primenjivost u obrazovanju o ublažavanju klimatskih promena – kritički pregled

Zaključno sa sredinom oktobra 2025. godine, a iz perspektive etičkih i drugih vrednosno relevantnih razmatranja, VI je imala najmanje kontroverzan dosadašnji učinak kada je u pitanju sposobnost da služi kao alat za unapređenje obrazovanja, učenja i nastavnih metoda. Kako su neki autori s pravom primetili, „sve empirijske studije […] predstavile su pozitivne efekte tehnika veštačke inteligencije na obrazovanje" (Zhai et al., 2021). Pored

toga, kada je u pitanju obrazovanje, kombinacija pristupa zasnovanih na znanju i onih zasnovanih na podacima predstavlja prirodan put napred (Holmes & Tuomi, 2022), uprkos značajnim kritikama koje se odnose na činjenicu da žurba u integraciji industrijski promovisanih alata veštačke inteligencije u obrazovanje nosi rizik od „epistemičke kolonizacije" (Chatzichristofis, 2026). Međutim, iako poboljšani ishodi učenja ostaju glavni razlog za usvajanje VI, neki autori ukazuju na opasnosti kolonijalizma vezanog za VI i asimetrije moći unutar i između država (Berliner, 2009; Holmes, 2020).

Najznačajnija kritika u vezi sa mestom VI u obrazovnom ekosistemu odnosi se na glavne ekonomske, a u manjoj meri i političke razloge koji su doveli do njenog uvođenja. U takvom kontekstu, kada praktično sve alate VI razvijaju i/ili obezbeđuju profitne organizacije – čiji je jedinstveni ili dominantni cilj komercijalizacija usluga na način koji maksimizuje ekonomsku dobit – potrebe učenika mogu lako biti potisnute drugim razmatranjima zasnovanim na produktivnosti, brzini i dobiti. Kako je s pravom istaknuto, „težnja ka tržišno isplativim proizvodima […] izgleda da definiše opšti pristup privatnog sektora, pre nego bilo kakvi motivi vezani za obrazovanje" (Knox, 2020, str. 16). U takvom kontekstu, pristup obrazovanju prilagođen pojedincu, zasnovan na individualnim pedagoškim potrebama učenika, ima velike šanse da bude zanemaren, a još više kada je reč o onlajn kursevima (Holstein & Doroudi, 2021; Ortagus, 2023). Stoga se poboljšani ishodi učenja pomenuti u prethodnom pasusu mogu posmatrati iz drugačijeg ugla, što omogućava dodatno preispitivanje načina na koji su mereni, posebno ako se uzme u obzir da uštede troškova usled automatizacije mogu značajno ugroziti individualni pristup u učenju. Štaviše, „veštačka inteligencija, srećom, još uvek nije u stanju da 'generiše' (ili čak imitira) inspiraciju, kontemplaciju, spontanost i žar" (Ćemalović, 2020, str. 158), osobine koje igraju važnu ulogu u obrazovnom procesu. Detaljna analiza, izrađena 2022. godine pod okriljem Saveta Evrope od strane grupe od pet autora (Wayne Holmes, Jen Persson, Irene-Angelica Chounta, Barbara Wasson i Vania Dimitrova), definisala je neke od glavnih pretnji koje VI u obrazovanju može predstavljati za ljudska prava, demokratiju i vladavinu prava. Iako je ovaj dokument najčešće ograničen na opis normativnih standarda, on takođe sadrži dobar pregled postojećih studija u ovoj oblasti; međutim, otvoreno priznaje da „postoji malo suštinske literature koja se posebno fokusira na, ili čak na značajan način pominje, veštačku inteligenciju, obrazovanje i ljudska prava" (Council of Europe, 2022, str. 51).

Primena VI u obrazovanju o ublažavanju klimatskih promena je složeno pitanje sa brojnim specifičnostima, od kojih su najvažnije njegova interdisciplinarna priroda, visoki globalni socio-ekonomski ulozi i potreba za postizanjem obrazovnih ciljeva. Prvo, interdisciplinarnost, u principu, zahteva brze analitičke alate sposobne da obrade velike količine podataka u kratkom vremenu; pored toga, značajno zavisi od spremnosti nastavnika za učenje, posebno onog koje je zasnovanog na „sveobuhvatnijem ekološkom okviru profesionalnog razvoja nastavnika" (Ehrenfeld, 2022, str. 489), što im omogućava da „uspešno integrišu alate VI uz istovremeno uvažavanje etičkih pitanja kao što su pristrasnost i zaštita podataka" (Pikhart & Al-Obaydi, 2025, str. 9). Drugo, visoki globalni socio-ekonomski ulozi

nameću potrebu za efikasnim, univerzalno primenljivim i pojednostavljenim obrazovnim alatima, sposobnim i da se suprotstave višeslojnim predrasudama, pogrešnim uverenjima i teorijama zavere o (ne)postojanju klimatskih promena, koje se stalno pojavljuju u brojnim zemljama sveta, posebno u vreme izbora ili drugih trenutaka kada se donose važne društvene odluke. Treće, zahtev za postizanjem obrazovnih ciljeva podrazumeva brze, prilagodljive i univerzalne pokretače nastavnih planova i programa (Lingard & McGregor, 2013), osmišljene tako da se lako integrišu u različite postojeće obrazovne module u osnovnim i srednjim školama, kao i u kreiranje obrazovnih politika (Linderoth et al., 2024), što posledično može dovesti do marginalizacije „vrednosti interakcija preko disciplinarnih podela" (Pasque et al., 2009, str. 126). Uzimajući u obzir sve navedene specifičnosti, može se zaključiti da obrazovni alati zasnovani na veštačkoj inteligenciji u obrazovanju o ublažavanju klimatskih promena mogu, u brojnim aspektima, biti bolje prilagođeni specifičnim pedagoškim ciljevima i potrebama učenika nego opšti obrazovni alati zasnovani na VI. Štaviše, čak ni neke relevantne kritičke primedbe u vezi sa uticajem učenja zasnovanog na VI na ljudska prava, demokratiju, vladavinu prava i privatnost (Pikhart & Al-Obaydi, 2025) nisu uvek primenljive (ili su primenljive u znatno manjoj meri) na obrazovanje podržano VI o ublažavanju klimatskih promena.

Zbog novine koju upotreba VI predstavlja u obrazovanju, ne postoji obilje nedavnih, strukturisanih, detaljnih i međunarodno sprovedenih i priznatih naučnih studija posvećenih ovom pitanju, a kamoli kada je reč o specifičnoj primeni sredstava zasnovanih na VI i tehnika u obrazovanju o ublažavanju klimatskih promena. Ipak, neke relevantne srodne studije ukazale su da je „pojavljivanje velikih jezičkih modela, demonstrirano široko dostupnim četbotovima, izazvalo značajno interesovanje za njihovu potencijalnu primenu u komunikaciji složenog naučnog znanja" (Al Khourdajie, 2025, str. 7). U sličnom duhu, uprkos sasvim razumljivim kritikama u vezi sa nedostatkom strukturisanih smernica za upotrebu VI u obrazovanju (Lane, 2025), neki autori ističu da bi njena upotreba mogla dovesti do pravednijeg, kreativnijeg i efikasnijeg okruženja za učenje (Tarlan & Gerstlberger, 2025). S druge strane, jedna nedavna studija istražila je brojne potencijalne rizike povezane sa upotrebom VI u visokom obrazovanju, naglašavajući probleme validnosti podataka, akademskog integriteta i rizika po privatnost (Pikhart & Al-Obaydi, 2025). Fenomen nastave i učenja zasnovanog na VI još uvek je relativno nov, dok primena VI u obrazovanju o ekološkim pitanjima – naročito o klimatskim promenama i njihovom ublažavanju – još uvek nije dostigla stepen razvijenosti koji bi omogućio stabilne i neupitne nalaze, a kamoli univerzalno primenljive i proverljive naučne zaključke.

Rezultati i diskusija

Ankete su sprovedene na osnovu dva odvojena, ali međusobno povezana i komplementarna upitnika. U1 je bio upućen na adrese 14 istraživača koji su već postigli značajne rezultate u ovoj oblasti (kriterijumi izbora su objašnjeni u odeljku posvećenom metodologiji), i osmišljen je sa ciljem da se utvrde glavni aspekti postojećih studija o primeni alata VI

u obrazovanju o ublažavanju klimatskih promena. Odziv anketiranih istraživača može se oceniti kao zadovoljavajući, imajući u vidu da je 12 od 14 istraživača poslalo svoje odgovore sa popunjenim upitnicima (85.7% od ukupnog broja poslatih upitnika). Jedan od glavnih razloga za takav odziv bili su, najverovatnije, lično angažovanje istraživača i njihova želja da učestvuju u naučnom istraživanju i debati, kao i da šire rezultate svog rada, ili jednostavna činjenica da je, prema nekima od njih, „uloga veštačke inteligencije obrazovanju brzo napredovala od automatizacije rutinskih administrativnih zadataka do omogućavanja visoko personalizovanog i adaptivnog iskustva učenja" (Tarlan & Gerstlberger, 2025).

U2 je poslat na adrese 52 odabrane obrazovne institucije širom sveta i bio je usmeren na najnovije i najrelevantnije uticaje VI u obrazovanju i podizanju svesti o ublažavanju klimatskih promena. Radi obezbeđivanja većeg odziva, U2 je najčešće upućivan odabranim licima u okviru obrazovnih institucija (profesorima, rukovodiocima katedri, osobama odgovornim za razvoj nastavnih programa itd.). Odziv anketiranih obrazovnih institucija može se oceniti kao umeren do nizak (27 od 52) – 51.9% od ukupnog broja poslatih U1.

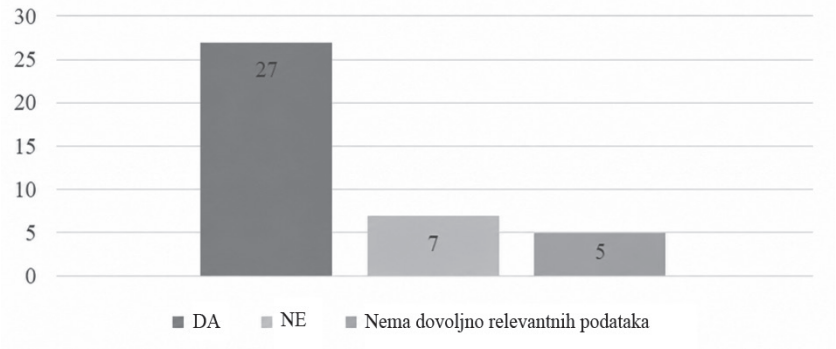
Geografska raspodela anketiranih pojedinaca i institucija bila je zamišljena kao globalna, sa ravnomernom pokrivenošću svih kontinenata. Međutim, odgovori evropskih subjekata bili su nesrazmerno veći (34% poslatih i 61% primljenih odgovora), najverovatnije usled različitih perioda akademskih raspusta, kao i blizine i/ili zajedničkih oblasti interesovanja sa istraživačem.

U1 i U2 su osmišljeni tako da omoguće prikaz kako zajedničkih (neka identična ili slična pitanja) tako i specifičnih stavova istraživača i nastavnika/predstavnika obrazovnih institucija. Ovaj pristup je omogućio razlikovanje opštih i specifičnih rezultata, dalju ekstrapolaciju, kao i primenu deskriptivnih i inferencijalnih statističkih metoda u obradi prikupljenih podataka. Pojedina pitanja, iako formulisana na sličan ili identičan način u oba upitnika (na primer, U1 – pitanja 6 i 7 i U2 – pitanja 8 i 9; U1 – pitanje 12 i U2 – pitanje 10), uvedena su kao korektivna varijabla.

Opšti rezultati anketa (zasnovani na oba upitnika) mogu se svrstati u tri glavne teme:

1. Ukupna sposobnost alata zasnovanih na VI da značajno unaprede obrazovanje, učenje i nastavne metode;
2. Stvarna primena VI u unapređenju obrazovanja o ublažavanju klimatskih promena i njen uticaj;
3. Budući potencijal alata zasnovanih na VI da značajno doprinesu obrazovanju i/ili podizanju svesti o ublažavanju klimatskih promena, adaptaciji, smanjenju uticaja i ranom upozoravanju.

Slika 1
Opšti stavovi o zastupljenosti VI u obrazovanju



Napomena. Odgovori na pitanje „Da li VI, uopšteno posmatrano, može značajno da poboljša obrazovanje, učenje i nastavne metode?"

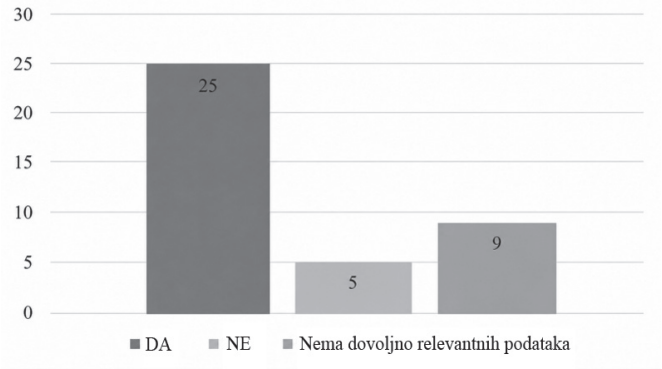
Iako nije iznenađujuće da je na pitanje formulisano u opštim (i, u izvesnoj meri, namerno nepreciznim) terminima većina (72%) anketiranih subjekata odgovorila pozitivno, važno je napomenuti da 13% istraživača i nastavnika i dalje smatra da ne postoje relevantni podaci o potencijalu VI da predstavlja prekretnicu u obrazovanju (Slika 1).

Istraživanje pokazuje značajnu neusklađenost između (iako prilično opšteg i maglovitog) poverenja da VI može unaprediti obrazovanje (67%), s jedne strane, i izostanka njene primene u obrazovanju o ublažavanju klimatskih promena (59%), s druge strane, uz značajan udeo (33%) onih koji su izjavili da ne postoje relevantni podaci. Ovakvi rezultati potvrđuju nalaze nekih ranijih istraživanja koja mesto VI u obrazovanju više definišu kao pedagošku priliku nego kao tehnokratsku pretnju (Chatzichristofis, 2026), ne diskreditujući u potpunosti kritičnije stavove koji ukazuju na višestruke rizike (Pikhart & Al-Obaydi, 2025). Međutim, od malog udela (7.7% – 3 od 39) onih koji smatraju da se VI trenutno koristi za unapređenje obrazovanja o klimatskim promenama, svi su procenili da je značajno da na unapređenje kvaliteta obrazovanja o ublažavanju klimatskih promena pozitivno utiču alati zasnovani na VI.

Iako je veoma mali broj istraživača i nastavnika procenio da se alati VI aktivno koriste u obrazovanju o ublažavanju klimatskih promena, većina njih (64%, vidi Sliku 2) veruje da će ti alati u doglednoj budućnosti dati značajan doprinos obrazovanju i/ili podizanju svesti o ovom pitanju. Ovo ukazuje na postojanje značajnog potencijala za budući razvoj prilagođenih, namenski osmišljenih, inovativnih i prilagodljivih alata zasnovanih na VI, koji bi mogli brzo odgovoriti na hitnu potrebu za postizanjem obrazovnih ciljeva i doprineti podizanju svesti o klimatskim promenama.

Slika 2

Potencijal alata zasnovanih na veštačkoj inteligenciji u obrazovanju o ublažavanju klimatskih promena



Napomena. Odgovori na pitanje „Da li verujete da će alati zasnovani na veštačkoj inteligenciji u doglednoj budućnosti značajno doprineti obrazovanju i/ili podizanju svesti o ublažavanju klimatskih promena, adaptaciji, smanjenju uticaja i ranom upozoravanju?"

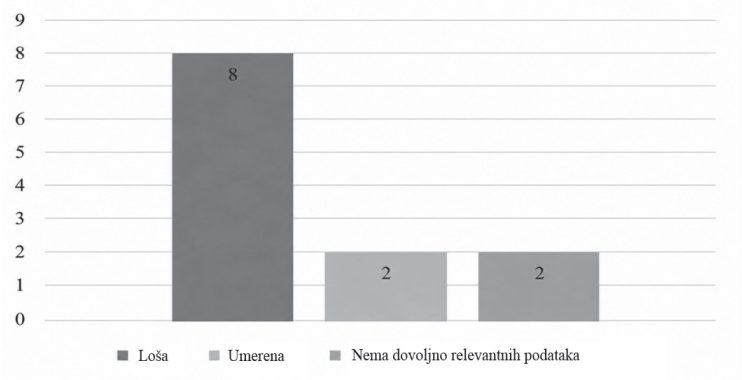
Istraživanje među istraživačima bilo je usmereno na sledeća tri glavna specifična pitanja:

1. Broj, obim, dubina i učestalost izmena nastavnih planova i programa povezanih sa upotrebom alata VI u obrazovanju o ublažavanju klimatskih promena;
2. Nivo interoperabilnosti obrazovnih alata zasnovanih na VI u oblasti ublažavanja klimatskih promena u tehničkim, prirodnim (biologija, hemija) i društvenim naukama (političke nauke, pravo, studije životne sredine) u postojećim nastavnim programima visokog obrazovanja;
3. Broj i obim predloženih, usvojenih i/ili sprovedenih nacionalnih i nadnacionalnih regulatornih promena usmerenih na unapređenje ostvarivanja potcilja održivog razvoja 13.3.

Treba napomenuti da, iako smatraju da se VI retko koristi za unapređenje obrazovanja o ublažavanju klimatskih promena, istraživači veruju da postoje izvesne izmene nastavnih planova u tom pravcu; iako broj i obim ovih izmena ostaju mali, njihova učestalost nije zanemarljiva, a još manje njihova dubina, kada se jave.

Većina istraživača procenila je da je nivo interoperabilnosti obrazovnih alata zasnovanih na VI u oblasti ublažavanja klimatskih promena umeren (42%) ili značajan (17%). Ako se to dovede u vezu, s jedne strane, sa njihovom procenom dubine i učestalosti promena nastavnih programa u ovoj oblasti, a s druge, sa vremenom potrebnim za njihovu potpunu primenu (Smeed et al., 2015) i omogućavanje „kognitivnog restrukturiranja" (Fauziah & Setyowati, 2019), može se zaključiti da obrazovni alati zasnovani na VI mogu doprineti značajnoj komplementarnosti i konvergenciji nastavnih programa posvećenih klimatskim promenama u tehničkim, prirodnim i društvenim naukama, što vodi ka pravednijem, kreativnijem i efikasnijem okruženju za učenje (Tarlan & Gerstlberger, 2025). U zaključku, ukoliko bi dosledno bilo primenjeno u većem broju nastavnih programa, unapređeno okruženje uz podršku VI moglo bi značajno doprineti pozitivnom uticaju alata VI na ostvarivanje potcilja održivog razvoja 13.3.

Slika 3
Ocena regulatornih promena



Napomena. Odgovori na pitanje „Kako biste ocenili broj i obim predloženih, usvojenih i/ili sprovedenih nacionalnih i nadnacionalnih regulatornih promena usmerenih na unapređenje ostvarivanja potcilja održivog razvoja 13.3?

Konačno, u pitanju koje je bilo isključivo posvećeno njima (v. Sliku 3), od istraživača je zatraženo da daju svoju procenu u vezi sa nacionalnim i nadnacionalnim regulatornim promenama usmerenim na unapređenje obrazovanja, podizanja svesti i ljudskih i institucionalnih kapaciteta u oblasti ublažavanja klimatskih promena, adaptacije, smanjenja uticaja i ranog upozoravanja. Kao jedno od retkih pitanja u U1, koje nije direktno povezano sa pitanjima veštačke inteligencije, ono je služilo i kao kontrolna varijabla i kao način za poređenje rezultata u nastavnim i regulatornim promenama. Važno je napomenuti da je samo relativno mali deo anketiranih lica stručan u oblasti pravnih ili političkih nauka, ali – za razliku od njihovih odgovora na druga pitanja – niko od njih nije naveo nedostatak relevantnih podataka, verovatno zbog činjenice da nastavnici imaju tendenciju da veruju da nastavnička autonomija može usmeravati VI (Chatzichristofis, 2026). Odgovori učesnika na ovo pitanje ukazali su na značajan nalaz: istraživači često smatraju da su bolje informisani o onome što se radi na nacionalnom i nadnacionalnom regulatornom nivou nego o onome što se dešava u samom obrazovnom okruženju.

Istraživanje među nastavnicima/predstavnicima obrazovnih institucija bilo je usmereno na sledeća tri glavna specifična pitanja:

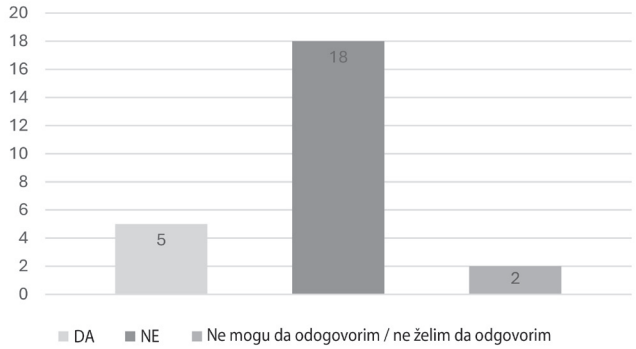
1. Upotreba alata zasnovanih na VI u obrazovnim i/ili istraživačkim aktivnostima;
2. Prisustvo tema povezanih sa VI u nastavnim planovima i programima i/ili institucionalnim obrazovnim/istraživačkim ciljevima;
3. Broj i obim izmena nastavnih planova i programa povezanih sa upotrebom alata VI u obrazovanju.

Upotreba VI u obrazovnim i/ili istraživačkim aktivnostima i dalje nije široko rasprostranjena (33%) u obrazovnim institucijama, kako na osnovnim tako i na postdiplomskim

studijama. Međutim, zanimljivo je napomenuti da – čak i u okviru sopstvene institucije – nastavnici često nisu svesni (15%) da li njihove kolege u drugim odeljenjima/jedinicama koriste neke alate zasnovane na VI, a još manje na koji način se ti alati koriste. Ovo pokazuje da je VI – barem na globalnom nivou – još uvek novina u obrazovnom okruženju, kao što je već navedeno u literaturi, posebno kada je reč o strukturisanim smernicama za nastavnike (Lane, 2025).

Slika 4

Prisustvo tema povezanih sa veštačkom inteligencijom u nastavnim programima



Napomena. Odgovori na pitanje „Da li su teme povezane sa veštačkom inteligencijom prisutne u vašim nastavnim programima i/ili institucionalnim obrazovnim/istra živačkim ciljevima?

Rezultati su bili još upečatljiviji kada su nastavnici upitani o prisustvu tema povezanih sa VI u nastavnim programima i/ili institucionalnim obrazovnim/istraživačkim ciljevima njihove institucije (v. Sliku 4). Ogromna većina (74%) odgovorila je negativno, dok su oni koji su naveli da VI – na transparentan i formalno utvrđen način – ima svoje mesto u njihovim nastavnim programima i/ili među institucionalnim obrazovnim/istraživačkim ciljevima najverovatnije profesori koji su i sami osmislili te programe i trenutno predaju po njima.

Iako su gotovo podjednako pesimistični kao i istraživači u pogledu broja izmena nastavnih programa povezanih sa upotrebom alata VI u obrazovanju, odgovori nastavnika se značajno razlikuju u pogledu obima tih izmena, pri čemu 55% njih procenjuje da su one značajne (42%) ili umerene (13%). To, najverovatnije, dovodi do ključnog uvida ovog dela istraživanja: kada se jednom sprovedu izmene nastavnih programa u vezi sa upotrebom alata VI u obrazovanju o klimatskim promenama, njihov obim je najčešće značajan, što je nalaz potvrđen i u nedavnoj sistemskoj analizi literature (Tarlan & Gerstlberger, 2025). Kada se ovo dovede u vezu sa već iznetim tvrdnjama, može se zaključiti da obrazovni alati zasnovani na VI imaju značajan potencijal da doprinesu ostvarivanju potcilja održivog razvoja 13.3.

Zaključci i projekcije

Na osnovu kombinovanih i ekstrapoliranih nalaza iz anketa, kao i analiza istraživanja o VI u obrazovanju i njenoj ulozi u ublažavanju klimatskih promena, izvedeno je nekoliko ključnih zaključaka i projekcija (vidi Tabelu 1), sa fokusom na to kako se različiti tipovi kurikuluma usklađuju sa specifičnim potrebama obrazovanja o ublažavanju klimatskih promena.

Tabela 1
Kako različiti tipovi kurikuluma odgovaraju specifičnim potrebama obrazovanja o ublažavanju klimatskih promena

Specifične potrebe/ odlike obrazovanja o klimatskim promenama	Tradicionalni kurikulumi (bez podrške VI)	Opšti obrazovni alati uz podršku VI	Obrazovni alati uz podršku veštačke inteligencije prilagođeni obrazovanju o klimatskim promenama
Međudisciplinarnost	Od niske do umerene - često insistiraju na strogoj podeli između prirodnih i društvenih nauka - sporo se prilagođavaju međudisciplinarnim pitanjima povezanim sa održivošću	Umerene - češće integrišu međusektorska pitanja - češće uključuju interaktivne obrazovne alate	Umerena do visoka - sposobni da prikažu složenost pitanja povezanih sa održivošću - uvek uključuju interaktivne obrazovne alate
Visoki globalni socio-ekonomski ulozi	Slaba prilagodljivost - uglavnom spori i neefikasni u suzbijanju predrasuda, zabluda i teorija zavere o klimatskim promenama - ne reaguju na nove kanale informisanja i komunikacije	Prilagodljivi, uz visoke rizike - prilagodljivi brzim društvenim promenama i dinamičnom okruženju - mogu se lako koristiti u obmanjujuće i manipulativne svrhe	Visoko prilagodljivi - sposobni da prikažu društvene uticaje klimatskih promena - efikasni u suzbijanju predrasuda, zabluda i teorija zavere - reaguju na nove kanale informisanja i komunikacije
Brzina postizanja obrazovnih ciljeva	Uglavnom spori - najčešće osmišljeni za postizanje složenih obrazovnih ciljeva - usmereni na dugoročne pedagoške ciljeve	Potencijalno brzi, uz rizike - mogu doneti brze rezultate, uz upitnu održivost - mogu biti podložni manipulaciji	Brzi - sposobni da pruže sažetu i prilagođenu obuku - efikasni u podizanju svesti i podsticanju ekološkog aktivizma

Alati zasnovani na VI mogu značajno unaprediti obrazovanje, učenje i nastavu o ublažavanju klimatskih promena, ali se i dalje relativno retko koriste. Izmene u nastavnim programima povezane sa upotrebom alata VI u ovoj oblasti obrazovanja ostaju ograničene po broju i obimu; ipak, njihova sve veća dubina i učestalost ukazuju na verovatno širenje alata i praksi zasnovanih na VI u nastavnim programima vezanim za ublažavanje klimatskih promena. Istovremeno, predložene i sprovedene nacionalne i nadnacionalne regulatorne promene usmerene na postizanje potcilja održivog razvoja 13.3 i dalje su nedovoljne; dugotrajni proces usvajanja Akta Evropske unije o veštačkoj inteligenciji (Pravilnik EU 2024/1689), zajedno sa njegovim ograničenim dometom, najverovatnije će rezultirati ograničenim efektima i mogućim izazovima u primeni u državama članicama EU.

U prirodnim naukama (kao što su biologija i hemija) i društvenim naukama (uključujući političke nauke, pravo i studije životne sredine), očekuje se da će rasti interoperabilnost obrazovnih alata u segmentu povezanom sa ublažavanjem klimatskih promena, čime će se ojačati održivost pedagoških ciljeva. Uzimajući u obzir specifične potrebe i karakteristike obrazovanja – kao što su međudisciplinarnost i visoki globalni socio-ekonomski ulozi u postizanju obrazovnih ciljeva – verovatnije je da će alati zasnovani na VI prilagođeni obrazovanju o ublažavanju klimatskih promena postići pedagošku efikasnost nego opšti alati ovog tipa. Ovaj zaključak se, pre svega, nameće zbog njihove sposobnosti da bolje prikažu složenost pitanja održivosti, obuhvate društvene uticaje klimatskih promena, suprotstave se dezinformacijama i zabludama i prilagode se promenljivim kanalima komunikacije. Pored toga, oni su efikasniji u pružanju sažetog, prilagođenog učenja i delotvorniji u podizanju svesti i podsticanju ekološkog angažovanja.

U celini, kada se procenjuju prema sposobnosti da ostvare obrazovne ciljeve, tradicionalni nastavni programi (bez podrške VI) obično su sporiji zbog naglaska na dugoročnim pedagoškim ishodima. Opšti alati VI mogu doneti brze obrazovne rezultate, ali uz neizvesnu održivost, dok su alati prilagođeni obrazovanju o ublažavanju klimatskih promena, uprkos izvesnim strukturnim rizicima, bolje prilagođeni da obezbede ciljano, efikasno i uticajno učenje, istovremeno unapređujući međudisciplinarnost i prilagodljivost složenim globalnim socio-ekonomskim kontekstima.

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Education on Climate Change Mitigation and Artificial Intelligence – Critical and Empirical Analysis[1]

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Abstract *Artificial Intelligence (AI) presents a range of new threats and opportunities across numerous critical public sectors, including education. While the aspiration to develop a genuinely human-centric AI may appear idealistic, increasing resources are being devoted to this goal. Another globally significant issue is climate change mitigation, yet most university curricula inadequately address – or entirely omit – this topic. This article critically explores the risks and potentials of AI in education on climate change mitigation, focusing on the extent to which AI tools in this domain are cross-disciplinary, accessible and impactful. To evaluate AI's role in education, learning, and teaching methods (AIED), the author employed two primary methodological approaches, placing the focus of scientific interest on the concepts related to interactions between AIED systems and human decision-makers, as well as on their applicability in education on climate change mitigation. First, a critical review of the existing scientific literature on AIED was conducted, focusing on its relationship with educational programs and methods dedicated to climate change mitigation; when it comes to the place of AI in educational ecosystem, the recent studies have expressed the most substantial criticism regarding the issues of major economic and, to a lesser extent, political reasons that have led to its introduction. Second, the evaluation of the impact of AI in education on climate change mitigation was based on two adapted questionnaires, while descriptive and inferential statistical methods were used to process the gathered data. The findings indicate that AI-assisted educational tools specifically tailored to climate change mitigation are significantly more effective in achieving pedagogical objectives than general AI-based tools, allowing their wider use in educational practice. However, challenges remain regarding risks and accessibility, limiting their broader adoption and impact.*

Keywords: *education; climate change mitigation; Artificial Intelligence (AI) in education; sustainable development.*

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Introduction - purpose and context of the research

After the adoption of the 2030 Agenda for Sustainable Development by the Member States of the United Nations, the 17 Sustainable Development Goals (SDGs), broken down into 169 targets, have become a "shared blueprint for peace and prosperity for people and the planet" (United Nations [UN], The 17 Goals, 2015). While some members of the scientific community have expressed certain criticism regarding the way SDGs are formulated – estimating that they are "inconsistent, difficult to quantify, implement and monitor" (Swain, 2018, p. 341), but also criticizing them "for reproducing a universal template grounded in a western and neoliberal ideology" (Arora-Jonsson, 2023, p. 2) – it is difficult to deny that the SDGs represent a good global and universally known common ground, both for governmental and civil society activities, as well as for further reflection within the widest expert and scientific fora.

The moto of the SDG 13 (Climate Action) is "take urgent action to combat climate change and its impacts". No one serious denies the more and more harmful consequences of climate change all over the globe, with "climate records […] shattered in 2023 [and] the communities around the world suffering the effects of extreme weather, which is destroying lives and livelihoods on a daily basis" (UN – Progress towards the Sustainable Development Goals, 2024, p. 19). As one of three targets within SDG 13, Target 13.3 (Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning) tackles one of the crucial issues of climate action – the need to adapt the way we learn, teach and inform about climate change mitigation. Unfortunately, the results achieved in this field are very modest. According to the latest Progress Report of the UN Secretary-General, "a study in 2023 of more than 530 grade 9 science and social science subject curricula found that 69% contained no reference to climate change and 66% made no mention of sustainability" (UN, Progress towards the Sustainable Development Goals, 2024, p. 20). These discouraging findings are, to a certain extent, toned down by adding that "three-quarters of countries reported they have plans to revise their curricula in the next three years to focus more on climate change and sustainability". There is, however, no mention on how those "three-quarters of countries" consider to revise the curricula, on which levels, in the context of which subject matters and, above all, using what kind of educational methods and techniques. It is, however, important to note that the process of curricular reforms in this direction was timidly initiated in some countries, while the potential of AI tools in education on climate change has been undoubtedly underscored in the recent scientific literature (Allam et al., 2025; Tapalova & Zhiyenbayeva, 2022; Tarlan & Gerstlberger, 2025). For example, in a report published on 4 September 2024, Oxford, Cambridge and RSA Examinations (OCR) called for the creation of an independent body to maintain a "far more contemporary and forward-looking" curriculum ("England's school curriculum…", 2024), more focused on climate change and sustainability, but also insisting on the need for education about the appropriate use of Artificial Intelligence (AI).

AI has an undisputed aptitude to serve as a tool in improving education, learning and teaching methods (AIED). The objective of this article is to evaluate the specific im-

pact of AI on SDG target 13.3, with a focus on education on climate change mitigation. To do so, the author used two main methods. On the one hand, the research was based on critical examination of the existing scientific research dedicated to AIED, with a special focus on its applicability in various educational programs and methods dedicated to climate change mitigation; the main results are presented in the Chapter "State of the research…" of this article. On the other hand, the evaluation of the future potential impact of AIED on education on climate change mitigation was both qualitative and quantitative, based on two adapted questionnaires; the main results of this aspect of research are presented in Chapters "Results and discussion" and "Projection and conclusions".

Methodological approach

While plethora of studies have already assessed the possible advantages and shortcomings of AI as a tool in improving education, learning and teaching methods (Alfayez & Rasool, 2025; Edam et al., 2024; Yuskovych-Zhukovska et al., 2022; Zawacki-Richter et al., 2019), those exclusively dedicated to the scientifically founded and well documented study on the impact of AIED on climate change mitigation are practically inexistent. However, significant number of recent works include important findings on the use of AI in sustainability teaching and learning (Abulibdeh et al., 2024; Leal Filho et al., 2025), but also addresses the issue of the place of AI in Environmental, Social, and Governance (ESG) education and practice (Correia & Água, 2024; Gupta & Agarwal, 2025; Tarlan & Gerstlberger, 2025).

The key element of the conducted study is qualitative and quantitative evaluation of the impact of AI in education on climate change mitigation. It is based on two adapted questionnaires (Q1 and Q2, more details about the results of the survey in Chapter "Results and discussion"), while descriptive and inferential statistical methods were used to process the gathered data. Due to the lack of sufficiently numerous and detailed data published in peer-reviewed scientific articles, some of the used references are reputed media sources and reports published by international organisations.

Some of the key criteria to determine and measure the impact of AIED on the achievement of SDG target 13.3 were:

1. Level of inclusion of AI-based educational tools in the existing higher education curricula;
2. Level of interoperability of the above tools in natural and social sciences; and
3. Feedback given by educators in their answers to Q2. The results obtained through the surveys were scrutinized and quantified.

The research operated with two big sources of data. This choice was imposed by the complexity of possible interactions between AIED systems and human decision-makers (Gupta & Agarwal, 2025; Holstein & Doroudi, 2021), as well by the nature of interplay between automated and human decision-making (Yuan et al., 2023).

The first bundle of data (see Chapter "State of the research…") was collated through the critical examination of numerous existing studies that have already assessed the possible advantages and shortcomings of AIED; gathered data is then scrutinized, in order to distil whether or not (and, if yes, to what extent) AIED impacted or could impact the realisation of SDG target 13.3.

The second valuable source of data (see Chapter "Results and discussion") was gathered through two different, tailor-made questionnaires (Q1 and Q2).

Questionnaire 1, addressed to the researchers who have already achieved significant results in the field of AI studies, was designed in order to try and distil the climate change related aspects of the existing studies of AIED. Q1 consisted of 16 questions, focusing on how AI may improve education in general and, more specifically, climate-change education, including its current use, perceived impact, and future potential. It also asks respondents to assess changes in curricula, regulatory developments related to SDG 13.3, and the interoperability of AI tools across different academic disciplines. The researchers to whom the targeted questionnaires were sent had been selected on the basis of three combined criteria: 1. recently (2018-2024) published (preferably in WoS indexed journals) papers or internationally recognized books and/or participation in reputable scientific projects related either to the use of AI in education or to the broader societal, ethical or technical issues related to AIED; 2. relatively equal geographic distribution; 3. inclusion of researchers from different scientific fields, including technical sciences (with understandable preference for social sciences). Due to the limited timeframe for conducting the research and highly selective criteria, the questionnaire was sent only to 14 researchers; this sample is relatively small and does not allow sufficient territorial and disciplinary variety, but provided a solid feedback from sufficiently varied spectre of researchers. More details regarding the response rate, possible reasons for it, as well as the interpretation of results can be found in Chapter "Results and discussion".

Questionnaire 2 (Q2) was sent to the representatives of 52 selected educational and research institutions worldwide and was focused on the recent and most relevant impacts of AI in education and awareness-raising on climate change mitigation. Q2 consisted of 14 questions, exploring whether the respondent's institution uses AI in education or research, whether AI-related topics appear in curricula, and whether AI is seen as useful for improving teaching and learning. It also focuses on AI in climate-change mitigation education by asking about current use, curriculum changes, interdisciplinary interoperability, and the future opportunities and risks of AI-based tools in climate-related education. The institutions to which the questionnaires were sent had been selected on the basis of three combined criteria: 1. relatively equal geographic distribution (no continent neglected); unfortunately, in spite of this effort, the response rate from European and Asian universities was disproportionately higher; 2. cross- or trans- disciplinarity in educational and/or scientific mission of the institution; and 3. estimated reputation of the institution, but entirely disconnected from its excellence in the field of AI-based educational or research methods. Despite the fact that the questionnaire was sent to 52 institutions, only about one half responded; although this sample was limited, it allows a good level of territorial and disciplinary variety. More details regarding

the response rate, possible reasons for it, as well as the interpretation of results can be found in Chapter "Results and discussion".

The key research questions underlying the entire analysis and assuring the complementarity of Q1 and Q2 are the following:

1. When compared in terms of their exigency to reach educational goals, what is the crucial difference between traditional, general AI-assisted educational tools and AI-assisted educational tools adapted to the Education on Climate Change Mitigation (ECCM)?
2. Can AI-assisted educational tools which are adapted to ECCM score higher in cross-disciplinarity and be more adaptable to complex global socio-economic context than traditional and general AI-assisted educational tools?

The main tools used to process and present the gathered data were descriptive and inferential statistical methods, while the four central issues related to which the results of the surveys were systematised are (from general to specific): 1) overall attitude on AI in education; 2) potential of AI-based tools in education on climate change mitigation; 3) evaluation of regulatory changes related to the content of the curricula; 4) presence of AI-related issues in the curricula. General results (above-mentioned issues 1 – 3) have been based on the combined results of the surveys (both Q1 and Q2), while the presence of AI-related issues in the curricula concerned only institutional respondents.

State of the research on AIED and its applicability in education on climate change mitigation – a critical overview

Until now, as of mid-October 2025, and from the perspective of ethical and other value-related considerations, AI has had its least controversial track record in its ability to serve as a tool for improving education, learning and teaching methods. As some authors have appropriately remarked, "all empirical studies […] presented the positive effects of AI techniques on education" (Zhai et al., 2021), while in educational applications, the combination of knowledge-based and data-driven approaches represents a natural path forward (Holmes & Tuomi, 2022), in spite of significant criticism related to fact that the rush to integrate industry-promoted AI tools in education risks "epistemic colonization" (Chatzichristofis, 2026). However, while improved learner outcomes remain the top reason for adopting AI, some point to the dangers of AIED colonialism and asymmetries in power across and between nations (Berliner, 2009; Holmes, 2020).

The most substantial criticism related to the place of AI in educational ecosystem is the one that focuses on the major economic and, to a lesser extent, political reasons that have led to its introduction. In such a context, when practically all AI tools are developed and/or provided by profitable entities – whose unique or predominant objective is to commercialize their services in a way that maximizes economic gain – the needs of learner can easily be overrun by other considerations based on productivity, rapidity and gain. As it was rightfully pointed out, "pursuit of marketable products […] appears to define the general approach of the private sector, rather than any underlying educational

rationale for the design and development of AI applications" (Knox, 2020, p. 16). In such a context, tailor-made approach to education, based on learner's individual pedagogical needs, has all the chances to be neglected, and even more so when it comes to online courses (Holstein & Doroudi, 2021; Ortagus, 2023). Therefore, improved learner outcomes mentioned in the previous paragraph can be seen under a different light, allowing to further question the ways they were measured, especially if one takes in consideration that cost savings due to automation can significantly compromise the individual approach in learning. Moreover, "AI is, luckily, still unable to 'generate' (or even imitate) inspiration, contemplation, spontaneity and fervour" (Ćemalović, 2020, p. 158), features playing an important role in educational process. A detailed analysis, elaborated in 2022 under the auspices of the Council of Europe by a group of five authors (Wayne Holmes, Jen Persson, Irene-Angelica Chounta, Barbara Wasson and Vania Dimitrova) defined some major threats AIED could represent for human rights, democracy and rule of law. Although this document is most often limited to the description of normative standards, it also includes a good review of the existent studies dedicated to AIED; however, it openly admits that "there is little substantive literature that focuses specifically on, or even mentions in any meaningful way, AI, education and human rights" (Council of Europe, 2022, p. 51).

ECCM is a complex issue and has numerous specificities, out of which the most important are its cross-disciplinary nature, high global socio-economic stakes and exigency to reach educational goals. First, cross-disciplinarity, in principle, requires rapid analytical tools, capable of processing large amount of data in a short time; moreover, it depends significantly on a better teacher learning, based on a "more thoroughgoing ecological framing of teacher professional development" (Ehrenfeld, 2022, p. 489), allowing them to "successfully integrate AI tools while keeping ethical issues like bias and data protection in mind" (Pikhart & Al-Obaydi, 2025, p. 9). Second, high global socio-economic stakes impose the need for effective, universally applicable and decomplexified educational tools, also capable of combating multifaceted prejudices, misbelieves and conspiracy theories about (non)existence of climate change, that are constantly popping-up in numerous countries of the world, especially in times of elections or other moments when important societal choices are made. Third, an exigency to reach educational goals demands rapid, adaptable and universal curricula drivers (Lingard & McGregor, 2013), designed in a way that can easily be integrated in various existing educational modules in elementary and high schools, as well as in educational policy making (Linderoth et al., 2024), which, consequently, can lead to side-lining of "the value of interactions across disciplinary divisions" (Pasque et al., 2009, p. 126). All the above-mentioned specificities taken into consideration, it can be concluded that AI based educational tools in education on climate change mitigation can be, in numerous aspects, more adapted to specific pedagogical goals and learners' needs than AI educational tools in general. Moreover, even some pertinent critical remarks regarding the impact of AI based learning on human rights, democracy, rule of law and privacy (Pikhart & Al-Obaydi, 2025) are not always applicable (or are applicable to a much lesser extent) to AI-assisted education on climate change mitigation.

Due to the novelty of the AIED as a global phenomenon, there is no plethora of recent, structured, detailed and internationally conducted and recognized scientific studies

dedicated to this issue, let alone when it comes specifically to the application of AIED-related methods and techniques in the ECCM. However, some relevant connected studies have pointed out that "the advent of large language models (LLMs), demonstrated by widely accessible chatbots, has generated significant interest in their potential application for communicating complex scientific knowledge" (Al Khourdajie, 2025, p. 7). In the similar vein, in spite of entirely understandable criticism regarding the lack of structured guiding on the use of AI for educators (Lane, 2025), some authors insisted on the fact that the use of AI in education could bring about a more equitable, creative and effective learning environment (Tarlan & Gerstlberger, 2025). On the other hand, a recent study explored numerous potential risks associated with the use of AI in higher education, stressing the issues of the validity of data, academic integrity and privacy risks (Pikhart & Al-Obaydi, 2025). The phenomenon of AI-based teaching and learning is still relatively new, while the application of AIED in education on environmental issues – especially on climate change and its mitigation – has not yet gained sufficient progress to allow stable and undisputable findings, let alone more universally applicable and verifiable scientific conclusions.

Results and discussion

The surveys were carried out on the basis of two separate – but intrinsically interconnected and complementary – questionnaires. Q1 was addressed to 14 researchers who had already achieved significant results in the field (selection criteria were explained in the section dedicated to the methodology), and was designed to establish the main aspects of the existing studies of AIED applicable to education on climate change mitigation. The responsiveness of the surveyed researchers can be assessed as satisfactory, given that 12 out of 14 researchers sent their responses with filled-in questionnaires – 85.7% of total number of Q1 sent. One of the main reasons for such responsiveness was, most probably, the personal involvement of the researchers and their wish to engage in scientific study and debate, as well as to disseminate the results of their research; on the other hand, maybe it was the simple fact that, according to some of them, "AI's role in education has swiftly advanced from automating routine administrative tasks to facilitating highly personalized and adaptive learning experience" (Tarlan & Gerstlberger, 2025).

Q2 was sent to 52 selected educational institutions worldwide and was focused on the recent and most relevant impacts of AI in education and awareness-raising on climate change mitigation. In order to ensure higher responsiveness, Q2 was most often sent to selected persons within educational institutions (professors, heads of departments, persons responsible for curricular development etc.). The responsiveness of the surveyed educational institutions can be assessed as moderate to low (27 out of 52) – 51.9% of total number of Q1 sent.

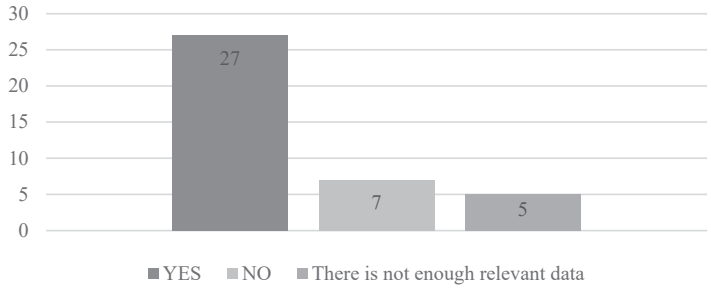
Geographical distribution of surveyed individuals and institutions was intended to be global, covering equally all continents. However, the response of European entities was disproportionally higher (34% of sent and 61% of received answers), most probably due to varying periods of academic vacation, as well as proximity and/or common fields of interests with the surveyor.

Q1 and Q2 were designed in a way that allows to display both common (some identical or similar questions) and specific standpoints of researchers and educators/representatives of educational institutions. This approach allowed the differentiation of general and specific results, as well as and further extrapolation the use of descriptive and inferential statistical methods to process the gathered data. Some of the inquiries, even if formulated in a similar or identical ways in both questionnaires (for example, Q1 – question 6 and 7 and Q2 – questions 8 and 9; Q1 – question 12 and Q2 – question 10) were introduced as a corrective variable.

General results of the surveys (both Q1 and Q2) can be classified in three major topics:

1. Overall aptitude of AI-based tools to significantly improve education, learning and teaching methods;
2. Actual use of AI to improve the education on climate change mitigation and its impact;
3. Future potential of AI-based tools to significantly contribute to education and/or awareness-raising on climate change mitigation, adaptation, impact reduction and early warning.

Figure 1
Overall attitude on AI in education



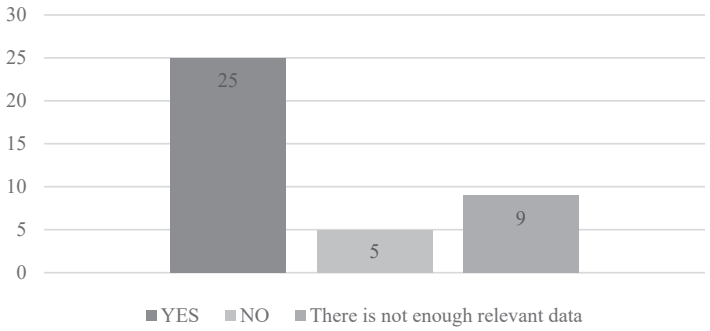
Note. Answers to the question "Can AI, in general, significantly improve education, learning and teaching methods"?

While it is not surprising that, to a question formulated in general (and, to some extent, deliberately imprecise) terms, the majority (72%) of surveyed entities responded positively, it is important to note that 13% of researchers and educators still consider that there is not relevant data regarding the potential of AI to represent a game changer in education (Figure 1).

The survey shows a significant discrepancy between (although quite general) trust that AI could improve education (67%), on the one hand, and the absence of its use in education on climate change mitigation (59%), on the other, with a significant share (33%) of those who declared that there is not relevant data. Such results confirm the findings of some previous researches defining AI in education more as a pedagogical opportunity, than a technocratic

threat (Chatzichristofis, 2026), without entirely discrediting more critical views insisting on multifaceted risks (Pikhart & Al-Obaydi, 2025). However, out of the small proportion (7.7% - 3 out of 39) of those who consider that AI is presently used to improve education on climate change, everyone estimated that it was significant for the improvement of the quality of the education on climate change mitigation to be positively impacted by AI-based tools.

Figure 2
Potential of AI-based tools in education on climate change mitigation



Note. Answers to the question "Do you believe that AI-based tools will, in the foreseeable future, significantly contribute to education and/or awareness-raising on climate change mitigation, adaptation, impact reduction and early warning?"

Even if very few researchers and educators estimated that AI tools are actively used in education on climate change mitigation, majority of them (64%, see Figure 2) believe those tools will, in the foreseeable future, give a significant contribution to education and/or awareness-raising on this particular issue. This shows that there is an important potential for future development of adapted, tailor-made, innovative and responsive AI-based tools, that would be able to rapidly respond to the pressing need to reach educational goals and contribute to awareness-raising on climate change.

Survey among the researchers was focused on the following three major specific issues:

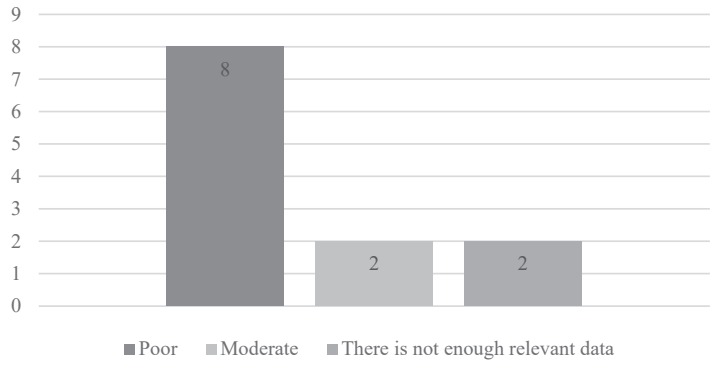
1. Number, scope, depth and frequency of modifications in curricula related to the use of AI tools in education on climate change mitigation;
2. Level of interoperability of AI-based educational tools on climate change mitigation in technical, natural (biology, chemistry) and social sciences (political science, law, environmental studies) in the existing higher education curricula;
3. Number and scope of proposed, adopted and/or implemented national and supra-national regulatory changes intended to improve the achievement of SDG target 13.3.

It should be noted that, even if they estimate that AI is rarely used to improve education on climate change mitigation, researchers believe there are some modifications in

curricula in this direction; while the number and scope of these modifications remain low, when they occur, their frequency and, even more, depth and not negligible.

The majority of researchers estimated that the level of interoperability of AI-based educational tools on climate change mitigation is moderate (42%) or significant (17%). If correlated with, on the one hand, their assessment regarding the depth and frequency of curriculum changes in this field, and, on the other, the time needed to fully implement them (Smeed et al., 2015) and allow "cognitive restructuring" (Fauziah & Setyowati, 2019), it can be concluded that AI-based educational tools can contribute to a significant complementarity and convergence of curricula dedicated to climate change in technical, natural and social sciences, leading to a more equitable, creative and effective learning environment (Tarlan & Gerstlberger, 2025). In conclusion, when consistently implemented in higher number of curricula, an improved AI-assisted environment could significantly contribute to the positive impact of AIED on the achievement of SDG target 13.3.

Figure 3
Evaluation of regulatory changes



Note. Answers to the question "How would you evaluate the number and scope of proposed, adopted and/or implemented national and supra-national regulatory changes intended to improve the achievement of SDG target 13.3?"

Finally, in a question exclusively dedicated to them (see Figure 3), the researchers were asked to give their estimation regarding national and supra-national regulatory changes aiming to improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning (SDG target 13.3). As one of the rare queries in Q1 not directly related to AI issues, it served both as a control variable and as a way to compare results in curricular and regulatory changes. It is important to note that only a relatively small proportion of surveyed persons are experts in legal or political sciences, but – unlike it was the case of their answers to other questions – none of them invoked the absence of relevant data, possibly due to the fact

that educators tend to believe that teacher agency can direct AI (Chatzichristofis, 2026). Participants' responses to this question revealed an important finding: researchers often consider themselves better informed about what is done on national and supra-national regulatory level than about what is done in the milieu of education.

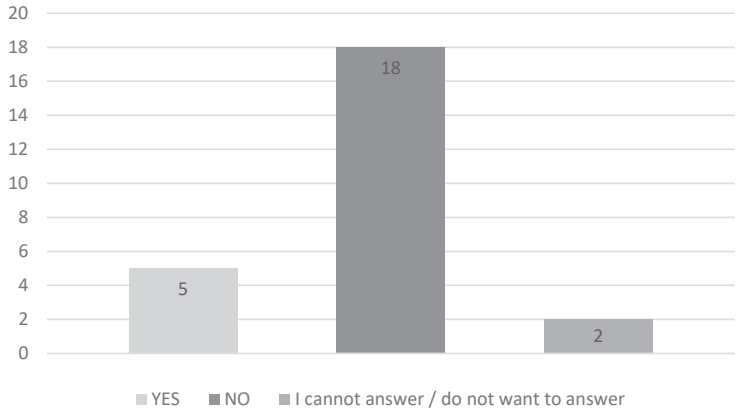
Survey among the educators/representatives of educational institutions was focused on the following three major specific issues:

1. Use of AI-based tools in educational and/or research activities;
2. Presence of AI-related issues in curricula and/or institutional educational/research objectives;
3. Number and scope of modifications in curricula related to the use of AI tools in education.

The use of AI in educational and/or research activities is still not widespread (33%) in educational institutions, both on graduate and under-graduate level. It is, however, interesting to note that – even within their own institution – educators are often unaware (15%) of whether their colleagues in other departments/units are using some AI-based tools, and even less when it comes to the ways of this use. This shows that AI – at least on the global level – is still a novelty in educational milieu, as it has already been mentioned in the literature, particularly when it comes to the structured guidance for educators (Lane, 2024).

Figure 4

Presence of AI-related issues in the curricula



Note. Answers to the question "Are AI-related issues present in your curricula and/or your institutional educational/research objectives"?

The results were even more striking when educators had been asked about the presence of AI-related issues in curricula and/or institutional educational/research objectives of their institution (see Figure 4). The overwhelming majority (74%) responded negatively, while those who stated that AI has – in a transparent and formally established way – its place in their curricula and/or among their institutional educational/research objectives were, most probably, professors who, themselves, designed those curricula and are presently teaching according to the curricula.

While they are almost as pessimistic as researchers when it comes to the number of modifications in curricula related to the use of AI tools in education, teachers' answers are outstandingly different regarding the scope of these modifications, with 55% of them estimating they are significant (42%) or moderate (13%). This leads to, most probably, the crucial insight of this part of the survey: once we undertake the curriculum changes related to the use of AI tools in education on climate change, their scope is most often significant, which is a finding confirmed by a recent systemic literature review (Tarlan & Gerstlberger, 2025). When put in correlation with what has already been alleged above, it can be concluded that AI-based educational tools have a significant potential to contribute to the achievement of SDG target 13.3.

Conclusions and projections

Based on combined and extrapolated findings from surveys and analyses of research on AI in education (AIED) and its role in climate change mitigation, several key conclusions and projections (*see Table 1*) have been drawn, with a focus on how different types of curricula align with the specific needs of education on climate mitigation (ECCM).

Table 1
How different types of curricula correspond to the specific needs of ECCM

Specific needs/ characterictics of ECCM	Traditional (non AI-assisted) curricula	General AI-assisted educational tools	AI-assisted educational tools adapted to ECCM (projection)
Cross-disciplinarity	Low to moderate - frequently insist on strict division between natural and social sciences - slow in adaptation to cross-disciplinary issues related to sustainability	Moderate - more often integrate cross-cutting issues - often include interactive educational tools	Moderate to high - able to illustrate the complexity of sustainability related issues - always include interactive educational tools
High global socio-economic stakes	Weak adaptability - mostly slow and inefficient in combatting prejudices, misbelieves and conspiracy theories about climate change - irresponsive to new channels of information and communication	Adaptable, with high risks - adaptable to quick societal changes and rapidly changing environment - can easily be used for deceptive and manipulative purposes	Highly adaptable - capable to present the societal impacts of climate change - efficient in combatting prejudices, misbelieves and conspiracy theories - responsive to new channels of information and communication
Exigency to reach educational goals	Mainly slow - most often designed to reach complex educational goals - focused on long-lasting pedagogic objectives	Potentially rapid, with risks - can deliver rapid outcomes, with questionable sustainability - can be subject to manipulation	Rapid - capable to provide concise and tailor-made training - efficient in raising consciousness and encouraging environmental activism

AI-based tools can significantly improve education, learning, and teaching on climate change mitigation, yet they are still relatively rarely used. Modifications in curricula related to the use of AIED tools in ECCM remain limited in number and scope; however, their increasing depth and frequency suggest a likely expansion of AI-based tools and practices in ECCM curricula. At the same time, proposed and implemented national and supra-national regulatory changes aimed at achieving SDG target 13.3 remain insufficient; the delayed adoption of the European Union's Artificial Intelligence Act (Regulation EU 2024/1689), together with its limited scope, will most likely result in constrained effects and potential enforcement challenges across the EU Member States.

The interoperability of AI-based educational tools for climate change mitigation across natural sciences (such as biology and chemistry) and social sciences (including political science, law, and environmental studies) is expected to grow, thereby strengthening the sustainability of pedagogic objectives. Taking into account the specific needs and characteristics of ECCM – such as cross-disciplinarity and the high global socio-economic stakes involved in achieving educational goals – AI-assisted tools specifically adapted to ECCM are more likely to achieve pedagogic effectiveness than general AI-based tools. This is due to their ability to better represent the complexity of sustainability issues, address societal impacts of climate change, counter misinformation and misconceptions, and adapt to evolving communication channels. In addition, they are more efficient in delivering concise, tailored learning and more effective in raising awareness and fostering environmental engagement.

Overall, when evaluated in terms of their capacity to meet educational goals, traditional (non-AI-assisted) curricula tend to be slower due to their emphasis on long-term pedagogic outcomes. General AI-assisted tools can produce rapid educational results, though with uncertain sustainability, whereas ECCM-adapted AI tools, despite certain structural risks, are better suited to provide targeted, efficient, and impactful learning, while also enhancing cross-disciplinarity and adaptability to complex global socio-economic contexts.

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