

# Can you trust Wikidata?

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**Abstract.** In order to use a value retrieved from a Knowledge Graph (KG) for some computation, the user should, in principle, ensure that s/he trusts the veracity of the claim, i.e., considers the statement as a fact. Crowd-sourced KGs, or KGs constructed by integrating several different information sources of varying quality, must be used via a trust layer. The veracity of each claim in the underlying KG should be evaluated, considering what is relevant to carrying out some action that motivates the information seeking. The present work aims to assess how well Wikidata (WD) supports the trust decision process implied when using its data. WD provides several mechanisms that can support this trust decision, and our KG Profiling, based on WD claims and schema, elaborates an analysis of how multiple points of view, controversies, and potentially incomplete or incongruent content are presented and represented.

Keywords: Trust, contextual, KG Profiling

## 1. Introduction – WD as information source

Wikidata [26] (WD) is currently one of the most extensive publicly available Knowledge Graphs (KGs). Numerous other websites are regularly using it, services (search engines, personal assistants, libraries, and museums [9,27]), applications (Daimler, Lufthansa, Novartis, data journalists, ...), and research projects [11]. It is regarded by many as part of the Semantic Web (e.g., [16]).

In some applications using KGs [3], one needs to obtain the value of some property of an entity (item in WD parlance) to make some computation. For example, finding the capital city of a country or province; obtaining a person's birth or death date; determining the author of some artifact; obtaining some physical property of a known substance; etc. By design, WD contains statements based on claims about items. In principle, there is no guarantee of the truthfulness of claims.

Suppose a person wants to claim some inheritance from Ana Maria Imeni by being a descendant of Menotti Garibaldi, the son of the famous revolutionary Giuseppe Garibaldi. According to WD, there are two claims for who his mother was; see Fig. 1. Which one is true? Can a person have two mothers? If yes, under which circumstances?

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Fig. 1. Menotti Garibaldi mothers.

We have argued elsewhere [22,23] that crowdsourced KGs, or KGs constructed by integrating several different information sources of varying quality, must be used via a Trust Layer. Given the goal of carrying out some action, this layer is where a decision is made about the veracity of each relevant claim in the underlying KG, necessary to carry out that action. Consequently, the data user should have their own trust criteria to accept a claim as valid and use it in an intended computation. This additional layer, with some generalizations, has already been proposed regarding statements in WD, and more generally about the Semantic Web, [2]. It has also been recognized in the context of *polyvocal KGs* [25] that incorporate multiple *voices* (or points-of-view) about a subject.

The present work aims to assess how well WD supports the trust decision process implied when using its data. The remaining sections detail WD structural and ontological features and our KG Profiling approach used to evaluate those in WD to support trust decisions through a Trust Layer. We examine the explicit support for disagreements about the veracity of statements. We also look at incompleteness and how well constraint violations capture them. We investigate the support for detecting incongruences and what additional information it provides to resolve them in a trust decision. We also look closely at the support for provenance from a broader perspective. Finally, we present an analysis of the observations made on how well WD supports a trust decision based on the mechanisms mentioned earlier, discuss related work, and point to ongoing and future work.

## 2. Background – WD trust mechanisms and data

The two main components of interest in WD are Entities and Properties. Entities are uniquely identified by an Item ID (aka QNode) and properties by a Property ID (aka PNode). Figure 2 about Brazil (Q155) represents a claim with qualifications and reference. Each statement has at least a property and its value (a value can be another Entity or a literal) and can be augmented with qualifiers and their values (which can also be another Entity or a literal), with references, and rank. To allow a more precise terminology and avoid ambiguity, in this paper, we refer to the role of a property in a (main value) statement as **Predicate**; to a pair (property value) associated to a statement as a **Qualification**; to the role of the property in a qualification as **Qualifier**; and a property appearing in (property value) pair in a reference associated with a statement as **Referrer**.

Given an item, WD allows it to be the subject of multiple statements with different values for the same predicate, i.e., expressing different perspectives about a subject even if they contradict one another. While this may be entirely appropriate in some cases (e.g., spouse, head of government, etc.), it is not so for others, such as inverse functional properties (e.g., mother, date of birth, etc.). The values for specific predicates are sometimes time-dependent (e.g., position held, capital) or location-dependent (e.g., boiling point), or, more generally, context-dependent. The predicate alone may not be sufficient to specify the semantics of the relationship

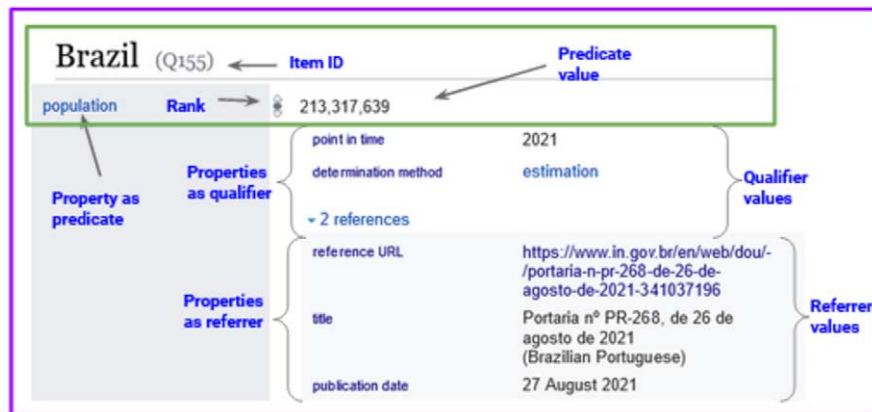


Fig. 2. An example of a WD statement, composed by a claim (inside the green rectangle) with qualifications and reference.

or property. Such dependencies are represented in WD through the use of Qualifiers [28], which provide contextual information for statements. The qualifiers' value complements the claim and establishes the context in which somebody can interpret it.

The intended semantics are further characterized by specifying constraints over these properties, which formulate restrictions on how these properties should be used within statements in WD.<sup>1</sup> Constraints are rules on properties that specify how properties should be used. There are two types of constraints to check predicates and their qualifiers: required qualifiers (Q21510856) and allowed qualifiers (Q21510851). For example, the position held should have start time, defined via a required qualifier constraint for this property, and possibly end time qualifiers, specified via an allowed qualifier constraint for this property.

Another constraint of interest is property scope (Q53869507) that specifies how a property should be used: as main value, as qualifier, or as reference. However, constraints in WD work as hints and are not automatically enforced. Consequently, it turns out that many statements in WD that should have such contextual information in actuality do not.

Although, there are situations when no context applies (e.g., for pure inverse-functional properties such as date of birth), a query may result in multiple different values for the same item, even when including contextual information. Such is the case when the truth of the one statement may imply the truth of another one (e.g., (George Washington place of burial Mount Vernon) and (George Washington place of burial Washington's Tomb), since Washington's Tomb is located in Mount Vernon), and there is no contradiction in both being true at the same time. On the other hand, there are situations in which the two (or more) values for that property cannot be true in the same context (i.e., for the same values of qualifiers, if available). We refer to this situation as an incongruence.

Sometimes an item should have only one value related to a property, which ideally is expressed through the single-best-value constraint.<sup>2</sup> Still, in practice, there are occurrences of multiple values. The rank of the statements, together with a qualifier related to the context, can be used to define which statement is the "best-one" and why. When the temporal context of claims is known, the annotation of preferred reinforces the notion of current or at least more recent value, as shown in Fig. 3 about Brazil's population in the year 2021.

In other situations, multiple values in a query result are not necessarily controversial. This can be the result of an improperly (incompletely) formulated query or the result of a shortcoming in the data present in the KG. For instance, if someone is interested in who is the head of state of Brazil (Q155), a query looking only at the statements (ignoring qualifiers) will retrieve the last eight presidents in WD. However, all statements have the required qualifier start time (P580) as well as the allowed qualifiers position held (P39) and determination method (P459). Seven statements have the allowed qualifier end time

<sup>1</sup>[https://www.wikidata.org/wiki/Help:Property\\_constraints\\_portal](https://www.wikidata.org/wiki/Help:Property_constraints_portal)

<sup>2</sup>[https://www.wikidata.org/wiki/Help:Property\\_constraints\\_portal/Single\\_best\\_value](https://www.wikidata.org/wiki/Help:Property_constraints_portal/Single_best_value)



Fig. 3. Brazil's population of 2020 and 2021 years where 2021 (most recent available) is marked as preferred (green).

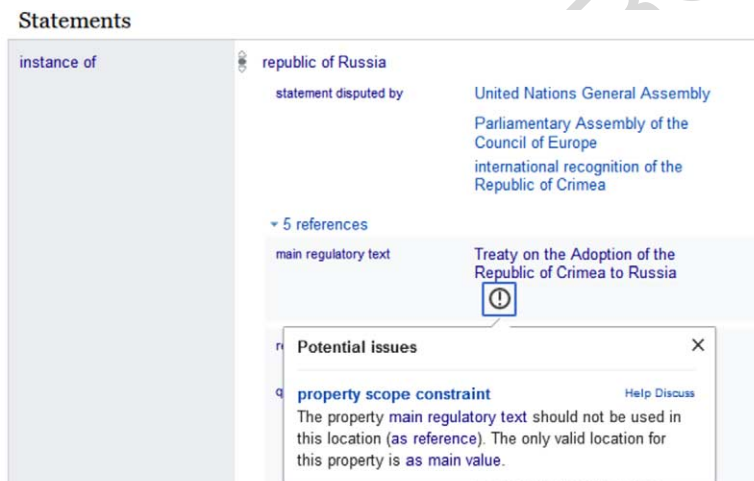


Fig. 4. Main regulatory text constraint scope violation shown in a WD browser for the Republic of Crimea (Q15966495) item.

(P582). By taking into account the contextual information (in this case, start time and end time, it is clear that there is no incongruence among the statements, even though they all refer to the head of state property of Brazil.

Provenance in WD is given mainly through references. A referrer is any property whose type is Wikidata property to indicate a source (Q18608359). Their value can be an item in WD itself (e.g., a person or organization) or refer to an external source via URL. Some of these referrers can be used both as the main value of an item and as a qualifier in the role of reference to a statement. We also observe that some properties are actually used as a referrer in references but are not of the proper type (Q18608359). One often occurring example of this is main regulatory text (P92), which in addition only has as main value in a scope constraint (so it should not be used in a reference). Figure 4 about Republic of Crimea (Q15966495) shows an example of this misuse.

In addition to these *structural* mechanisms, WD also provides ontological support recording controversial statements by explicitly marking them with the *disputed by* Qualifier (P1310). Using this property as a qualifier explicitly indicates that some source (a person, organization, but also a document, or legal instrument) disputes the veracity of the qualified statement. In an ideal disagreement record, each source should state what it claims is the

## Jerusalem

**Q1218**

Aelia Capitolina | J'lēm | Yerushalayim | Jerusalem, Middle East | Al-Quds

city in Western Asia, claimed by both Israel and the Palestinian Authority as its capital

capital of	<b>Israel</b>	
	start time	1950
	statement disputed by	United Nations
	statement supported by	United States of America
	<b>State of Palestine</b>	
	applies to part	East Jerusalem
	statement disputed by	Israel
		United States of America

Fig. 5. An example of a dispute with multiple points of view.

## Republic of Crimea

**Q15966495**

Crimea

administrative division of Russia since 2014 [see Q756294 for Ukrainian subdivision proclaimed in 1991]

instance of	<b>disputed territory</b>	
	statement is subject of	Autonomous Republic of Crimea
	territory claimed by	Ukraine
	<b>republic of Russia</b>	
	statement disputed by	Parliamentary Assembly of the Council of Europe
		United Nations General Assembly
country	<b>Russia</b>	
	statement disputed by	NATO
		Parliamentary Assembly of the Council of Europe
		Ukraine
		United Nations General Assembly

Fig. 6. An example of an one-sided disagreement.

correct value for the property being disputed. For example, Jerusalem (Q1218) is the capital of (P1376) Israel (Q801), this statement is ranked as preferred and disputed by United Nations (Q1065). Another statement asserts that Jerusalem (Q1218) is the capital of (P1376) State of Palestine (Q219060), this statement has normal rank, and applies to part (P518) East Jerusalem (Q212938) and is disputed by United States of America (Q30) and Israel (Q801), see Fig. 5.

Interestingly, however, there are many cases in which a disagreement is recorded using this qualifier, but no alternative value is claimed. For example, the Republic of Crimea (Q15966495) is claimed to be an instance of (P31) republic of Russia (Q41162) – but no indication as to who is making this claim – which is disputed by (P1310) both the Parliamentary Assembly of the Council of Europe (Q939743) and the United Nations General Assembly (Q47423). There are no claims by the latter about what Republic of Crimea is an instance of, distinct from republic of Russia, see Fig. 6.

### 3. Methodology – why and how to identify WD incongruences?

According to the Cambridge Dictionary [6], a controversy is a *disagreement, often a public one, that involves different ideas or opinions about something*; Merriam–Webster’s [7] definition is *a discussion marked especially by the expression of opposing views*, and the Oxford English Dictionary [8] defines it as *disagreement, typically when prolonged, public, and heated*. From these definitions, one could interpret the occurrence of statements with multiple different values for the same item in a KG as indicators of potential controversies. A more careful examination of such occurrences indicates the existence of three different types of situations – incompleteness, incongruences, and controversies. We discuss each one next.

Following the dictionary definitions of *controversy* given previously, one can rephrase them, for our purposes, as an *incongruence that also involves a discussion and disagreement among authors of the statements involved, possibly over an extended period*. For crowdsourced online resources such as WD and Wikipedia, a controversy is manifested through the *talk* pages associated with an entry, as well as by patterns in their edit history (see [5,20,21,29]). Such analysis is outside the scope of this paper and is left for future work; in this respect, we will focus on incomplete and incongruent content in WD.

We have already pointed out that to use a value stated in a WD claim for some computation, the user should, in principle, ensure that s/he trusts the veracity of the claim, i.e., considers the statement a fact. This points to the need for an additional layer above the KG, which we call the Trust Layer, where trust policies and decision criteria are represented. The trust decision is made (for each user) based on the intended use (action) for the data retrieved from WD and additional information about the context in which the statement should be considered. This additional information comes in three forms, in WDs data model [16]:

- Qualifiers, statements about statements, better characterize the relation being asserted. For example, `<<France capital Versailles> (start time 1682), (end time 1789)>>`, which states the temporal context of the statement `<France capital Versailles>` as being valid from 1682 to 1789. Here `start time` and `end time` are examples of qualifiers. In general, qualifiers provide context for statements in WD<sup>3</sup> but can also be used to record actors’ disagreements about a statement’s veracity explicitly. Qualifiers themselves cannot be further qualified.
- WD statements have a rank, which can be `normal`, `preferred`, or `deprecated`. The latter two are meant to indicate a community consensus about the veracity or falsehood of the statement. Although seldom used, it is possible to provide a reason for some statements having a deprecated rank, or a preferred rank, via the respective qualifiers.
- Statements can also have references (or sources) to support their veracity. A reference can be a URL of some external source or a link to a WD item that supports the claim being made. References cannot be associated with qualifiers of a statement since the WD data model does not follow a multi-layer graph model [1].

Even though the trust process applies to statements that assert a single value for a property of an item, it is more crucial in situations where there are multiple statements about a property of an item each with a different value, and a single value is needed for some computation. In such cases, beyond applying the trust process to each asserted value, the user is further confronted with the additional decision of which value to choose.

Given the additional information, the user must apply their trust policies, taking them into account to decide whether to accept or reject the claim’s veracity. An important criterion often used in trust policies is provenance – e.g., who made a claim, or how the claim was established. Provenance may be given through references or through some of the qualifiers (e.g., `stated in`). However, there are often statements without references (see Section 4.5) or qualifiers. In such cases, the source of the statement must be attributed to the user who asserted it in WD.

Unfortunately, the id of the user who asserted a statement is not directly available as an item in WD itself, although it can be retrieved by accessing the underlying database (Wikibase). This significantly hampers the ability to build a trust layer on top of WD alone, as trust policies relying on the authorship of a statement (claim) would not be able to be evaluated.

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<sup>3</sup>[https://www.wikidata.org/wiki/Help:Property\\_constraints\\_portal/Qualifiers](https://www.wikidata.org/wiki/Help:Property_constraints_portal/Qualifiers)

Table 1  
Property scope constraint distribution

Property scope	Property count
As main value	8663
As reference	6058
None	1099
As qualifier	745

This paper will not elaborate further on how such a Trust Layer could be defined and implemented. Rather, we analyze using our KG Profiling approach the current status of WD to support a trust process. This support entails properly recording multiple points of view, explicitly representing controversies, characterizing potentially incomplete or incongruent content, and providing provenance information.

KG Profiling focuses is on computing frequencies and statistical measures to understand the KG characteristics in terms of the structure and the contents [15]. It can help the initial KG exploratory stages in order to identify whether the dataset can satisfy the current information need or complementary resources are necessary. Our KG Profiling approach aims to:

1. Compute the usage of the disputed by qualifier (P1310) by predicate to explicitly express disagreements.
2. Compute violations of the required qualifier constraint by predicate to identify incomplete statements.
3. Compute missing required qualifiers to identify which contexts are affected by incompleteness.
4. Compute ranking usage by predicate to identify community consensus coverage.
5. Compute statements with multiple values and no qualification by predicate to identify potential incongruities.
6. Compute reference usage by predicate to identify provenance coverage.

#### 4. WD profiling results

This section presents WD profiling data concerning incompleteness, incongruences, ranking, references, and provenance. This data was compiled using the DWD dump provided by the KG Center at ISI,<sup>4</sup> reflecting the WD dump of June 2022. Note that this dump does not include instances of `scholarly article` (Q13442814) and `review article` (Q7318358) and their subclasses, since their frequency (over 50,00% of all statements) would distort the statistics. It also does not include statements annotated with `deprecated rank`.

##### 4.0.1. Dataset statistics

First, we present some general statistics about WD to give an overview of this KG. There are 559,038,971 claims using 9,653 properties as predicates, and 141,983,745 qualifications are associated with claims using 9,906 properties as qualifiers. There are 10,089 properties, and 90,00% of them have a `property scope constraint` assigned to them, distributed according to Table 1. *None* represents approximately 10,00% of the properties without `property scope constraint`.<sup>5</sup>

We observe that only 363 properties have a `required qualifier constraint` specification, and 761 have a `allowed qualifier constraint` specification, representing respectively 3,60% and 7,50% among 10,089 properties. Figures 7 and 8 present the distribution for both predicates and qualifiers for the top 50 most frequent ones. Those predicates account for 62,25% of all statements, and qualifiers account for 93,50% of all qualifications. Table 2 and 3 detail the top-10 of each one.<sup>6</sup> It is essential to mention that: (1) According to the Property Talk page,<sup>7</sup> there are more than 108 million claims using P31 property, but our dump version is from June 2022. Furthermore, the dump excluded almost 50,00% of statements, as noted in a previous footnote, (2) Qualifier of (P642

<sup>4</sup>[https://drive.google.com/drive/folders/1a6cUIIUEWRTNbvqTLAfJU0wEJ4ssTqdz?usp=share\\_link](https://drive.google.com/drive/folders/1a6cUIIUEWRTNbvqTLAfJU0wEJ4ssTqdz?usp=share_link)

<sup>5</sup>All data collected, statistics, scripts, and queries used for conducting this research can be found in <https://github.com/versant2612/WD-Profiling>.

<sup>6</sup>Accumulated Frequency, in all tables, is the sum of the previously reported frequency.

<sup>7</sup>[https://www.wikidata.org/wiki/Property\\_talk:P31](https://www.wikidata.org/wiki/Property_talk:P31) accessed in Feb 2023.

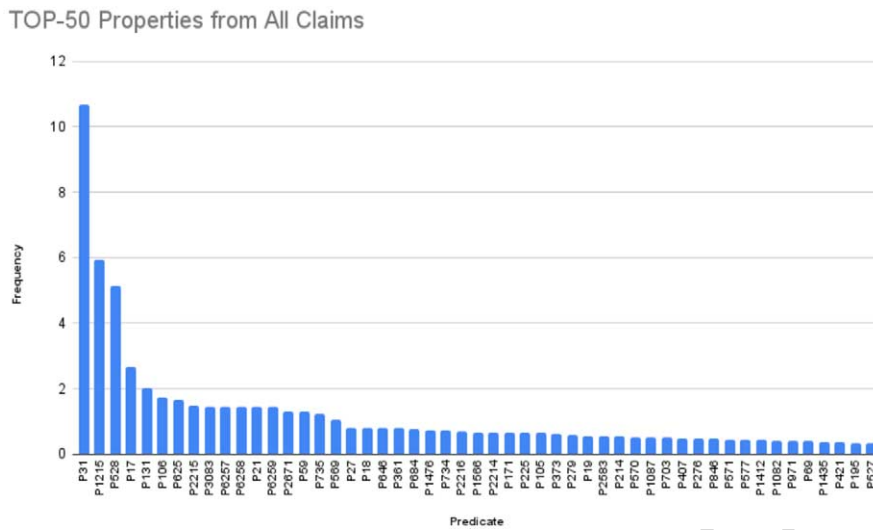


Fig. 7. Top-50 properties used as predicates from claims.

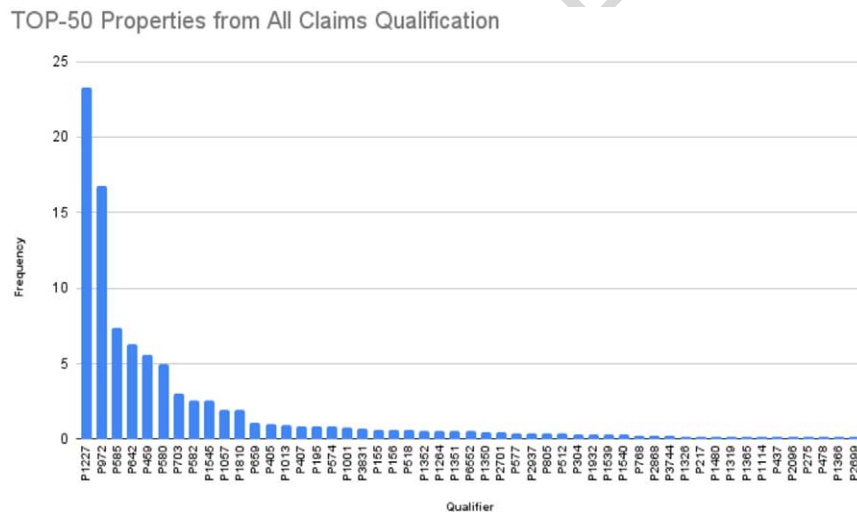


Fig. 8. Top-50 properties used as qualifiers from qualifications.

property), while being among the most used for qualifications, is slated to become deprecated, see,<sup>8</sup> and (3) there are disproportionately many astronomical filters (P:1227).<sup>9</sup>

We identified that only 21,00% of WD claims have qualifications. Due to its crowdsourced and distributed authoring model, incompleteness often creep into the WD KG [19,24].

<sup>8</sup><https://www.wikidata.org/wiki/Property:P642>.

<sup>9</sup>While it is difficult to provide a definitive explanation why, it is possible to detect that some users who participated in the discussion about the creation of this property ([https://www.wikidata.org/wiki/Property\\_talk:P1227](https://www.wikidata.org/wiki/Property_talk:P1227)) appeared in the Astronomy project (<https://www.wikidata.org/wiki/Wikidata:Astronomy>) and the project documentation ([https://www.wikidata.org/wiki/Wikidata:WikiProject\\_Astronomy/Properties](https://www.wikidata.org/wiki/Wikidata:WikiProject_Astronomy/Properties)) also listed this property. This suggests that data have been loaded into WD using bot extraction of information from Astronomy databases where this meta information could be found.



Table 2  
Top-10 predicates in all claims. The frequency is relative to the total number of statements

Predicate	Count	Label	Frequency %	Accumulated frequency %
P31	59,717,980	Instance of	10,68	10,68
P1215	33,122,376	Apparent magnitude	5,92	16,60
P528	28,738,709	Catalog code	5,14	21,74
P17	14,996,553	Country	2,68	24,42
P131	11,371,144	Located in the administrative territorial entity	2,03	26,45
P106	9,608,349	Occupation	1,72	28,17
P625	9,267,000	Coordinate location	1,66	29,83
P2215	8,207,685	Proper motion	1,47	31,30
P3083	8,150,658	SIMBAD ID	1,46	32,76
P6257	8,091,255	Right ascension	1,45	34,21

Table 3  
Top-10 qualifiers in all qualifications. The frequency is relative to the total number of qualifications

Qualifier	Count	Label	Frequency %	Accumulated frequency %
P1227	33,122,324	Astronomical filter	23,33	23,33
P972	23,776,643	Catalog	16,75	40,08
P585	10,432,968	Point in time	7,35	47,43
P642	8,966,228	Of	6,31	53,74
P459	7,930,570	Determination method	5,59	59,33
P580	7,048,511	Start time	4,96	64,29
P703	4,317,830	Found in taxon	3,04	67,33
P582	3,601,028	End time	2,54	69,87
P1545	3,597,770	Series ordinal	2,53	72,40
P1057	2,776,317	Chromosome	1,96	74,36

#### 4.1. Explicit record of disagreements

We examine here the detailed record of disagreements via the use of the `disputed by` qualifier (P1310), which indicates explicitly that some source disputes the veracity of the qualified statement. There is another way to represent a `disputed by` assigning a `sourcing circumstance` (P1480) qualifier to a statement with a value `disputed` (Q18912752). We ignore this usage since their frequency is very low. The `disputed by` property is also used as a predicate to directly represent an opposition of concepts rather than a disagreement between statements. For example, the opposition of `Capitalism` (Q6206) and `Marxism` (Q7264). We will disregard this type of disagreement, as it is different from the phenomena we are interested in. Furthermore, this use violates the `scope` constraint on the `disputed by` property.

##### *Disputed by frequencies*

Next, we present statistics about explicit disputes in WD. There are 1577<sup>10</sup> claims out of 559,038,971 in total, having `disputed by` as qualifier, representing 0,0003%. We also found that only 140 different properties, out of 9653 in total, were used as the predicate in these claim statements. In Fig. 9, we show the top-50 most frequent properties, corresponding to 92,00% of statements with `disputed by` qualifiers. Nearly 77,00% among the ten most frequent are properties about territory, medicine, diseases, people, and fiction (see Table 4).

This profiling information indicates that only a tiny fraction of statements in WD record explicit disagreements (0,0003%), perhaps unsurprisingly involving topics that are already controversial in the physical world. The statements capturing these disagreements often do not use the available properties in a way that can support a user in

<sup>10</sup>According to the Property Talk page [https://www.wikidata.org/wiki/Property\\_talk:P1310](https://www.wikidata.org/wiki/Property_talk:P1310) accessed in Feb. 2023, more than 2246 qualifications are using the P1310 property.

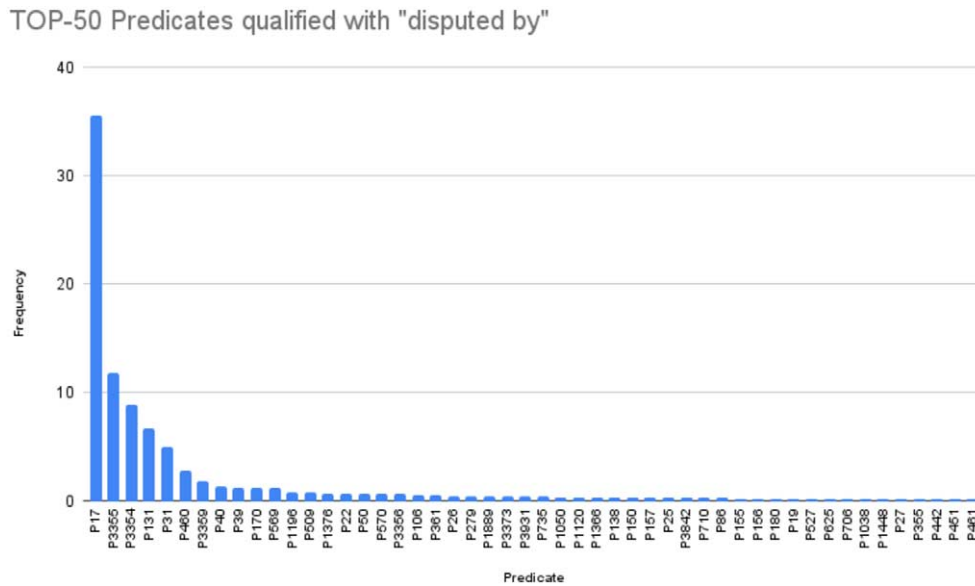


Fig. 9. Top-50 most frequent properties in claims qualified with *disputed by*.

Table 4

Property types for the top-10 claims predicates qualified with *disputed by*

Property label	Property type
Child	Wikidata property for human relationships
Creator	Wikidata property associated with people Wikidata property for items about fictional characters Wikidata property related to creative works
Position held	Wikidata property for items about people
Instance of	Wikidata property for the relationship of the element to its class
Positive therapeutic predictor for	Wikidata property related to disease biomarkers Wikidata property related to medicine
Negative therapeutic predictor for	Wikidata property related to disease biomarkers Wikidata property related to medicine
Negative prognostic predictor for	Wikidata property related to disease biomarkers Wikidata property related to medicine
Country	Wikidata property related to places
Said to be the same as	Wikidata property to describe the elements of identity
Located in the administrative territorial entity	Wikidata property to indicate a location

deciding which statement to accept as a fact if they must do so. This is further hampered by limitations of the WD data model, for example, needing to give some provenance information (or reference) to a qualifier statement (since qualifiers cannot be qualified). For instance, it might be essential to have a reference to the qualifier statement supported by United States of America used for the statement (Jerusalem the capital of Israel) (see Fig. 5). Another hampering factor is the lack of author information for a statement as data in WD itself.

#### 4.2. Incompleteness of data/constraint violations

Qualifiers and constraints are essential mechanisms to provide a context in WD. Looking at all statements, there are 141,983,745 qualifications over 116,211,413 claims, using 5,082 properties as predicates; qualifications were

associated with claims using 9,905 properties as qualifiers. This means that only roughly 21,00% of 559,038,971 statements provide some context information using qualifiers.

One can identify contextually incomplete statements by looking at violations of the required qualifier constraint. A required qualifier constraint can have a constraint status, which in turn can be mandatory or suggested. For simplicity, we refer to those required constraints with constraint status mandatory as mandatory required qualifier constraint, and likewise for suggested required qualifier constraint. The statistics presented next characterize them.

We found 17,934,765 claims using predicates with mandatory required qualifier and 7,824,405 with suggested required qualifier constraint. Among them, there are 359,445 with mandatory required qualifier violation, representing 2% of the first group and 0,0643% of all claims. In comparison, 3,448,673 violated the suggested required qualifier constraint of their predicates, meaning nearly 44% of the second group and 0,62% of all claims. Claims with these constraint violation are those where at least one missing qualifier was found. Figures 10 and 11 show the top-10 most frequent predicates used in those claims.

There were 395,604 mandatory required qualifier absences and 3,478,979 suggested required qualifier absences. Note that more than one qualifier may be missing for the same claim. Tables 5 and 6 show the top-10 missing qualifiers of each set.



Fig. 10. Top-10 required qualifier constraint violations: mandatory.

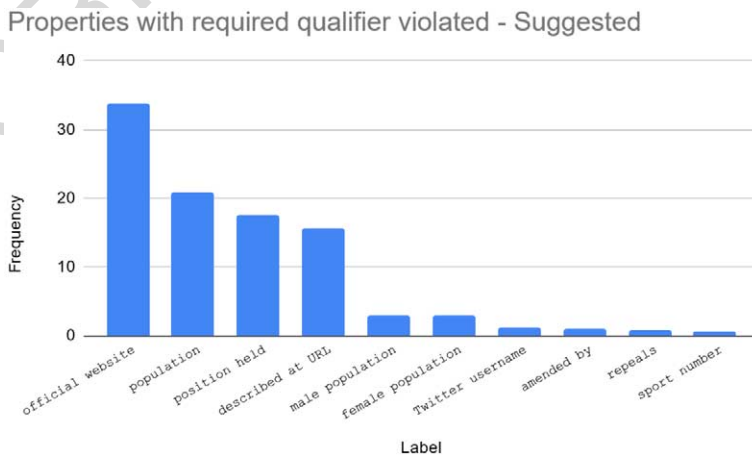


Fig. 11. Top-10 required qualifier constraint violations: suggested.

Table 5

Top-10 missing qualifiers mentioned in required qualifier mandatory constraint. The frequency is relative to the total number of qualifications absence. Highlighted predicates involve time

Qualifier	Label	Count	Frequency %	Accumulated frequency %
P585	Point in time	112128	28,34	28,34
P580	Start time	50230	12,70	41,04
P3415	Start period	38268	9,67	50,71
P1013	Criterion used	24668	6,24	56,95
P642	Of	22462	5,68	62,63
P560	Direction	21502	5,44	68,07
P195	Collection	15414	3,90	71,97
P7367	Content descriptor	12795	3,23	75,20
P2093	Author name string	10896	2,75	77,95
P459	Determination method	9929	2,51	80,46

Table 6

Top-10 missing qualifiers mentioned in required qualifier suggested constraint. The frequency is relative to the total number of qualifications absence. Highlighted predicates involve time

Qualifier	Label	Count	Frequency %	Accumulated frequency %
P407	Language of work or name	1717233	49,36	49,36
P459	Determination method	926034	26,62	75,98
P580	Start time	656267	18,86	94,84
P585	Point in time	103465	2,97	97,81
P6552	Twitter user numeric ID	19426	0,56	98,37
P2676	Rating certificate ID	13329	0,38	98,75
P972	Catalog	8662	0,25	99,00
P137	Operator	5202	0,15	99,15
P7367	Content descriptor	4085	0,12	99,27
P4390	Mapping relation type	3561	0,10	99,37

The qualifiers *Point in time*, *Start Time* (related to temporal context), *Content Description*, and *Determination Method* are present in both sets. Indeed, the temporal qualifiers make up 51,00% of the mandatory ones and 22,00% of the suggested ones.

Some properties, defined as having a restrictive qualifier (Q61719275) type, must be used as qualifiers to restrict or modify the referent. Their absence may turn the statement inaccurate or meaningless. Among the missing required qualifiers, we found eight that correspond to restrictive qualifiers, and Table 7 shows their number of violations. It should be noticed that the qualifier *applies to jurisdiction* (P1001) is an illustrative example of location-related restrictive qualifier since it restricts the statement in terms of territorial jurisdiction: a country, state, municipality, and so on.

#### 4.3. Ranking

In the analyzed dataset, there were 5,480,866 preferred ranked claims, nearly 1,00% of all claims, and only 71,609 have the qualifier *reason for preferred* (P7452).<sup>11</sup> Table 8 presents the top-10 most frequent properties in preferred ranked claims without the reason qualifier. We observe that demography properties are time-dependent and, for this reason, should not be specified with a single-value constraint, but rather the single-best-value seems to be more appropriate. In cases when the point in time qualifier about these statements are unknown, the most recent one can be annotated as preferred.

<sup>11</sup> According to the Property Talk page [https://www.wikidata.org/wiki/Property\\_talk:P7452](https://www.wikidata.org/wiki/Property_talk:P7452) accessed in February 2023, there are approximately 122.000 qualifications.

Table 7  
Missing restrictive qualifiers from mandatory required qualifiers constraints

Qualifier	Label	Count (all qualifications)	Count (multi value qualification)
P3415	Start period	38268	17555
P1013	Criterion used	24668	16
P642	Of	22462	592
P2210	Relative to	91	4
P1552	Has quality	39	0
P1001	Applies to jurisdiction	13	2
P518	Applies to part	8	5
P1264	Valid in period	4	0

Table 8  
Property types and frequency for the top-10 preferred ranked claims the frequency is relative to the total number of preferred claims

Property label	Frequency %	Constraint	Property type
Apparent magnitude	72,37	Single-value	Wikidata property for items about astronomical objects
Population	4,17	Single-value	Wikidata property for number of people, Wikidata property related to demography
Social media followers	3,23		Wikidata property for number of people, Wikidata property related to online communities
Located in the administrative territorial entity	3,15		Wikidata property to indicate a location
Country	1,63		Wikidata property for items about places
Instance of	1,43		Wikidata property for the relationship
Contains administrative territorial entity	1,14		Wikidata property for items about places
OKTMO ID	1,10	Single-value	Wikidata property for authority control for administrative subdivisions
Male population	0,94	Single-value	Wikidata property implying third-parties' gender, Wikidata property for number of people, Wikidata property related to demography

Ranking statements, as preferred, can be regarded as a mechanism to indicate a community consensus about the veracity (or at least the likelihood) of a statement. From the trust process point of view, it is a proxy for a more detailed determination process that each user goes through and does not consider for what purpose that claim will be used.

This is supported by observing, for example, that nearly 72,00% of ranked statements (for apparent magnitude) are associated with a specific community, in this case, astronomy.

The statistics show that this mechanism is seldom used (1,00% of the statements) and even less frequently justified. Consequently, if a user must choose among multiple possible values for a property, s/he would rarely be able to rely on ranking. Furthermore, little support is given to help them determine if the criteria used by the community match their own for the intended action.

#### 4.4. Incongruences

Incongruences among statements where multiple values are present for the same property of the same WD item should be detected after evaluating their values and contextual information. In the analysed dataset there are many instances of statements that assert multiple different values for the same property of the same item and do not provide any qualifier to differentiate among them. Such statements indicate either a gap in the recorded information in WD or potential incongruences.

### Multiple value statements statistics

Next, we present statistics about multiple value statements in WD and property constraints:

- There are 132,552,453 statements with multiple values for the same item and the same property corresponding to 23,71% of all statements.
- We separate this set into statements with and without qualifiers. Of these, 91,148,503 have at least one qualification (approximately 16.30% of all statements).
- Overall, 1,333,012 statements with multiple values, representing 0.24% of all statements, violate one or more required qualifier constraints.
- Among the top-10 qualifier absences there are 3 time-related properties: `point in time` (P585): 36,74%, `start period` (P3415): 18,57% and `start time` (P580): 6,41%.

In a best-case scenario, where one assumes that all violations have been corrected, only 16.54% of all statements with multiple values would provide some contextual information. There are still 41,403,950 statements; 31,30% of those with multiple values (7,41% of all statements) do not have any qualifications.

We computed required qualifier constraint compliance based on the statement predicates, shown in Table 9. The top-10 qualifiers, present in Table 9 correspond to nearly 19,2% of the total number of multiple valued statements, with about 8,00% of them, involving qualifiers about time (`point in time`, `start time`).

We also checked the allowed qualifier constraints for the predicates in multiple valued statements. Once more, 4 qualifiers about time were among the top-10 most frequent, but here they correspond to only 26,50% of all multiple value statements. See Table 10.

Table 9

Top-10 required qualifiers in multiple valued statements. The frequency is relative to the total number of all statements with multiple values. Highlighted predicates involve time

Qualifier	Label	Count	Frequency %	Accumulated frequency %
P642	Of	8209469	9,01	9,01
P585	Point in time	6548388	7,18	16,19
P459	Determination method	1524643	1,67	17,86
P580	Start time	696591	0,76	18,62
P407	Language of work or name	134829	0,15	18,77
P1352	Ranking	131878	0,14	18,91
P1111	Votes received	81761	0,09	19,00
P447	Review score by	57777	0,06	19,06
P3294	Encoding	44798	0,05	19,11
P195	Collection	43065	0,05	19,16

Table 10

Top-10 allowed qualifiers in multiple valued statements. The frequency is relative to the total number of all statements with multiple values. Highlighted predicates involve time

Qualifier	Label	Count	Frequency %	Accumulated frequency %
P972	Catalog	22175343	24,33	24,33
P585	Point in time	6715923	7,37	31,70
P580	Start time	3101279	3,4	35,10
P582	End time	2358699	2,59	37,69
P459	Determination method	1837514	2,02	39,71
P1545	Series ordinal	1156594	1,27	40,98
P1264	Valid in period	751061	0,82	41,80
P1351	Number of points/goals/set scored	736338	0,81	42,61
P1350	Number of matches played/races/starts	692587	0,76	43,37
P1013	Criterion used	654304	0,72	44,09

Table 11

Top-10 properties to indicate a source used as qualifiers. Frequency is calculated based on qualifications using a property of type Wikidata property to indicate a source

Qualifier	Count	Label	Frequency %	Accumulated frequency %
P407	1242876	Language of work or name	41,17	41,17
P577	537468	Publication date	17,8	58,97
P304	441380	Page(s)	14,62	73,59
P478	187030	Volume	6,2	79,79
P291	105546	Place of publication	3,5	83,29
P2093	98772	Author name string	3,27	86,56
P1476	92759	Title	3,07	89,63
P813	68490	Retrieved	2,27	91,90
P1343	50777	Described by source	1,68	93,58
P958	45364	Section, verse, paragraph, or clause	1,5	95,08

It is important to note that not all cases where multiple values are present, are inconsistent, as there may be a functional dependency or logical implication between them. Even though the statements are fully qualified and referred to, the incongruence may be only detected while applying the trust process to each asserted value according to task-specific criteria. Suppose a person has a biological mother and a foster (legally defined) mother. Two claims using predicate `mother` (P25) are recorded in WD, each statement has the qualifier `object has role` (P3831) with values to reflect the different roles of her mother. The relevant information to evaluate health issues is about the biological mother. The relevant information to assess inheritance issues is about the legally defined adoptive mother.

#### 4.5. Provenance and references

We focus only on properties used as reference qualifiers in qualifications since, as such, they serve to provide provenance information.

Among the top-10 properties indicating the use of a source as qualifiers, shown in Table 11 and representing 2,11% of all qualifications, seven have all three possible scopes (as main value, as qualifier, as reference). Strangely, place of publication (P291) does not have any scope constraint at all; described by source (P1343) has scope as main value, and as qualifier but not as reference; and retrieved (P813) has scope as qualifier and as reference, but not as main value.

Because the ISI dump does not include references, we extracted them using the WD Virtuoso SPARQL Endpoint<sup>12</sup> that contains 1,428,322,719 statements and 103,740,680 references. We retrieved 241,831,575 referrer/value pairs that make up references considering only data types of values `wikibase-item`, `url`, `external-id`, and `string` since those represent provenance information. One reference can have several associated pairs, although, in practice, most references are composed of at most three pairs. We computed the frequency of each of the 5049 Referrers. We observed that seven of the top-10 most used referrers, shown in Table 12, are of type Wikidata property to indicate a source and the remaining three are external identifiers. Among the 5049 properties used as referrers, there are 4105 whose data type is an external identifier corresponding to 17,90% as presented in Fig. 12.

It should be noted that provenance, in its broader sense, includes not only the sources but also the activities and other elements that are involved in the creation of an artifact (see, for example, the Prov-DM data model<sup>13</sup>). This means that other WD Properties can serve the role of provenance when used as qualifiers, e.g., `determination method` (P459), which has 7,930,570 occurrences as a qualifier. Still, this use is practically non-existent as a predicate (329 occurrences) and infrequently as a referrer (1,535,639 occurrences). As additional examples, the top 50 most frequent qualifiers include taxonomy-related properties defined as qualifiers using `property scope`

<sup>12</sup><https://wikidata.demo.openlinksw.com/sparql> accessed on Feb-04-2023.

<sup>13</sup><https://www.w3.org/TR/2013/REC-prov-dm-20130430/>

Table 12  
Top-10 properties used as referrers in references. External identifiers are highlighted

Referrer	Count	Label	Types
P248	87044656	Stated in	Wikidata property to indicate a source
P854	66044529	Reference URL	Wikidata property to indicate a source
P698	30007333	PubMed ID	Wikidata property for authority control for works Wikidata property related to medicine Wikidata property for items about scholarly articles
P887	7312604	Based on heuristic	Wikidata property to indicate a source Non-restrictive qualifier
P4656	5658353	Wikimedia import URL	Wikidata property to indicate a source Wikidata property to link to Commons Wikidata property about Wikimedia entities
P143	5183797	Imported from Wikimedia project	Wikidata property to indicate a source
P932	5123097	PMCID	Wikidata property for authority control for works Wikidata property for items about scholarly articles
P214	3846213	VIAF ID	Wikidata property for authority control for people Wikidata property for authority control for places Wikidata property for authority control for works Wikidata property to identify organizations Wikidata property for authority control, with reciprocal use of Wikidata Wikidata property for authority control by VIAF member Wikidata property for an identifier that does not imply notability Wikidata property widely reused by third-party entities Wikidata property for an identifier that generally has just one value, but rarely can have two or more values for the same entity
P1810	2525708	Subject named as	Wikidata qualifier Wikidata property to indicate a name Wikidata property with datatype string that is not an external identifier property constraint
P351	2321925	Entrez Gene ID	Wikidata property related to biology Wikidata property to identify genes

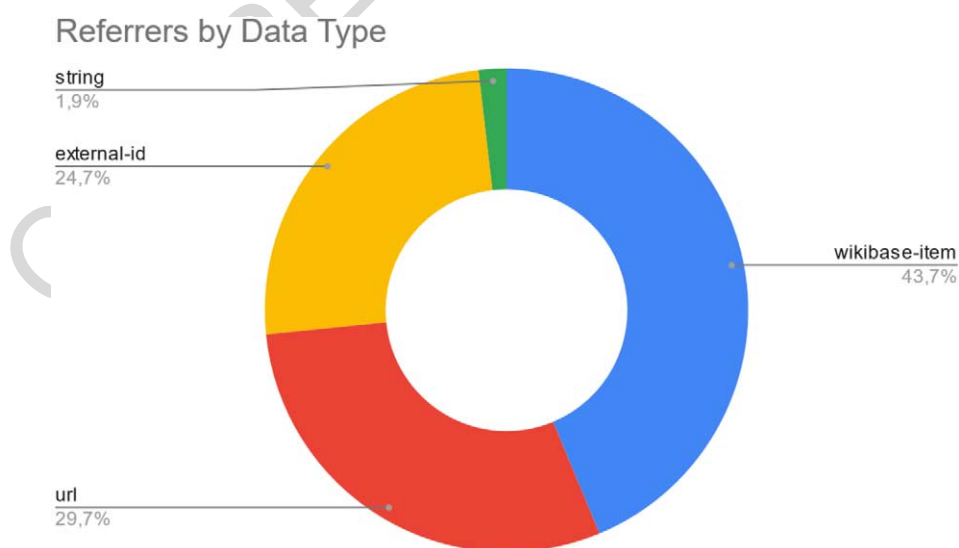


Fig. 12. Data type distribution of referrers.



constraint. For instance, `taxon author` (P405) – the author(s) that (optionally) may be cited with the scientific name, `year of taxon publication` (P574) – the year when this taxon was formally described or established, and `found in taxon` (P703) – the taxon in which the item can be found.

## 5. Related work

Piscopo and Simperl (2019) [19] analyzed 28 previous papers about WD quality metrics using different dimensions and, similarly to Bizer et al. [2], they also considered that (i) data quality depends on the task and (ii) its relevance to a task is user-subjective. Although the authors stated that completeness is the dimension covered by the most significant number of papers, different from those, we chose to focus on qualification completeness based on required qualifiers violations. Such constraint violations may lead to incongruence and controversies in interpreting the data since it affects claims contextualization.

The authors of [24] developed a framework to detect and analyze low-quality statements in WD. They propose three metrics to identify WD Quality: Community-based indicators, Deprecation-based indicators, and Constraints-based indicators. Differently from those concerned with WD data quality in general, our analysis aims to detect WD incongruences, incompleteness, and controversy that affect criteria often used in trust policies, such as provenance and timeliness.

Regarding Provenance, [18] developed an approach to evaluate the relevance and authoritativeness of Wikidata references based on two complementary methods: microtask crowdsourcing and machine learning. Our analysis is complementary, looking at constraint violations and analysis of types of references.

WD Property Talk pages have useful information such as the property's current usage, query examples, and report about constraint violations. WD also has definitions of schemas in the form of shapes (subgraph patterns to describe a concept) using ShEx shape expressions. Some schemas, besides predicates with `p:` or `wdt:` prefixes, also uses qualifiers with `pq:` prefix (see `p:710` and its allowed qualifiers in `EntitySchema:E84`<sup>14</sup>) and referrers with `pr:` prefix (see `EntitySchema:E43`<sup>15</sup> and the `pr:P854` specification) to define a well-formed concept.

In [12], the authors proposed a set of SPARQL queries, formalizing all current WD property constraint specifications. These queries can be used to verify if a statement violates a constraint in online mode. Our profiling approach was developed using the Kypher language in the KGTK toolkit [14]. Still, we used the same query logic to verify some constraint violations of interest among all WD claims in batch mode. We complement our data using SPARQL queries to extract references data from an EndPoint.

Statistical methods to automatically build knowledge graphs create a simplified representation of knowledge where diverse perspectives tend to be resolved as conflicts. This approach introduces bias and loses traceability [25]. According to them, data is created based on a particular perspective or view. Data models that advocate being perspective-aware should be able to trace provenance in a broader sense, including creation and transformations.

WD, as a crowdsourcing effort where a voice corresponds to the data contributor perspective, enables the representation of provenance of claims at the individual level. Still, references are associated only with the data provider. The viewpoint of data contributors is unknown, and rank annotation of some statements reflects the consensus from a particular domain community. Complementary to this perspective, another viewpoint must be considered when building a contextualized knowledge graph to support the Trust Layer: the data consumer. The Trust layer will apply trust policies to this perspective over data representing different viewpoints.

Bizer et al. [2] argued that web information should have its quality assessed according to task-specific criteria before being used. Their work is supported by Quality-based information filtering policies, that is, policies that users may choose for deciding if some piece of web information may be accepted or rejected to accomplish a specific task. They developed the WIQA – Information Quality Assessment Framework composed of a set of software components dealing with uncertain information. Their proposed *quality layer* is similar to what we envisage for the trust layer for KGs to support the trust decision process implied when using its data.

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<sup>14</sup><https://www.wikidata.org/wiki/EntitySchema:E84>

<sup>15</sup><https://www.wikidata.org/wiki/EntitySchema:E43>

Table 13  
WD profiling summarization

Trust process support aspects	WD Profiling findings
Incompleteness	0,0643% of all claims have mandatory required qualifier constraint violation 0,62% of all claims have suggested required qualifier constraint violation 21,00% of all claims provide some context information or additive information using qualifiers
Ranking	5,480866 (nearly 1,00% of all claims) are preferred ranked claims 0,0131% of preferred ranked claims have the qualifier reason for preferred (P7452)
Potential incongruences	0,0003% of all claims record explicit disagreements using disputed by (P13130) qualifier 23,71% of all claims are claims with multiple values for the same item and the same property 91,148,503 (16.30% of all claims) are claims with multiple values that have at least one qualification 1,333,012 (0.24% of all claims) are claims with multiple values that have one or more mandatory required qualifier constraint violation 31,30% of those with multiple values (7,41% of all claims) do not have any qualifications
References and provenance	2,11% of all qualifications correspond to Wikidata property to indicate a source qualifiers 43,70% of all references points to a WD item 24,70% points to external items (identifiers from others KBs) and 29,70% points to websites URL

Generating statistics on specific domains may have different characteristics from those we use in our approach. In [17], in addition to their tool to visualize research profile, the authors also present how WD has been used to store and disseminate bibliometric information and present scientometric statistics extracted from this information. Our approach can be applied to any sub-domain present in WD, such as Academics, Astronomy, Genomics, Biology in general, etc. Since the goal is to analyze WD support for the trust process through multiple points of view, controversies, and potentially incomplete or incongruent content.

## 6. Conclusions

Before conclusion, we go over again, in Table 13, our main findings from WD Profiling about WD mechanisms and data to support trust process.

### 6.1. Discussion

To gain some insight on what these statistics tell us, there are several factors to consider, to whit:

- Some statements are missing qualifications because of a simple lack of information at creation time, and authors expect that either themselves or other users will eventually fill in this information when it becomes available, similar to Wikipedia missing links in page contents;
- Constraints for some properties are possibly mis-formulated – i.e., their intended semantics need to be understood by the user community that creates statements. In some sense, constraints reflect a community consensus about the semantics of properties that all users may not share. Furthermore, constraints do admit violations in some exceptional cases;
- Some properties require qualification, but this has yet to be captured in constraints when they were defined, despite the editorial process. This can also happen if the understanding of the semantics of the property evolves due to new knowledge being brought in or created;
- Finally, users are simply ignorant that certain properties should be qualified (although the editing interface warns them of this, and they are flagged in the standard WD browser);
- Incorrect or incomplete import scripts to automate the ingestion of new sources or unavailability of that information in the imported source.

We summarize here our observations about the various mechanisms provided by WD to support a trust decision about one of its claims.

Although the explicit recording of disagreement may seem like a natural way to capture these real-world situations in WD, only a negligible fraction of statements and a very small number of properties are present using this mechanism. The properties used in these statements involve mostly territory, medicine, diseases, and relations among people. The analysis also highlights a shortcoming of the WD data model, which prevents a qualifier from being further qualified or having a reference. A trust decision, therefore, cannot verify, for example, if some provenance information supports a qualification.

Considering that qualifications provide context information, we observe that only 21,00% of statements are qualified. Regarding mandatory required qualifier constraint violations (3,22% of all statements), one can see that even if they were to be satisfied, there would still be only 24,20% qualified statements.

Suggested required qualifier constraint violations have complex semantics to interpret since they are merely suggestions. Nevertheless, even if one considers the best case in which the data was provided to satisfy all of them (0,65% of all statements), there would still be only 24,80% qualified statements altogether.

This means that approximately 75,20% of statements do not have any context information via qualifiers. For those, any support for a trust decision would come from provenance information via authorship, which we already indicated that it is not provided in WD or through references.

We could not determine the total number of referenced statements in WD for computational reasons, as we had to extract those from the full dump. However, we can make some approximations based on the proportion of statements excluded from the ISI dump we used for all the other statistics. For this dump, it left out approximately 50,00% of all statements by ignoring scholarly and review articles and their sub-classes. Applying this proportion to the total reported in Section 4.5, we estimate there are 51,870,340 references, of which only 43,70% refer to WD items, amounting to 22,667,338 references. As a lower bound, if we assume all of those references hypothetically apply to only those statements without qualification (which we know is not the case), this would still represent only 5,40% of all such statements. Therefore it is safe to conclude that at least 69,60% of all WD statements do not have any support for trust decisions.

As already pointed out throughout the paper, author information about statements is unavailable as part of the KG in WD. This would be the only possible information for those statements without qualifiers or references that can provide information to the trust process and therefore has a significant negative impact on WD's support for trust decisions.

Statements with multiple values for the same property for the same item can represent potential incongruences. For such statements, the trust decision must, in addition, filter each value claimed and often choose one of them to perform a computation. Again in a best-case scenario in which all constraint violations were to be corrected by providing missing values, there would still be 41,403,950 statements, 31,30% of those with multiple values (7,41% of all statements) without any qualifications.

It is worth noting that temporal information, often essential to properly determine the context of the veracity of a claim, is missing in 57,00% of claims that violate a time-related mandatory required qualifier constraint.

WD provides no, or at best very little, support to detect implicit disagreements, differentiate them from incomplete data, and support trust decisions.

In situations with multiple values, the user has to decide which value to choose beyond applying the trust process to each asserted value. WD provides the concept of ranking to aid the user in making this decision. We identified a rarified occurrence of ranked statements and even fewer with a qualifier to specify a reason for preferred, making it difficult to use the community consensus about the claims' veracity. Furthermore, multiple values are typical and expected for time-series types of information, and time-related qualifiers are crucial to dispel apparent incongruences. However, 61,70% of constraint violations of multiple-valued statements involve precisely time-related qualifiers.

The analysis shows that provenance is also available through qualifiers, and other types of properties related to methods and processes should also be considered as provenance. Even though 43,70% of references point to WD Items, there is still a large number of reference information pointing to external data sources using identifiers (24,70%), URLs (29,70%), and strings (1,90%). These external references typically require additional (often non-trivial) processing to be used in a trust decision about the claim where it is used as a reference. Furthermore, the WD model does not allow references to be associated with qualifiers since it is not a multi-layered model [1].

Looking at tools provided by Wikidata to support the trust process, one can look at ways to retrieve statements with preferred rank in case of multiple value statements. One such way proposed in WD is to use, when querying WD, statements annotated with preferred rank to retrieve the best non-deprecated ranked statement for a given property using the prefix `wdt`.<sup>16</sup> However, this applies only to predicates but not to qualifications, including the reason for preferred (P7452) qualifier, and references need reification. Thus, the information returned is incomplete in providing available information for the trust decision.

Another tool is that constraint violations can be visually verified using the standard WD browser interface, but it is very complex to infer this information at query time. A SPARQL query example for required qualifier violations, extracted from [12], is illustrated in.<sup>17</sup>

From these analyses, it is possible that WD's support for trust decisions about its statements is low and could be improved significantly. Including a warning mark to indicate claims that do not have provenance data (in qualifiers or references) as well as allowing the author of the claim to be viewed (whether human user or bot) could encourage data completion.

## 6.2. Future work and conclusions

Any open KG constructed collaboratively by contributors with different levels of domain knowledge and world views can suffer from wrong, biased, outdated, incomplete, and inconsistent content. The knowledge retrieved from a KG to be used to accomplish a specific task has to be more contextualized as possible to support the trust process. Here we adopted the context definition from [13]: *By context, we refer to the scope of truth, and thus talk about the context in which some data are held to be true.*

After analyzing the current status of WD, we realized that given the characteristics of the data model (such as the lack of references for qualifiers, incorrect specification of property scope in addition to the absence and ambiguities of definitions in constraints) and in the data (violations of constraints that generate incompleteness and possible interpretation errors) it is necessary to have an additional and separate layer, that will be user and task-dependent. And, to provide all information required by this layer, the knowledge retrieved from the KG should be explicitly contextualized, at least in terms of Provenance, Temporal, and Location dimensions.

As part of ongoing and future work, we are looking at ways to improve the ontology and the data model of a KG to support a trust layer better [10]. This process will necessarily involve human participation through knowledge engineers, helped by automated and semi-automated tools. Even though this paper has explicitly focused on WD, we are looking at the problem from the point of view of KGs in general. The design of a trust layer itself is left as future subsequent work.

KG Summarization & Profiling [4], based on instances or schema, can assist knowledge engineers in evaluating context dimensions already present in the KG. For each property in the role of Qualifier or Referrer, the knowledge engineer would identify which context dimensions it belongs to. It can also help formulate semantic rules interpretations for qualifiers' existence, absence, and possible claim contradictions.

Identifying context dimensions is challenging since any information that characterizes an element can, in principle, be considered as context. Knowledge engineers should build on top of an existing KG a set of mappings and rules that makes contextual dimensions explicit about transforming a standard KG into a Contextual KG (CKG).

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